Kenya Soil Health Consortium
Collating, harmonizing, Disseminating
Soil Health Innovations

Soil Fertility Management

Book of Abstracts for Kenya

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Growing Africa's Agriculture

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Preface

The fundamental importance of agriculture in the development of Kenya's economy cannot be underscored. Agriculture is the backbone of Kenya's economy directly contributing 26 per cent of Gross Domestic Product (GDP) annually and indirectly 27 per cent through linkages with manufacturing, distribution and other service related sectors. It also accounts for 65 percent of total exports and provides 18 per cent and 60 per cent of formal and total employment respectively. Thus, the sector is not only the driver of Kenya's economy but also the means of livelihood for the majority of Kenyans; in particular, over 80 per cent of the rural population. Evidence has shown that agriculture-led growth in Kenya is more than twice as effective in reducing poverty as compared to growth led by industry. It is estimated that a 1% increase in the sector results in a corresponding 1.6% GDP growth in the overall economy. However, in spite of the importance of agriculture in Kenya's economy, the sector's performance has continued to decline with time. Further, the country remains food and nutrition insecure. Several factors have caused the continuous decline in the performance of the agricultural sector including: poor soil health, low adoption of improved soil health technologies and limited uptake and use of mechanized farming practices especially among smallholder farmers. Yet soil health research started in 1925 in Kenya. To avoid costly duplication of soil health research in the country, the Kenya Soil health Consortium (KSHC) compiled all the soil health research published abstracts for use by researchers, tutors and students in institutions of higher learning in Kenya. The volume of soil health research publications emanating from Kenya is large and the scope equally wide, however the main thrust of soil health research have been identified. These are dealt with in the following chapters: Inorganic fertilizers, Organic fertilizers, Organic and inorganic fertilizer combinations, Beneficial Microbes, Cropping systems and modelling, Soil and water management, Analytical methods and Socio-economics. The Abstracts were compiled for the period starting 1925 to 2014 from theses, referred journal articles, book chapters, conference proceedings and technical reports.

Foreward

This compilation of soil health abstracts covers 90 years of research. Soil health research is of fundamental importance for agricultural development in Kenya due to its high potential to boost the country's economy and food security. However, this is limited by low agricultural production brought about by poor soil health, limited adoption of appropriate/effective Integrated Soil Fertility Management (ISFM) technologies coupled with limited uptake/use of mechanized farming practices. Costly duplication of research efforts can be avoided by reference to materials from this wide range of published information resource. This book of abstracts is available in both print and soft copies and will be a valuable resource for researchers, tutors and students. The volume of soil health research publications emanating from Kenya is large and the scope equally wide, however the main thrust of soil health research have been identified. These are dealt with in the following chapters: Inorganic fertilizers, Organic fertilizers, Organic and inorganic fertilizer combinations, Beneficial Microbes, Cropping systems and modelling, Soil and water management, Analytical methods and Socio-economics. Abstracts of published literature were compiled for the period starting 1925 to 2014 from theses, referred journal articles, book chapters, conference proceedings and technical reports. We acknowledge that this may not be exhaustive of all the work done during the stated period but at least this book of abstracts provides significant information about most of the work that has been done in Kenya.

Contents

Inorganic Fertilizers

Overview

Inorganic fertilizers are natural materials or compounds formed through chemical processes for use to improve soil fertility and plant nutrition. Inorganic fertilizers come in mult-nutrient formulas or single nutrient. Mult-nutrient formulas include complete and balanced fertilizers which contain major nutrients such as nitrogen, phosphorus and potassium as well as secondary such as calcium, magnesium and sulphur and micronutrients: boron, zinc, molybdenum, manganese and others. There exist huge gaps in understanding the applicability of different inorganic element combinations for boosting crop nutrition across various agro-ecosystems in Kenya. The Kenyan government has been on the forefront to develop policies that promote beneficial and sustainable use of fertilizers through subsidy programs. This section highlights some of the work and the results of studies carried out in different parts of Kenya to evaluate the roles and functions that fertilizers can play in improving food crop production in Kenya.

Nyambati R. O. and Opala P. A. (2014). The effect of minjingu phosphate rock and triple superphosphate on soil phosphorus fractions and maize yield in Western Kenya. Hindawi Publishing Corporation ISRN Soil Science; Volume 2014, Article ID 920541, 8 pages; http://dx.doi.org/10.1155/2014/920541

We tested the effects of triple superphosphate (TSP) and Minjingu phosphate rock (MPR), when applied at phosphorus (P) rates of 50 or 250 kg P/ha in a factorial combination with urea or Tithonia diversifolia green manure as nitrogen sources, on P availability and maize yields for two seasons at Nyabeda and Khwisero in Kenya. Phosphorus availability was determined by the Olsen method or sequential fractionation. There was no significant difference in Olsen P as influenced by TSP and MPR at 50 kg P/ha irrespective of the N source at both sites in both seasons. However, at 250 kg P/ha, TSP gave significantly higher Olsen P than MPR. The labile P fractions generally followed the same trend as the Olsen P.Maize yields increased with increasing amount of P applied. Generally, there was no significant difference between TSP and MPR on maize yields irrespective of the N source. The Olsen-P, Resin-P, and sodium bicarbonate inorganic P correlated well with maize yields when TSP was used but the correlations between these P tests and maize yields for MPR were not consistent and therefore their use on soils treated with MPR should be exercised with caution.

Barasa J.N., Omami E.N., Okalebo J.R. and C.O.Othieno (2013). Effect of lime and phosphorus fertilizer applications on performance of French beans in Uasin Gishu district, Kenya. Global journal of biology, agriculture and health sciences. *G.J.B.A.H.S., Vol.2(3):35-41;* ISSN: 2319 – 5584

Soil acidity and low phosphorus status are the key factors underlying low crop production in Uasin Gishu District. An on farm experiment was conducted during the 2007 and 2008 cropping season to test the effects of agricultural lime (20.8% CaO) and Triple superphosphate (TSP) (12-14% CaO) on some soil properties and two French bean varieties namely: Samantha and Amy. The bean varieties grown in acid soils (pH 5.0) at Kuinet, Uasin Gishu District received 0 and 2 t/ha lime and 0, 20 and 40 kg P/ha (TSP) and their combinations. Lime significantly increased soil pH from 5.5 to 6.3 and 5.4 to 6.0 for the first and second seasons, respectively at the end of the study period. P alone had no significant effect on soil pH, but increased soil available P between 8.7 and 14.7g/kg. Positive responses of the two crop varieties were observed. This gave GM of Kshs 84,200 and 44,200 respectively. The effects of lime and TSP (With Cao component) were attributed to a favorable positive change in soil pH which increased the availability of soil nutrients through organic matter decomposition or direct release from TSP and availability to the crop and subsequent uptake of the nutrients by the crop. Economic analysis of the crop yields reflected higher returns from both lime and P, particularly in the pods harvested seven weeks after planting. The study demonstrated the superiority of Samantha French bean variety over Amy despite being the most popular within the region. The need for complementary lime and phosphorus application is recommended for acid soil fertility improvement and high crop yields.

Lugalichi F. K. (2013) Assessment of advanced common bean (*Phaseolus vulgaris* l.) for nutrient uptake, phosphorus efficiency and yield in low phosphorus soil types of Kakamega County. Msc. Thesis, University of Eldoret

Common bean (*Phaseolus vulgaris* L.) is an important source of food protein and cash in Kakamega County. Production is constrained by soil Phosphorus which is mainly due to low phosphorus content of soils, export of phosphorus in crop produce , soil erosion and fixation by oxides in acidic soils, a study was conducted to evaluate bean genotypes to two sites in KARI Kakamega (34^0 32′ and 34^0 57′ E ; 0^0 07′ and 0^0 15′ N); this site has Rhodic-Nitisol in which P availability is limited by active iron and the second site was Kabras (34^0 54′ E and 0^0 54′ N) with nito-rhodic ferralsols in which P availability is limited by active iron (Fe) and aluminium (Al) oxides. Assessment of germination/emergence, plant count at harvest was taken to determine the plant tolerance as affected by low soil P. Shoot P and N uptake, phosphorus use efficiency (PUE), yield and economic analysis components were done using two levels of phosphorus, P0 (control) and P30 (30 kg P/ha) and 13 common bean lines with two local checks (GLP2, GLP585) in a randomised block design. Data for germination stand count, harvest, and yield were subjected to analysis of variance using the SAS Software programme. Nutrient uptake and nutrient efficiency were subjected to student T-test. The means were separated using Least Significant Difference (LSD) (protected) test. The pH of the soils was found to be 4.90 and 5.38 for Kabras and KARI site respectively implying that the soils are acidic. The available P was low (2.45 ± 0.96 ppm and 7.69 ± 0.96 ppm for Kabras and KARI, respectively). The total nitrogen (%) was also low with 0.13 ± 0.02 and 0.2 ± 0.02) for Kabras and KARI Kakamega sites respectively. Kabras site had soils which have good physical characteristics but are chemically poor while KARI Kakamega site had soils which are considered fertile but have low level of 'Available' phosphorus. The germination and emergence of the different common bean lines varied between the sites with a weak intergenotype relationship between applied P on the stand count at both germination and harvest. There are varying responses of genotypes in performance in terms of shoot biomass P uptake, PUE, N uptake, yield and Marginal Rate of Return (MPR) in

treatments with addition of P. No significance difference ($p<0.05$) was observed between lines CC13, CC547, MLB-48 -89A, FEB195,A774, 286/6 and DOR755 for phosphorus uptake but it was higher compared to local checks. Lines 217-2, 222/1, AB136, and RWR221 had low uptake as the local checks ($p<0.05$) the inter-genotypic difference for nitrogen uptake was strong in the biomass and in the grain. Lines such as FEB195, DOR755, CC13, 3MS8-3, A774, UBR (95), and CC547 had a high uptake compared to the mean and local check lines 217-2, 222/1, 286/6, AB136, RWR221, and MLB-48-89A had a lower uptake together with local check GLP585. Yield (tons /ha) increased with applied P with Kabras site having an average of 5 bags per hectare and KARI had 6 bags per hectare. There was however a weak inter genotype significance ($p<0.05$) within the lines for yield both at KARI and Kabras sites. The highest net present value of benefits (PNB) for all the varieties was obtained from variety FEB195 (Ksh. 64,650/ha) at KARI site with application of phosphorus, while the lowest (D) was from the local checks (G585) at Kabras site. The varieties had a normal trend at both sites but KARI had a high return to land compared to Kabras. Genotypes DOR755, CC13, FEB195, UBR (95), A774 and CC547 were outstanding in all parameters tested. Therefore, these genotypes can be recommended for use in low-phosphorus environments as well as breeding materials.

Mbingo J. M. (2013). Response of maize to potassium and phosphorus fertilizers combinations on acidic soils of western Kenya. Msc. Thesis, University of Eldoret.

The low and un-sustainable agriculture productivity, attributed to soil fertility depletion contributes to food insecurity in Africa. In Western Kenya, about 0.9 million hectares of land has acidic soils, with pH<5.5 and low P availability. Due to lack of awareness of appropriate fertilizer combinations, mode of application and the consequences of increased fertilizer use, as well as weak extension services reaching the farmers, replenishment of soil fertility has been subjected to poor agronomic practises and hence poor yields. The main objective of this study was to determine the effects of four different combinations of P and K fertilizers on the maize performance and their residual effect on selected soil properties in western Kenya. A field study was carried out in two districts; Siaya and Kakamega North in Western Kenya for two seasons (2010 short rains and 2011 long rains). The study tested; two forms of Mavuno Basal fertilizers from Athi-River Mining Company - one blend without Potassium and the other blend without Potassium were tested against Triple Super Phosphate + Murate of Potash with lime, Triple Super Phosphate + Murate of Potash without Lime, and Minjingu Phosphate Rock + Murate of Potash and Control. Soil Samples were taken in different periods for determination of soil Chemical properties and yields were recorded. Economic analysis was done to determine the economic rate of the different fertilizer combinations used. Results indicated that the soils improved in terms of pH, available P and Exchangeable K, and in uptake of these elements by the crops upon application of all the treatments. Cumulative crop yields for both seasons suggest the best treatments to be Mavuno without potassium for Siaya and Mavuno with Potassium for Kakamega District. In Siaya district, Available Phosphorus was positively correlated to exchangeable potassium and soil pH at $p<0.05$ and $p<0.01$ levels in the first season, respectively. Yields were positively correlated to available phosphorus ($p<0.05$) in the first season and negatively correlated in the second season ($p<0.01$). In Kakamega District, Soil pH was positively correlated to exchangeable Potassium ($p<0.05$) and yields negatively correlated to available phosphorus ($p<0.05$) all in the first season due to K antagonism. Economic analysis of the fertilizer materials used, in terms of profitability and the final output when other factors were considered, treatments with the highest marginal rate of return in Siaya District were, high rate of mavuno without potassium (0.44 t/ha Mavuno) in Kakamega District, when other factors were considered, the most economical fertilizer was a low rate Mavuno with potassium (0.22 t/ha Mavuno).

Nadir S. W. (2013). Evaluation of Nitrogen Fertilizer, Lime and Soil-Water Effects on the Yield and Malting Qualities of Barley (*Hordeum vulgare* L.). Msc. Thesis, University of Eldoret

Barley (*Hordeum vulgare* L.) is cereal crop that grows over a wide range of environments and in Kenya it is grown primarily for malting. Barley requires adequate nitrogen (N) for good grain yields and quality malting, but the balance between adequate and excessive N is important therefore an experiment was set up between July 2011and July 2012 to address the problems of N fertilizer use and use of soil moisture effects on grain yield and malting qualities. The experiment was conducted at medium altitude in Mau-Narok (2740m asl). The objective was to evaluate effects of nitrogen fertilizer rates. Liming and varying soil water on the grain yield and malting qualities of barley. The experiments were done in the field and in the green house. For the field experiment, nitrogen as C.A.N fertilizer was applied at 5 levels 0, 30, 40, 50 and 60 kg N/ha, all at planting, phosphorus inform of TSP at 45 Kg/ha as P_2O_5, and potassium in form of muriate of potash at 35 Kg/ha as K_2O, were applied at 2 levels (0 & 1.5 t/ha). Split plot arrangement in RCBD design was used in the field. Two different experiments were conducted in the green house; the first one being a simulation of the field experiment which had similar treatments as those in the field. The second green house experiment was a split-split arrangement in CRD design, with 3 soil water contents (field capacity, 80% field capacity and 50% field capacity) applied in 4 nutrient types (nitrogen, phosphorus, lime and control having all combined) tested on two site soils. The results indicated the soils of two sites were acidic and deficient in phosphorus; Mau-Narok site had more soil N than University of

Eldoret. The effect of Nitrogen on grain yield was highly significant (P≤0.001). Increasing N rates beyond 40 Kg N/ha increased the grain protein content beyond the malting range. Effect of lime on grain yield in the field was significant at (P≤0.01) while (P≤0.01) in the green house for both site soils. Lime treatments had higher grain protein contents than non -limed ones but not significantly different. Lime - nitrogen interaction on kernel weight was highly significant (P≤0.001) but not significant for grain yield. The differences in grain yield, Kernel weight and biomass due to soil type were highly significant (P≤0.001). There was a significant relationship (P≤0.001) between soil moisture content and lime on barley growth. Limed treatments of both site soils utilized less water to produce mature grains compared to the un-limed ones. The effect of soil moisture levels on biomass and tillering was highly significant (P≤0.001). Application of lime in combination with N rates at 30 and 40 N kg/ha produced best results for grain yield (>7 t/ha for both field and green house), biomass, kernel weight and grain crude protein (10-13.5%) with soil moisture contents of between field capacity and 80% field capacity being ideal for barley growth on both soils. Nitrogen rates at 30N and 40 N Kg/ha produced highest grain yield, highest kernel weight and ideal maltable grain protein content for both sites. In addition, liming was recommended for Chepkoilel while increase in phosphorus use for Mau-Narok.

Njeru E. M., Maingi J. M., Cheruiyot R.1, Mburugu G. N. (2013). Managing soybean for enhanced food production and soil bio-fertility in smallholder systems through maximized fertilizer use efficiency. International Journal of Agriculture and Forestry 2013, 3(5): 191-197 DOI: 10.5923/j.ijaf.20130305.01

The production of promiscuous soybean by smallholder farmers in Kenya would improve soil fertility through biological nitrogen fixation (BNF), boost food security, and contribute to generation of cash. The present study was conducted to determine the effects of soil amendments on growth and yields of promiscuous soybean cultivars under varying soil carbon levels. Field experiments using early maturing SB 19 and late maturing SB 20 promiscuous soybean cultivars and different levels of phosphorus (P), potassium (K) and sulphur (S) fertilizers were conducted in two sites in the south-eastern slopes of Mt. Kenya, approximately 1500 m above sea level. The soybean cultivars were observed for phenology, plant biomass production, pod fresh weight, 1000 seed weight and haulm weight. Significant differences were observed on most yield components due to field carbon level, soybean cultivar and fertilizer amendments, while the plant height was only affected by fertilizer application and soy bean cultivar. However, the effects due to the interaction of these factors were not significant. Therefore, the benefits of combined use of BNF by soybean and application of PKS fertilizers could be a promising entry point into maximized fertilizer use efficiency by smallholder systems in Kenya. **Keywords** Promiscuous Soybean, Soil Amendments, Biological Nitrogen Fixation, Smallholder Farmers

Tuwei C. C (2013). Effect of phosphate fertilizer on growth and leaf yield of African Nightshade (*solanum* L section solanum) genotypes in Uasin Gishu county Kenya. Msc. Thesis, University of Eldoret Department of Seed and Crop Horticulture

The African Nightshade vegetable is in high demand in many parts of western Kenya. This demand has not been met due to yields caused by low use of fertilizer inputs in the region. Most of the soils found in Uasin Gishu are acidic and deficient of Phosphorous but there is inadequate information available on the appropriate rate of phosphorous to be used to produce optimum yields of the African nightshade. The specific objectives of this study were to evaluate the effect of phosphate fertilizer application rate on growth; leaf yields and financial benefits of growing the three African nightshades in Uasin Gishu County. The experiments treatments consisted of three genotypes *Solanum scabrum* (C1), *Solanum villosum* var villosum (C2) and *Solanum villosum* var miniatum (C3) and four rates of phosphorous; 0 (P0), 20 (P1), 40 (P2) and 60 (P3) kg P/ha arranged in a factorial combination. A randomized complete block design with three replications was used. The study was conducted in two consecutive seasons in Moiben location, Eldoret East district. Phosphate fertilizer as triple superphosphate was applied at planting time while top dressing with calcium ammonium nitrate (CAN) at 60 kg N/ha was done six weeks later. Soils were sampled prior to planting and later analyzed for available phosphorous using standard procedures. The plant height, leaf area, number of leaves, fresh and dry weight leaf yields were taken from 45 days after sowing and harvesting done 78 and 77 days after sowing for season one and two respectively by picking all leaves and tender shoots. Leaf yields were determined by weighing the fresh weight and also dry weight after drying them in an oven at 70°C to a constant weight. A benefit cost analysis ratio for each treatment was done to determine their economic attractiveness. Plant height, leaf area, number of leaves and number of branches in the main stem increased significantly (p<0.001) in two seasons. The fresh leaf yields increased over the control by 285-346% and 84-407% in season one and two respectively. The dry leaf yields increased over the control by 162-328% and 163-362% in season one and two respectively. There was a significant (p≤0.05) interaction between genotype and phosphorous on leaf yields in two seasons. *Solanum villosum* var villosum had high percentage increase over the control in the number of leaves in a plant and leaf yields in season one. It also had higher increase over the control in the height, number of leaves, number of branches, leaf area and leaf yields. *Solanum villosum* var villosum and *Solanum Villosum* var miniatum had high benefits in season one and two respectively. It is recommended that 60

kg P/ha should be used for all sampled genotypes in the long rains. In the short rains season 40 kg P/ha should be used for *Solanum villosum* var villosum and 60 kg P/ha for *Solanum villosum* var miniatum and *Solanum villosum* var villosum respectively. Further work need to be done on the effect of *Solanum villosum* var villosum higher than 40 kg P/ha in the short rain season.

Wasike J. W. (2011) Influence of nitrogen application rate and plucking interval on yield of tea. Msc. Thesis, Moi University, Chepkoilel Campus

Nitrogen level and plucking interval are important management practices that can be manipulated to determine tea yield. Previous studies concentrated on the effect of individual treatment, i.e. plucking interval and nitrogen rates, but, limited knowledge was to determine how different nitrogen levels and plucking intervals affect yield of tea. The experiment was carried out at the Tea Research Foundation of Kenya (TRFK), Kericho; in the months of July, August and September of the year 2008. It was arranged as 5x3 factorial experiments in a split plot design with 4 blocks. Three levels of plucking intervals, (7, 10 and 14 days) and five levels of nitrogen rates (0, 50, 75, 100 and 200 kg N/ha in form of NPKS 25:5:5:5) were investigated on clone EPK TN 14-3 that was planted in 1987. Plucking tea at intervals of 10 days and applying 100 kg N/ha gave the highest ($P<0.05$) yield. The study showed the combined advantage of a shorter plucking interval and optimum fertilizer rates for higher yield.

Barasa J.N. (2010). Lime and phosphorus applications to improve acidic soils productivity: A case study of French bean production in Uasin Gishu District, Kenya. Msc. Thesis, Moi University, Kenya

Soil acidity, one of the main soil chemical contributors to low soil fertility, is a major factor behind low land productivity in Uasin Gishu District. The soils in this area are inherently infertile, underlain by petrophylite materials and have been under wattle tree production for decades. This situation of low productivity is worsened by high population growth, continuous monocropping of either maize or wheat; use of soil acidifying fertilizers, a situation which further enhances soil acidity restricts the availability of phosphorus and contributes to aluminium toxicity to some crops. Against this background, on farm field experiment was conducted in Uasin Gishu district (Kuinet site) of Kenya to test the effects of liming and phosphate fertilizers on soil pH, available phosphorus, organic nutrients, uptake, nodulation and yield of two (Samantha and Amy) French beans. Hence the agricultural lime (20.8% CaO) mined and processed at Koru, Kisumu, Kenya at the rates of 0 and 2 tons/ha was tested against TSP source of P (at 0, 20 and 40 Kg P/ha), the rates. A 2x2x3 factorial arrangement, laid out on RCBD with three replications experiment was conducted during the long rains of 2007 and 2008 seasons. The residual experiment consisted of the plots set up in 2007 and continued in the long rains of 2008 without lime or phosphate inputs. A new experiment with similar treatments was set up in 2008 as a replicate of the previous year`s plots to monitor the changes in soil parameters due to the effect of lime and phosphorus applications. Soil sampling to assess the changes in soil properties from different treatments was done at 30 and 60 days after planting of each season. Addition of lime and phosphate gave an increase in soil pH as well as soil phosphorus, which were significant ($p=0.01$) during the 2007 and 2008 planting seasons. No significant differences were observed in the residual plots. The application of lime and phosphorus led to higher levels of soil organic carbon and total soil Nitrogen which increased with time giving the highest values in the residual experiment indicating the build up of these nutrients in soils over time. Lime and phosphorus applications led to significant yield responses from both (Samantha and Amy) French bean varieties, these were significant ($p<0.01$). The means obtained from the treatment materials showed highest 9.3 ton/ha Samantha pod yields from TSP in combination with Lime at 2 ton/ha lime together with 40 Kg P/ha TSP, Amy variety however gave the highest fresh pod yields of 6.5 tons/ha at 2 ton/ha lime and 20 Kg P/ha TSP combination. The grain responded similarly, giving the highest yields of 0.56 tons/ha for the same treatment combination for Samantha. No significant grain yield response was obtained for Amy variety from treatments applied. Treatments applied significantly increased N and P uptakes for each French bean variety. The economic analysis results also indicated higher returns due to soil acid correction input materials. It would appear that application of basal fertilizer in combination with liming material is more feasible and sustainable alternative to the recommended fertilizers. Finally, French bean variety Samantha is recommended for adoption by farmers in Uasin Gishu due to its good performance an acid soil and positive economic returns.

Macharia C.N., Njeru C. M., Gichangi A.W. and Kamundia J.W. (2010). Determination of location specific agronomic recommendations for a maize based farming system in western Kenya. *Proceedings of the 12th KARI biennial scientific conference*. PP 456-464

Multi-location studies were contacted in western Kenya region to evaluate maize yield response to variety, density, fertilizer rate nitrogen and time of sowing of beans in mixed crop culture. Constraint analysis survey presiding the study reviled that crop yield were about 0.75 h/ha for maize and 0.20 t/ha for beans with yield gaps as wide as 5 t/ha. The study reviled that grain yield was significantly low under low fertility and high density such that high crop density under low fertility had neither agronomic nor economic advantage. Delayed sowing of beans did not affect maize grain yield but significantly reduced bean yield. Starter Nitrogen at 20 to 40 kg N /ha increased

yield by 1.3 to 2.4 t/ha over the control which was significant and yield of local maize peaked at around 4 t/ha with 40 kg of N/ha which was similar to or higher than the yield of hybrid maize at the same level of fertilizer. As a recommendation, farmers should plant beans simultaneously with maize, apply a start up doze of 20-40 kgN/ha in maize and use hybrid varieties only if they can afford to apply 40 kgN/ha or more. Even though application of 40 kg N/ha did not reduce striga incidences it reduced stunning maize plants and increased maize grain yield significantly in both striga -free and striga infested fields.

Macharia C.N., Njeru C.M., Kamundia J. W., Nafuma L. S., Gichangi A., and Shiluli M.S (2010) Nitrogen Use Efficiency and Maize Yield Response to Rate and Mode of Nitrogen Application in the Kenya Highlands. In: Ouda *et al* (Eds) Proceedings of 12th KARI Biennial Scientific Conference. Pp103-109

Field experiments were conducted over three-seasons at Tatton Farm, Egerton University Kenya, to evaluate fertiliser use efficiency (NUE) and grain yield of maize in response to fertilizer nitrogen (N) applied at two rates (60 and 120 kg N/ha and six modes of application. The experimental units were stationary field plots in a randomized complete block design in four replications. Detection and separation of variation in maize grain yield between treatments was done according to analysis of variance and Tukey's Honestly Significant Difference test Procedures. NUE was determined using the agronomic efficiency (NUE-AE) and partial factor productivity (NUE-PFP) indices. Nitrogen applied in a single dose at 35 days after crop emergence (DAE) or in split application at either 0 or 35 DAE or at 35 and 70 DAE gave significantly (P=0.05) higher grain yields than other regimes, AE and PFP per kg of N applied ranged from 13.3 to 31.7kg and from 46.7 to 91.7kg of grain yield respectively. Grain yield and nitrogen use efficiency varied significantly with timing and mode of application strongly underscoring the necessity of fine tuning application in order to match nutrient supply to crop demand.

Mbakaya D. S, Okalebo J. R, Muricho M., Lumasayi, S. (2010). Effects of liming and inorganic fertilizers on maize yield in Kakamega North and Ugunja districts, western Kenya. In: Wasilwa et al (Eds) 12th KARI Biennial Scientific Conference. 8 – 12 November, 2010, Nairobi, Kenya pp 123-129

Soil fertility depletion on smallholder farms is one of the fundamental biophysical root cause responsible for declining food production in Africa. Studies in western Kenya have indicated that soils in the region are severely depleted of phosphorus (P) and nitrogen (N). To improve and maintain soil fertility, effects of liming, organic and inorganic fertilizers on yield of maize were studied in Kakamega North, East Kabras division and Ugunja district in Western Kenya in 2009. The study demonstrated integrated soil fertility management technologies (ISFM). Treatments included lime, Diammonium phosphates, Mavuno, Lime + Diammonium phosphates, Lime + Mavuno and conventional farmers practice (FP) as control. The study was conducted in 40 representative mother trials and 2000 individual representative farms (1200 and 800 in Kakamega North and Ugunja) respectively as babies. The test crop to evaluate technologies was several maize varieties (WS 505, Hybrid 516, Hybrid 6210, DK 8031 and KSTP94). The soil chemical analysis results showed most parts of Kakamega North and Ugunja were acidic with pH ranging from 4.63 to 5.81. Overall, farmers related DAP and Lime + DAP first, Mavuno alone third, Mavuno + Lime fourth, Lime alone fifth and farmers' practice last based on maize yields at harvesting. Liming was highly appreciated by all farmers due to appreciable maize yield increase realized compared to farmers' practice.

Muriithi C., Mugai E., Kihurani A. W., Nafuma C. J. and Amboga S. (2010) Determination of silicon from rice by-products and chemical sources on rice blast management. In: Wasilwa et al (Eds) 12th KARI Biennial Scientific Conference. 8 – 12 November, 2010. Nairobi, Kenya pp 7-13

Rice (*Oryza sativa*) is an important crop in Kenya. It ranks third after wheat and maize contributing to over 20% of the total calorie intake to humans. ITA 330, IR2793-80-1, BW 196 and basmati/pishori 370 are varieties commonly grown in Kenya. Basmati 370 is the most preferred for commercialization because it commands premium prices and occupy 80% of the land. However, it is susceptible to rice blast (*Pyricularia oryzae*) which is one of the most important diseases of rice causing an economic loss of 70-80% thereby threatening Kenyan food security. The objective of this study was to evaluate different rice blast management approaches using different sources of silicon rice by-products and chemical control. The experiment was carried out in Mwea Irrigation Scheme in Kirinyaga district. It was laid out in completely randomized design (CRD) with six treatments; Calcium silicate (1000 kg/ha), Potassium silicate (1 lit./ha) and rice by-products (rice straw, 0.7 ton husk ash equivalent to 2 tons before burning 0.6 ton straw ash equivalent to 2 tons/ha before burning). Basal fertilizers were added at 30 kg K_2O/ha, 58 kg P_2O_5/ha and N which was applied as a top dress (80 kg N) in two splits. Inoculums of Pyricularia oryzae (4 x 10 5 conidia/ml) was used to infect the rice plants and panicle blast infection assessed using a scale of 0-9, the IRRI standard. Treatments with Calcium silicate, ash husk and potassium silicate were not significantly different in yield and in control of rice blast. Yields were higher in plots that were treated with chemical silicate and rice husk ash, but they also had higher ratings of rice blast.

Mwangi P. W. (2010). Effect of intercropping and nitrogen fertilizer application on performance of maize and selected legumes. PhD Thesis, Chapter 4, University of Nairobi, Kenya

Intercropping legumes with maize is the common production system in the cod semi-arid areas of Laikipia district. Previous studies in the region indicated that butter bean (variety Ex-Kasuku) and grass pea (selection 1325) were comparable to chickpea (variety Desi) and common bean (variety Katumani 3330) and therefore suitable the region. However, the performance of these legumes under maize based intercropping system has not been established. A two season field study was therefore conducted in 2007 long rains and short rains seasons to determine the effect of intercropping and nitrogen fertilizer on performance of maize, butter bean, grass pea, chickpea, and common bean. Maize planted with Nitrogen (60 kg N/ha) and without nitrogen (0 kg N/ha) was intercropped with the legumes in a randomized complete block design with a factorial arrangement and replicated 3 times. Pure maize stands planted with 60 kg N/ha and without nitrogen supplements were included as the controls. Sole crops of the legumes planted without nitrogen were included to enable determination of land use advantages and plant competitiveness. Collected data included plant height, growth rate, leaf area index, photosynthesis active radiation interception, dry matter accumulation, total nitrogen uptake and yield. Productivity of the intercrops was evaluated based on land equivalent ratios and monetary advantage indices. The potential legumes to add nitrogen to the cropping systems was based on number of nodules and percent of nitrogen fixing nodules. Nitrogen supplementation on maize significantly increased leaf is index, photosynthetic active radiation interception, growth rate and dry matter yield of maize. However, it significantly reduced growth rate, dry matter, nitrogen yield and grain yield of intercropped legumes. Reduction of legume performance by nitrogen supplemented maize was highest in chickpea and lowest in butter bean. In most cases, the presence of legumes reduced growth rate, dry matter, nitrogen yield and grain yield of maize in Zero-N plots but had little effect in nitrogen supplemented plots. Generally butter bean had the most depressing effects on maize performance attributes. Butter bean may therefore not be preferred by farmers whose main crop is maize. Monetary benefits and land use advantages for dry matter, nitrogen and grain yield were in the order Maize/butter bean>maize/common bean> maize/chickpea intercrops while the opposite was observed in maize aggressively. Land equivalent ratios were greater than unity and consistently higher in zero-N intercrops than in nitrogen supplemented intercrops suggesting better resource utilization and productivity of intercrops than sole crops. The potential of the legumes to fix nitrogen was significantly reduced by intercropping in both zero-N and nitrogen supplemented maize. Butter bean, grass pea and common bean were comparable in most nitrogen fixation potential values while chickpea had the lowest nitrogen fixation potential. Maize/butter bean and maize/grass pea intercrops which had the highest land productivity may serve as alternative systems for crop diversification in the region. Further investigation on nitrogen fixation potential of the legumes is desirable as this would determine the amount of nitrogen added to the cropping systems.

Mwangi P. W. (2010). Performance of selected Legumes in the cold Semi-Arid area of Laikipia District, Kenya. PhD Thesis, Chapter 3. University of Nairobi

Legumes can play a major role in replenishing soil fertility in existing small holder farming systems of the cold semi-arid areas of Laikipia district. Information on the appropriate legumes for the cold semi-arid areas is however scarce. A two season field study was therefore carried out in 2006 long rains and short rains to identify "promising" multipurpose legumes for the cold semi-arid areas. Two varieties of each of the legumes including Lima bean (*Phaseolus lunatus* L.) soybean (*Glycine max* L.), grass pea (*Lathyrus sativus* L.), butter bean (*Phaseolus coccineus* L.), garden pea (*Pisum sativum* L.) hyacinth bean (*Lablab purpureus* L.) and one variety each of the local checks chickpea (*Cicer arietinum*) and common bean (*Phaseolus vulgaris* L.) were tested in a randomised complete block design with three replications. Data collected included emergence, pest infestations, survival rate, phenology, ground cover development, dry matter, accumulations, nitrogen use efficiency, soil moisture, water use efficiency, grain yield and grain yield components. Hyacinth bean (variety Highworth) had the highest emergence of 96.6 and 91.1% in the long rains and the short rains season, respectively, while soybean variety TGX1889-12F (54.5%) and garden pea variety Greenfeast (45%) had the lowest in the long rains and short rains seasons, respectively. Soybean variety TGX1895-33F, garden pea variety (variety Oregon Sugar). Common bean and Lima bean cultivars had the highest pest infestation while hyacinth bean (variety Highworth) and grass pea (selection 1325) were least affected. Butter bean cultivars had the highest survival rate while garden pea (variety Oregon Sugar) and lima bean cultivars had the lowest maximum % ground cover was attained earliest (45 days after emergence) in butter bean (variety ExKasuku), grass pea, common bean, garden pea, and lima bean and latest (75 days after emergence) in soybean and hyacinth bean cultivars. butter bean (variety Ex-Miharati) had the highest mean ground cover (44.0 and 30.8% in the long rains and short rains season, respectively. chickpea, butter bean, (variety Ex-Kasuku) and grass pea (selection 1325) had the highest growth rate, above-ground nitrogen accumulation while garden pea, soybean and lima bean cultivars had the lowest performance in these attributes. Mean Nitrogen Use Efficiency (NUE) of chickpea and butter bean cultivars were comparable to that of common bean but higher than for the common legumes. Plots planted with butter bean and grass pea cultivars had significantly higher soil moisture than plots of most of the other legumes at 15 to 45 cm soil depths during the early growth periods and significantly lower soil moisture than plots of soybean cultivars at 60 to 90 cm soil depths during the late growth periods.

The highest dry matter and grain water use efficiencies (WUEs) were observed in chicken pea and the lowest in soybean (variety TGX 1895-33F). Chickpea had the highest grain yield of1715.6 and 1485.6 kg/ha in the long rains and short rains season, respectively, while soybean and hyacinth bean cultivars had the lowest grain yields. Results have shown differential performance between and with legume species under the cold semi-arid areas implying the need to select legume species and varieties for these regions. Chickpea, grass pea (selection 1325) and butter bean variety (Ex-Kasuku) were indentified to be "promising" legumes and recommended for integration into the dominant maize based cropping system of the cold semi-arid areas of Laikipia district.

Ngesa H.O., Okora J.O., Ochieng J.A.W., Opondo M.A., Ayako P.O. (2010). Current performance of striga tolerant maize variety GAF4. *Proceedings of the 12th KARI Biennial Scientific conference,* 8 – 12 November 2010 KARI Headquarters, Kaptagat Road, Loresho, Nairobi, Kenya. PP 320-324.

Striga hermonthica causes low cereal production in maize among the resource poor farmers in western Kenya. Maize has low variability for tolerance to striga. To widen the genetic base for selection, 250 crosses were made between teosinte (*Zea diploperenis*) derived Striga-tolerant sources and adopted local germplasm. The F1s generated were evaluated for striga tolerance at Kibos, Homabay and Busia in 2000. Selected populations were advanced to S3 and used to constitute synthetic open pollinated varieties, which were evaluated in 2002 and 2003. three elite synthetic cultivars (GAF4, GFVC06 and GFVC08) with grain yields of over 4 t/ha in 2002, and 3.3 t/ha in 2002 and 2003, respectively, were submitted for the 2004 and 2005 national performance trial (NTP) Striga kit. GAF4 was released in 2007. When used as a check variety, GAF4 was outstanding with grain yields of 3.24 to 5.12 kg/ha across the eight sites in the 2009 NTP. In on-farm demonstrations in 2009 at the districts where NTP Striga kit was conducted, grain yields were 3.1, 2.2, and 1.4 t/ha for GAF4, farmer's purchased variety, and farmers own seed, respectively. The new variety GAF4 is better than Lagrotech early and KSTP94, all of which were earlier releases for striga tolerant. The yield gap between farmer preferred variety and GAF4 is clear indication that yields can be improved through gene transfer.

Ochola P. and Omollo J.O (2010). Influence of residual phosphorus on yield and quality of sugarcane. *Proceedings for the 12th KARI Biennial Scientific Conference*, 8 – 12 November, 2010, KARI Headquarters, Kenya, pp. 732-736

The effect of residual phosphorus (P) on yield and quality of six sugarcane varieties, N14, KEN82-216, KEN82-472, KEN82-808, KEN83-737 and EAK73-335 was evaluated in cambisol and vertisol soils, located at the experimental fields of KESREF- Kibos. This followed soil test in these fields which revealed high P levels and therefore P fertilizer may not be required for sugarcane growth. Sugarcane was planted without P fertilizer unlike the recommendation where P fertilizer is applied. The sugarcane varieties performed differently in terms of yield and quality under cambisol and vertisol. Performance was higher under cambisol soils than under vertisol soils, this was attributed to cambisol soils faster P release into the soil solution. Variety N14, KEN83-737 and EAK73-335 recorded yields higher than 90TCH and were of good quality under vertisol soils while varieties N14, KEN82-216, KEN82-472, KEN82-808 and KEN83-737 recorded higher yields than 100TCH under cambisol soils. This suggests variety N14, KEN83-737 and EAK73-335 may be efficient in P uptake in P fixing soils. The study concludes that P dynamics vary with soil types and therefore may influence P fertilizer management for sugarcane production.

Odundo S. N, OjiemO. J, Okalebo J. R, Othieno C. O, Lauren J. G, Medvecky B. A. (2010). Effect of phosphorus on survival, phosphorus accumulation and yield of cowpea (*Vigna unguiculata*) varieties across a soil fertility gradient in Western Kenya. In: Wasilwa et al (Eds) 12th KARI Biennial Scientific Conference. 8 – 12 November, 2010. Nairobi, Kenya. pp 271-278

Declining soil fertility and poor genetic potential of cowpea germplasm have resulted in decreased yield of the crop in smallholder farms in western Kenya. This is because of limited availability of Phosphorus (P) in the western Kenya soils resulting from inadequate use of fertilizers and P fixation, and susceptibility of the local farmer varieties to major pests and diseases. Due to limited nutrient recycling in these smallholder farms, use of external sources of P alongside improved cowpea varieties, tolerant to major pests and diseases could improve cowpea yields. Local and improved varieties were screened to investigate their adaptability, yield, and biomass P accumulation across a soil fertility gradient. Experiments were conducted in Nandi South district, western Kenya, during the long and short rain seasons 2009. Three local cowpea varieties (Enzegu, Khaki and Ilanda) and five improved varieties (ICV6, ICV12, CB46, IT92K-284-2 and IT-83D-442) were screened at four contrasting sites: Kapkerer, Kiptaruswo, Bonjoge and Koibem, representing low, medium-low, medium-high, and high soil fertility levels, respectively. The design was RCBD with three replications in factorial arrangement of treatments. P was applied at three levels of 0, 15 and 30 kg P/ha using triple superphosphate. Data was collected on plant count at 2 weeks after emergence, total above ground dry matter (DM) and grain yield. Varieties emerged were significantly ($P<0.05$) different across sites. Varietal survival significantly ($P<0.05$) differed across sites. Mean survival rate was best in Kapketer (80%) and worst in Bonjoge (39%). There were no significant ($P<0.05$) DM response to P

application. Averaged over varieties, the mean DM accumulation was 72 kg/ha under no P application and 221 kg/ha at 30 kg P/ha in Bonjoge. Similarly, at Koibem mean DM accumulation without P application was 360 kg/ha and 417 kg/ha at 30 kg P/ha. Application of P had significant (P<0.05) influence on cowpea grain yield. In Bonjoge site, variety CB46 had the highest grain yield of 434 kg/ha, which was significantly different from ICV6 (206 kg/ha) and IT90K-284-2 (217 kg/ha). In Koibem, however, ICV12 had the highest grain yield of 342 kg/ha, which was significantly different from Khaki (127 kg/ha) and IT83D-442 (128 kg/ha). The results of this study show that the cowpea varieties screened had differential adaptation to the test site environmental conditions. While productivity is influenced by soil fertility status, application of P is essential for enhancing both DM accumulation and grain yield.

Ogutu M. O. (2010). Effects of inter-specific interaction of Nitrogen fertilizer and bean-maize cropping systems on seed quality of beans in western Kenya. Msc. Thesis, Moi University School of Agriculture and Biotechnology

Common beans (*Phaseolus vulgaris*) seed qualities are often affected by soil deficient nutrients and sub-optimak intercropping systems practised by farmers. Combined effects of nitrogen fertilizer at 0 kg N/ha, 50 kg N/ha and cropping systems consisting of four patterns namely research, farmers, Mbili and Pure bean stand practices were studied and evaluated i an intercrop involving beans and maize (*Zea Mays*) in the year 2006. Objectives of this study were to determine the effects of cropping systems and nitrogen fertilization at different locations on seed qualities of beans. Two field experiments were conducted at KARI-Kibos and KARI-Kisii. Maize Hybrid 614D and bean variety KK8 were used as test crops. The experiments composed of 4 cropping systems and two nitrogen fertilizer levels in a Randomized Complete Experimental Design. The results from this study, showed that Mbili system significantly ($p \leq 0.05$) increased the seedling dry matter and seed vigour by 42% and 42% respectively, while the research method increased the seed germination percentage by 10.6%. However bean seed qualities parameters like seedling growth rate, shoot length and seed sizes were not affected by the intercropping systems. Addition of nitrogen fertilizer increased Thousand Seed Weight (TSW) at Kisii by 4.5%, while at Kibos it reduced the shoot length by 42%. Effects due to location revealed that TSW, seed germination and shoot length were of better quality in Kisii, than in Kibos while cropping system×N fertilizer × location interactions showed that seedling growth rate and vigour were increased by 20% and 18% respectively. Seed vigour which is one of the physiological characters of seed can be used as the best indicator to determine the performance of field crops under adverse conditions of temperature, water stress, weeds and pathogens.

Otieno K., Akello S.O., Odongo D., Lumumba A. (2010) The effect of fertilizer and pest control regimes on the incidence of pests, seed cotton yield and profitability of cotton in western Kenya. *Proceedings of the 12th KARI Biennial Scientific Conference*, 8 – 12 November, 2010, KARI Headquarters, Kenya, pp 499-507

Since the liberalization of the cotton sector by the government in 1991, the entire cotton-lint-textile-apparel industry has, like in other cotton growing countries, continued to experience negative growth. Factors responsible for the negative growth include competition from imports of second-hand clothes. At the farm level, the high cost of production has been cited as a major limiting factor. A study was undertaken at KARI Kibos Research Centre with the objective of comparing the effect of applying different regimes of fertilizer and spraying on pest incidence, seed cotton yield and profitability of the enterprise given the current input prices and the recommended farm gate price of seed cotton. Cotton (*Gosypium hirsutum* L) variety KSA 81M was used for the study. The crop was planted at a spacing of 100 cm x 30cm. A factorial split plot design replicated 3 times was used, with the main plot treatments being (a)application of basal fertilizer (Di-ammonium phosphate, DAP) at planting where appropriate, at the rate of 46 Kg P_2O_5/ha followed 26 Kg N/ha as Calcium Ammonium Nitrate (CAN) at topdressing, and (b) application of basal fertilizer at planting with no top dressing. The sub-plot treatments involved spraying with Beta-Cyfluthrin 1.5g+ chlorphyrifos 250 (Bulldock 025 EC, at 0.6 litres/ha), at f=different intervals (weeks) after planting with no (zero) spraying at all as control. The crop was hand weeded three times during the growth period. Data was collected on plant height at top dressing; days to 50% boll formation; number of bolls per plant; seed cotton yield and 1000 seed weight. The data were subjected to ANOVA using the GLM procedure of SAS computer package while profitability was computed using gross margin analysis. Scoring for pest incidence was initiated two months after planting and was undertaken at an interval of every two weeks to coincide with major growth stages. The major pests monitored were pink bollworms (*pectinophora gossypiella*), jassids, stainers (*Dysdercus suterellus*), red mites (*Tetranychus* sp.), white flies (*Bemisia tabacai*), aphids (*Aphis gossypii* Glover), thrips (*Caliothrips* sp.) and lygus. Spraying against pests was done at the end of each sampling. In general only pests observed to have major incidence were the aphids and white flies although no aphids were observed after third sampling. Fertilizer regimes did not have any significant effect on the incidence of aphids during all sampling stages. However, significant (P<0.05) differences between the fertilizer regimes were recorded on the incidence of whiteflies during both the first and fourth samplings. The incidence of aphids at the first and second sampling was not significantly different for all the spraying except no spraying which registered higher incidence. In all cases, there was a drastic drop in aphid population. At the third sampling no significant differences were recorded for all the spraying regimes. At the first sampling, significant (P<0.05) difference in whitefly incidence was recorded between for (4)

sprayings and no spraying. The rest of the spraying regimes did not register any significant difference in the mean incidence of whiteflies. No significant differences were registered at both the second (2) and third (3) sprayings. During the fourth sampling, only four (4) sprayings had significantly low incidence of whiteflies. None of the other parameters measured (i.e. days to 50% boll formation; number of bolls per plant; seed cotton yield and 1,000 seed weight) were significantly affected by top dressing. Most of the parameters were significantly ($P<0.05$) affected by spraying regimes. It is evident that four or five spraying gave the best mean seed cotton yield with the best 1,000 seed weight being achieved with five sprayings. The gross margins were all negative regardless of the fertilizer and spraying regime used.

Ashilenje D. S. (2009). Effect of potassium nutrition on growth leaf yield and Aphid incidence in vegetable African nightshades (*Solanum* L. section Solanum). Msc. Thesis, Moi university school of Agriculture and Biotechnology

Vegetable African nightshades play an important role in food security, nutrition and income generation. The yield and quality of this vegetable are limited to poor soil fertility: low levels of phosphorous, potassium, calcium and organic carbon as well as damage by aphids among other factors. Experiments were conducted in the field at Malava and Bukura areas and in a greenhouse at Ikolomani in western Kenya, to determine the effect of varied rates of potassium on the growth, leaf yield and aphid incidence in different species of vegetable African nightshade (*Solanum* L. section Solanum). An economic analysis was also done to determine the profitability of vegetable African nightshades at varied rates of K. The greenhouse experiment was setup as 4×4 factorial type in a RCBD with two factors; potassium rate and genotype. Genotype had four species namely: *Solanum villosum* subsp. Villosum (Orange berry, entire leaf margin), *Solanum villosum* Miller subsp. Miniatum (Orange berry, finely lobed dentate leaf margin). In the greenhouse each of the species received 0, 13.2, 26.4 and 39.6 mg K/kg of soil (KCI 60%K) obtained from the rates used in the fields (kg/ha). A 2×4×4 factorial experiment in a RCBD was established in the field with site (two agro-ecological zones), a genotype and potassium rate as the main factors. Each of the above species was supplied with 0, 33, 66 and 99 kg K/ha (KCI 60% K) in the field experiment. There were a total of sixteen treatment combinations replicated three times in each experiment. The soils from Bukura, Malava and Ikolomani were found to have low levels of exchangeable K which were 0.1, 0.2 and 0.2 Cmol/kg respectively. These soils were also acidic with low organic carbon contents. Genotype interacted significantly ($p\leq0.001$) with rate of potassium in their effects on the fresh leaf yields. Application of potassium at the rate of 66 kg/ha significantly ($p\leq0.05$) increased the mean fresh leaf yields from Bukura and Malava, in *Solanum villosum* subsp. villosum (4.89 tons/ha), *Solanum villosum* Miller subsp. Miniatum (4.58 tons/ha) and *Solanum scabrum* Miller (11.46 tons/ha) compared to the control where 3.88, 3.04 and 5.27 tons/ha were obtained respectively. The fresh leaf yields of *Solanum sarrchoides* Sendtner declined significantly ($P\leq0.05$) from 3.42 tons/ha in the control to 2.78 tons/ha at 66 kg K/ha. There was no significant variation ($p>0.05$) in the mean fresh leaf yield of Solanum scabrum Miller receiving 66 kg/K ha compared to 33 kg K/ha. Both *Solanum villosum* subsp. Villosum and *Solanum villosum* Miller subsp. Miniatum had significantly higher ($P<0.05$) mean fresh leaf yields at 66 kg K/ha than other rates of potassium. In the greenhouse experiment aphid incidence on vegetable African nightshades was significantly affected ($P<0.05$) by the rate of potassium and genotype as main effect (1.0) and 39.6 mg K/kg (1.04) *Solanum sarrachoides* Sendtner had a significantly lower ($p\leq0.05$) aphid score of 0.13 compared to the values from other species while that recorded in *Solanum scabrum* iller (1.83) was significantly higher ($P<0.05$) than the rest. The aphid incidence had a strong linear correlation with leaf dry weight in *Solanum villosum* subsp. villosum and *Solanum villosum* Miller subsp. Miniatum while that of *Solanum scabrum* Miller was weak. It was cost effective to produce *Solanum scabrum* Miller because of its higher Benefit/cost ratio when using 33 kg K/ha compared to *Solanum villosum* subsp. villosum and *solanum villosum* Miller subsp. Miniatum which had the highest values of 66 kg K/ha. *Solanum scabrum* Milleralso had the most profitable ($p<0.05$) leaf yield compared to the others. It was not economical to apply potassium in the production of *Solanum sarrachoides* Sendtner as these gave low to negative Benefit/Cost ratio values. It has emanated from this study that potassium application can increase the leaf yields of vegetable African nightshades despite an increase in aphid incidence. It is recommended that farmers should grow *Solanum scabrum* Miller and use 66 kg K/ha for maximum profits. There is need to establish how organic and inorganic sources of potassium and their combination can influence the yield of vegetable African nightshade and their attack by aphids in the field. This will provide the farmer with the options of using manure and inorganic fertilizers optimally to maximize the production of this important vegetable particularly to the small scale farmers.

Lusweti J. F. N. (2009). Effects of Phosphate fertilizers and seed priming on root and bean fly damage on beans and Lablab in Nandi south district. Msc. Thesis, University of Nairobi

Pulses are important for food and income earning for most households. However diseases and pests such as root rot and bean fly, can be overcome using soil fertility amendments and seed priming by enhancing the plant growth vigour. Research has identified some pulse varieties with both pest and disease tolerance and locally available fertilizers in the region to improve both the plant nutrition and soil nutrient status. Western Kenya is an important pulse production area in this study, three field experiments were conducted in Aldai division, Nandi south district, in four sites to determine the effects of Phosphate fertilizer and seed priming on root rots and bean fly in beans and lablab during the short rains of 2008.These were planted in the four sites along a fertility gradient in a randomized complete block design (RCBD), laid out in a split plot arrangements and replicated three times. Three legume varieties were lablab (cv Rongai), KK8, and GLP2 planted and evaluated on root rot and bean fly damage. Controls consisted of plots without phosphorous and without primed seeds. Data collected included emergence percentage, population at harvest, root rot and bean fly incidence and severity, biomass at flowering stage, days to 50% flowering, grain yield and yield components. Varietal difference and soil fertility affected root rot and bean fly damages in both beans and lablab. Root rot and bean fly damage was generally high in low fertility sites. Significant grain yield increase with the increasing soil fertility levels was observed in all sites with the supply of phosphate fertilizers. Priming improved plant survival percentage in low fertility sites by 30% compared to high fertility sites. It was observed that application of Phosphorous fertilizer and priming generally reduced the bean/lablab plant mortality and mortality rates were lower in high fertility compared to low fertility sites. Application of Phosphate fertilizer enhanced lablab plant biomass and 100 seed weight, irrespective of seed priming. There was a higher lablab grain yield in high fertility site (Koibem), compared to low fertility sites (Kapkarer), when P fertilizer was applied. Therefore, the field study confirmed that adequate soil nutrients in the soil are important for crop tolerance to both root rot and bean fly damage TSP application on KK8 beans gave the highest yields with least pest and diseases losses in all sites. Soil fertility measures and soil amendments could lead to higher yields of legumes in degraded soils after years of conversion from forestland to cropland. The results showed various parameters measured in legume varieties had different variable effects depending on age of plant, soil nutrients of the site and other prevailing environmental factors. Seed priming might not necessarily improve grain yield in high rainfall areas unlike in the low rainfall areas as the soil water available could be enough to facilitate germination of the seeds.

Kiiya W. W. (2009). Effects of lime, nitrogen and shade on selected soils chemical properties and growth of weeds. PhD thesis, Egerton University

The influence of household and farm characteristics on soil fertility, weed types and their distribution were determined. The farm survey and soil analysis carried out shows that the soils. In the study areas were acidic and deficient in available phosphorous, exchangeable calcium and magnesium. The problem was found to be more pronounced on small hold farms due to inadequate use of farmyard manure and inorganic fertilizers, coupled with continuous cultivation without adequate replenishment of mined nutrients. The study showed that the low soil fertility and high acidity favoured infestation of sheep sorrel weed which was spreading fast and difficult to control because of its several strong propagation channels. The best green manure legumes for growing in the cool highlands of the North rift were identified. Lupine, butter beans and purple vetch identified as suitable green manure legumes for growing in the cool highlands. These legumes grew rapidly attaining high ground cover and biomass suggesting that if incorporated into the soil as green manure through uptake of the released nutrients. However, nodulation and nitrogen fixation of these legumes were poor suggesting that the only way the legume can be used to improve soil fertility and reduce soil acidity was through incorporation as green manures. The effect of green manure legumes and inorganic nitrogen on selected soil chemical properties and growth of weeds in potato cropping system were determined. The study showed that lupine and garden pea when incorporated to the soil, raised the ph and increased soil available phosphorous and exchangeable calcium. An important mechanism by which the soil raised ph is believed to be through formation of organic AL complexes in soil solution by releasing low molecular weight organic acids from the decomposing legumes. The organic-AL complex lowers the concentration of phytotoxic AL^{3+} in solution. The study therefore showed that through incorporation of legumes or their use as smother crops, sheep sorrel weed density and biomass could be reduced. However, because of the low rate of legume decomposition, the positive effects on both the selected soil chemical properties and sheep sorrel weed were not realizable in one season. The effects of liming and nitrogen on selected chemical properties and weed growth were determined. Liming raised soil pH, increased soil available phosphorous and calcium confirming that it can be used effectively to improve soil fertility and ameliorate soil acidity. The study showed that sheep sorrel weed density and biomass reduced through liming, thus confirming that lime can effectively be used to manage this weed. In addition, the study showed that when lime is being used either alone or in combination with inorganic nitrogen to manage sheep sorrel weed, measures of early control for other weeds such as wild radish need to be put in place. This is because a sheep sorrel weed density and biomass reduced and the reverse was true for wild radish weed. The study further showed that the shade promoted germination and growth of sheep sorrel weed, explaining why the weed has remained of serious concern to farmers in the cool highlands of the North Rift.

Nganyi E. W. (2009). Pigeon pea response to phosphorus fertilizer, temperature and soil moisture regimes during the growing season at Katumani and Kampi ya Mawe in Machakos and Makueni districts of Kenya. Msc. Thesis, University of Nairobi College of Agriculture

Pigeon pea (*Cajanus cajan*) is an important grain legume grown in the semi arid areas of the tropics used for food, feed and as a cash crop. Food insecurity is a persistent problem, especially in the marginal regions where the rapidly raising population cannot be supported by the rain-fed agriculture, especially in highly variable, erratic and changing climate as well as declining soil fertility. A sound strategy in the alleviation of these challenges is the expansion of production of crops that are suited to marginal environments such as pigeon pea. The broad objectives in this research were to establish the response of pigeon pea to basal phosphorus fertilizer application. The specific objectives were to characterize the soil fertility factors at the experimental site, to determine the variations of soil moisture over the growing season of pigeon pea, to assess the response of pigeon pea to basal fertilizer application and to test the suitability of the Agricultural Production System (APSIM) software as a monitoring and forecasting tool in the pigeon pea production. Two field rain-fed experiments were conducted between November 2006 and September 2007 at Kenya Agricultural Research Institute sites at Katumani and Kampi ya Mawe (in Machakos and Makueni districts respectively). The experimental design was a randomized complete block design laid out as split-plot and replicated four times. The whole plot treatment was fertilizer application and the sub-plot treatment, five pigeon pea varieties which included one a local cultivar, Kionza as a local check. At the beginning of the experiment, soils were sampled for physical and chemical analyses. After every fortnight, crop phenology including height was recorded; soil moisture monitored using a neutron probe and weather data collected at nearby weather stations. At harvest, yield data was recorded and plant sampled for Nitrogen (N), Phosphorus (P) and Potassium (K) nutrient analyses. Results showed that in all varieties fertiliser application improved the ability of the crop to sequester soil moisture during dry spell but this did not influence the growth and development of the crop nor translate to better yields, seed quality or the shelling percentage for all the five varieties at Katumani; and for four varieties at Kampi ya Mawe; and only at Kampi ya Mawe. It also had significant effect on dry matter partitioning in N, P but not for K at that site. Although Katumani was more fertile and received more rainfall (1010 mm) during the cropping season, more than twice and better distributed than at Kampi ya Mawe (429 mm), only one variety (ICEAP 00040) performed better there (2044 kg/ha) by about twice. APSIM simulation predicted well the crop growth, development and yield in medium, but not in the long-duration varieties. It is recommended that factors that allow the local cultivar Kionza to respond to fertilizer application at only Kampi ya Mawe while not in the other varieties or site to be investigated. It should also be established if pigeon pea's phosphorus requirements have been adequately met and if not, what other factors could synergistically improve this crop's response. APSIM internal parameters need to be adjusted so that they can accurately predict the growth and phenological development of pigeon pea under field condition at the two experimental sites.

Okwuosa E. A., Riungu T.C., Mathu R.W., Lekasi J.K., Kagwe L.W. (2009). Beans response to phosphorus fertilizer application. Kenya Agricultural Research Institute, Muguga, Annual report pp.85-87

There was variation in response to P application amongst the bean genotypes tested. These could be attributed to the genotypic variation among the germplasm. The differential performance probably is an indication of better adaptation to low soil P for some of the genotypes especially those that can yield under low P conditions. The differences in responses to P application can be attributed to the difference in root structure which affects rate of P uptake. This needs to be investigated further and could form a basis for influencing breeding efforts to change plants ability for efficient P uptake. However this is one season's data and therefore not conclusive enough.

Gitari J. N. (2008). Determination of factors influencing the efficiency of legume green manures for maize production in Embu, Kenya: Maize performance as affected by legume green manures supplemented by different N fertilizer levels. PhD Thesis 2008, Experiment Three. Kenyatta University,

This section reports on N contribution of relay-cropped mucuna, crotalaria and lablab (raised in situ) to the succeeding maize crop with or without mineral N supplementation at 30 or 60 kg N/ha. There were large seasonal variations in legume biomass generation. On average, mucuna or crotalaria produced about 2.0-4.5 Mg/ha of the legume herbage contributing 30-80 kg N/ha while lablab biomass was low (<1.0 Mg/ha). These seasonal legume herbage quantities had some implication on maize growth was evident throughout the entire growth cycle of the maize crop. Plots with none or low quantities of legume residues where no mineral N was supplemented gave low grain and stover yields indicating the effectiveness of these residues as a source of N. Averaged across the five cropping seasons, plots with legume residues alone(no mineral N) produced 2.5,2.3 and 1.6 times more grain than the unammended control for mucuna, crotalaria and lablab, respectively. The study established that biomass quantities in excess of 2.0 Mg/ha may not require any mineral N supplementation. Furthermore, the rainfall data recorded at the site for the six consecutive seasons of experimentation showed that only two out of six seasons could be considered as having adequate and well distributed rainfall. This has great implication

on N use efficiency. Mineralization of soil N and maize N uptake information generated revealed that there is a slight mismatch between the two although this does not greatly hinder seasonal N utilization due to the length of the growing season typical of this study region where normal seasonal rainfall distribution hardly exceeds two months. On the other hand, commonly grown mid altitude maize cultivars (PHB 3253 ana H 513) take 70-74 days to reach 50% tasseling and silking.

Gitari J. N. (2008). Determination of factors influencing the efficiency of legume green manures for maize production in Embu, Kenya: The effect of legume residue placement methods on N release for maize growth. PhD Thesis 2008, Experiment two. Kenyatta University

This section reports on suitability of surface mulching versus soil incorporation as methods of legume residue placement. Maize grain and stover yields were similar under either mulching or incorporation treatment. There was a two-fold increase in maize grain yield above the control (no residues applied) in both in both mucuna or crotalaria treated plots. The exception was lablab whose performance was attributed to the low quantities of residues generated in situ and applied. Rapid breakdown of surface mulched residues was greatly aided by the high intensity of early seasonal rains together with the presence of certain macrofauna, particularly termites (Macrotermes spp.). The results of this study therefore indicate that under the rainfall and temperature regime patterns typical of the sub-humid central highlands of Kenya, the decomposition and nutrient availability from mucuna, crotalaria or lablab residues is similar whether placed on the surface or incorporated into the soil.

Gitari J. N. (2008) Determination of factors influencing the efficiency of legume green manures for maize production in Embu, Kenya: Performance of maize (*Zea mays*) and three green manure legumes under different intercropping densities and sowing intervals. PhD Thesis 2008, Experiment One. Kenyatta University

This section reports the effect of intercropping herbaceous legumes with maize at varying densities and relay-cropping intervals. The three herbaceous legumes were: Mucuna (*mucuna pruriens* (L) DC Var.utilis (Wright) Bruck, crotalaria (*Crotalaria ochroleuca* G.Don] and lablab (*Lablab purpureus* (L) Sweet cv. Rongai). The study established that neither the intercropping density nor the period to relaying the legumes affected the performance of maize. However, a high density of crotalaria planted at the same time with maize affected the performance of maize particularly in seasons when soil moisture was inadequate. Relay cropping the legumes later than the second week after the emergence of maize greatly affected their performance by depressing the biomass production possibly due to competition for growth resources, in particular light, where less than one third of the total incoming solar radiation is intercepted.

Gitari J. N. (2008) Determination of factors influencing the efficiency of legume green manures for maize production in Embu, Kenya: Farmer's knowledge and practices in using soil fertility indicators in de-leanating on-farm fertility gradient and use of plant residues to ameliorate soil infertility –Survey. PhD Thesis, Kenyatta University

The survey that was conducted at the beginning of the study, clearly showed that farmers are knowledgeable in issues of soil fertility. The farmers gave soil colour, soil structure and the occurrence of certain weed flora as their main soil fertility indicator was the dominance of certain weed flora. The most prevalent high soil fertility indicator weeds were: *Commelina benghalensis, Bidens pilosa*, *Galinsoga parviflora* and *Amaranthus* spp. whereas *Rhynchelytrum repens, Richardia scabra, Alternanthera philoxeriodes* and *pteridium equilinum* were the most prevalent low fertility indicator weed species. Laboratory analysis of the soils indicated that soil pH and exchangeable bases (Ca++ and Mg++) are the most sensitive soil parameters that corroborate farmers' perceptions and knowledge of soil fertility indicators. The pH of the soils collected from infertile and fertile farm sections were 4.8 and 5.4, respectively, for the cooler, wetter agro-ecological zones while that of the lower, warmer zones were 6.0 and 6.9 for infertile sections, respectively. The concentration of exchangeable bases in the fertile fields was 5-9 times higher than that of the infertile fields. The study established that the farmers perceptions corroborated by scientific laboratory measurements. Most of the indicators mentioned for fertile and infertile farm fields matched with the quantitative scientific measurements. Moreover, variation in data sets for samples collected from similar categories of different farms was high implying that such results could only be applied locally within given farm. This means that one farmer's fertile field may be another farmer's infertile field. Nonetheless, the results of this study present a strong case for not disregarding farmer's ideas and knowledge. Such knowledge may be useful for making provisional recommendations particularly in situations where scientific soil analysis is inaccessible or is not economically feasible.

Gitari J. N. (2008). Determination of factors influencing the efficiency of legume green manures for maize production in Embu, Kenya: The use of low quality residues in slowing down the rate of fast-decomposting green manure residues to improve N synchrony for maize performance. PhD Thesis, Experiment Four, Kenyatta University

This final part of the study investigated the effect of adding low quality (high carbon) residues to the legume residues as a method of slowing down their decomposition to maximize N synchrony. The inclusion of these high carbon residues did not affect N availability from legume residues. Maize N uptake and the resultant grain and stover yields were similar in both pure and mixed residue treatments. In general, grain and stover yields from the treatments with mixed residue were slightly higher suggesting that the presence of these low quality residues was somehow synergistic. For instance, the five seasons' average maize grain yields in plots with legume residues (2.0 Mg/ha) mixed with 6.0 Mg/ha of stover were 3.37 and 2.59 Mg/ha for mucuna, crotalaria and lablab while the corresponding yields in pure legume treated plots were 2.89, 2.62 and 2.61 Mg/ha for mucuna, crotalaria and lablab respectively. To gain greater understanding of these mixed residues, a separate litter bag study was conducted alongside the main experiment showed that mixed maize: mucuna residues in a ratio of 2:3 (w/w) had a decomposition half life (t_{50}) of 7.7 days compared to 6.9 days for the pure mucuna residues. Overall, these two simultaneous studies point to the complexity of decomposition patterns in such mixtures. This is probably attributed to the nature of mineralization-immobilization patterns in such situations. It is clear from the results of this study that these low quality residues have a role in soil quality improvement particularly the soil physical characteristics. For a period of three years, when this study was undertaken, the inclusion of high carbon residues (6.0 Mg/ha) significantly increased the soil organic carbon by 13% and also led to a decrease in soil bulk density by 8.3% when compared to the absolute control with no residues added.

Ikitoo, E. C. (2008). Crop response to fertilizer nitrogen (N) and phosphorus (P) and the N and P nutrients concentration in plant parts. PhD thesis, Moi University

Vertisols are universally low in N status and variable in available P content and their deficiencies common in the Vertisols worldwide. Thus crop responses to fertilizer N and P are frequent and soil fertility, depth, rainfall and fertilizer source, method and time of application influence the crop responses. The objective of the study was to determine the maize crop responses to fertilizer N and P under varying drainage condition in the cultivated Vertisols of Kenya. Field experiments were conducted at Kakindu, Mwea and ADC Namandala, Kitale. Four drainage land forms (DLs), three fertilizer P rates 0, 30, and 60 kg P/ha i.e. P0, P1 and P2, respectively and three fertilizer N rates in single and split doses 0, 60, 120, 60 (split) and 120 (split) kg N/ha, i.e. N0, N1, N2, N3 and N4 respectively, were tested in a 4 x 3 x 5 split-split plot factorial experiment, laid out in RCBD and replicated three times. Maize was used as test crop. In Mwea, significant (α=0.05) plant height increases of 15-29% in the 2001 LR and 6-12% in the 2002 SR due to the fertilizer N rates, were observed above the control N0 at flowering and maturity. Further, total biomass, grain, cobs and stover yield increases of 32-47, 20-76, 1-48 and 39-46% respectively, in the 2001 LR and 55-94, 220-520, 130-280 and 26-46% respectively, in the 2002 SR, were observed above the N0. In 2001 SR, significant total biomass and grain yield increases due to N1 and N3 were observed. In Kitale, significant plant height increases of 12-60% in the 2001 LR and 1-13% in the 2003 LR, were observed above the N0 at all stages of plant growth. Grain, cobs, stover and total biomass yield increases of 31-44, 22-31, 50-72 and 42-56%, respectively, in the 2001 LR and 26-48, 31-49, 21-33 and 23-39%, respectively, in the 2003 LR, were observed. In the 2002 LR, which had poor rainfall distribution, apart from the N4 the fertilizer N rates significantly reduced the plant height by 3-5% at all stages of plant growth. However, no significant treatment effects were observed in the total biomass and yield components. Differences between the single and split fertilizer N doses were not significant. The maize crop responses to fertilizer P were inconsistent. In Mwea plant height increases due to the fertilizer P rates P1 and P2 above the control P0, were insignificant in low rainfall seasons, i.e. 2001 LR (395 mm) and 2001 SR (221). However, in the 2002 SR (572 mm), significant plant height increases of 4-5, 5-10 and 3-5% were observed during early, flowering and maturity stages, respectively, with grain yield increases of 12-27%. In Kitale, significant plant height increases of 7-39 and 6-28% in the 2001 LR (1290 mm) and 2002 LR (1006 mm), respectively, were observed at all stages of plant growth and in the 2003 LR (1286 mm), a 5% increase was observed at maturity. Significant increases in the grain yield of 20-23% in the 2001 LR, stover yield of 12-15, 18-23 and 5-7% in the 2001 LR, 2002 LR and 2003 LR, respectively, and total biomass yield of 13-15% in the 2001 LR and 2002 LR, were observed in Kitale. The result indicated overwhelming fertilizer N influence in the maize growth and yield in wetter seasons, while in relatively drier seasons with poor rainfall distribution, he influence tended to be negative. Significant fertilizer P responses on the other hand, were observed mainly in the stover yield and much less in the grain yield, indicating existence of factors that limited its uptake during maturity and translocation from the vegetative sink to the reproductive sink. The N and P concentration in the maize leaf, stover and grain were determined to relate nutrient levels to crop uptake and yield. Results indicated highest N concentration in the leaf, i.e. 1.3-2.3%, intermediate in the grain 1.3-1.7% and lowest in the stover, i.e. 0.4-0.9%, while for P, the leaf and grain concentrations were similar i.e. 0.13-0.23% and higher than the concentration in the stover, i.e. 0.04-0.10%. The nutrient concentrations varied with rainfall, and were higher in seasons with low rainfall and lower in seasons with high rainfall. However, the concentrations were below the

required amounts for adequate maize growth and yield and the N uptake appeared to limit plant growth and yield in high rainfall seasons, indicating need for application of higher rates; while the P uptake, appeared to be limited by soil moisture content in seasons with low rainfall, indicating need for better soil moisture content conservation.

Wasonga C. J., Sigunga D. O., Musandu A. O. (2008). Phosphorus requirements by maize varieties in different soil types of western Kenya. *African crop science Journal*. Vol. 16, No.2 pp. 161-173.

Phosphorus and nitrogen deficiencies limit production of maize (*Zea mays* L.) in many soils of western Kenya. Considerable amount of work has been done in N nutrition of maize in the region. There is, however, paucity of information on which to consider base fertiliser P recommendations for increased maize production considering potential differences in responses due to varieties, soil type and climate. External and internal P requirements and P utilisation efficiencies of two open pollinated varieties (Ababari and Oking') and one hybrid (H513) Were examined at four P-deficient on-farm site (2 Ferric Alisol, 1 Haplic Ferrasol, and Ferric Acrisol) in western Kenya. The varieties were grown under P fertilisation rates of 13, 36, 39, 52 kg P/ha and a check (no P application). Maize performance varied with sites, rate of P application and variety. The highest grain yields (15% moisture content) at the sites varied from 2,732 to 6,479 kg/ha for Ababari, 2,350 to 5,835 kg/ha for H513, and 2, 299 to 4,459 kg/ha – for Oking'. Internal P requirements ranged from 7 to 24 Kg P/ha for Ababari, 4 to 18 kg P/ha for Oking' and 5 to 18 kg P/ha for H513. Internal P requirements depended on both variety and environment but more on environment than variety. Phosphorus physiological efficiency (kg grain/kg P) ranged from 111 to 314 for Ababari, 145 to 277 for Oking' and 127 to 390 for H513. Ababari performed as well as did H513, and the two were better than Oking'. Ababari is therefore, recommended for the region since it is open pollinated and hence, the peasant farmers do not have to buy seeds every season. Row application of P is inappropriate in case determination of crop external P requirement is required.

Ligeyo, D. O. (2007). Genetics of tolerance to aluminium toxicity and low phosphorus among Kenyan maize germplasm. PhD thesis, Moi University

Soil acidity is a major constraint to maize (*Zea mays* L) production due to aluminium (Al) toxicity and phosphorus (P) deficiency hindering root growth. The objectives of the study were to: (i) determine relative importance of additive and dominance genetic effects and their interactions under different soil pH and P levels, (ii) determine whether inheritance of Al tolerance among Kenyan inbred lines is quantitatively or qualitatively controlled. An understanding of the relative magnitude of additive, dominance and epistatic genetic effects would enable selection of a breeding procedure. Aluminium tolerance and sensitive inbred lines of maize were identified among Kenyan maize germplasm and in order to determine the genetics of their tolerance, a partial diallel cross involving three Al-tolerance and two AL-sensitive maize genotypes was made to develop F1, F2, BCP1 and BCP2 generations. The five generations including parents were evaluated under field conditions at two sites with characterized acidic soils in Uasin Gishu district (Chepkoilel and Kuinet). Four levels of treatments were utilized: control (no lime or phosphorus applied), lime (L) or phosphorus applied separately, and lime and phosphorus applied together (LP). Lime and phosphorus were applied at the rates of 4 t/ha and 36 kg P/ha, respectively. Large differences were indicated between the yields of parents and the F1 generations due to the large dominance effects. Application of L and P and P alone had significant increases in yield for most of the generations at both sites. Three crosses indicated significant additive genetic effects when L or P was applied and predominant additive x dominance interaction under P. The sensitive x sensitive cross exhibited significant dominance in genetic variance in the control while tolerance x sensitive crosses exhibited significant additive x additive genetic effects. The manifestation of dominance x dominance epistatic variance was not consistent for the ten crosses. Additive x additive epistasis was predominantly positive for yield. The magnitudes and positive additive genetic variance and dominance genetic variance indicated that reciprocal recurrent selection would be effective for developing improved maize varieties for acid soils. When aluminium tolerance in roots of crosses involving two tolerance and one susceptible inbred line were studied using intact roots of maize seedlings grown in a nutrient solution (222 μM Al) at controlled pH (4.2) and temperature (26 ºC), inbred line AL 237/67 had the highest root growth while Reg00114 had the lowest root growth. Back crosses involving the susceptible parent showed the least growth. The F2's generally had less root growth compared to the F1's for the crosses used. Additive variance was more preponderant compared to dominance variance in the inheritance of aluminium tolerance and it contributed 66% and 82% of the total genetic variance in the two crosses studied. The number of genes controlling aluminium tolerance was found to be about 8 for the first cross and 4 for the second cross. The results from both crosses show that aluminium tolerance is controlled by multiple genes. Estimates of genetic effects showed that additive genetic effects were significant and positive for both crosses signifying an enhancing effect of these genes in the inheritance of aluminium tolerance. Tolerance to Al toxicity in inbreds G and R11C7-44 is qualitatively inheritance.

Ligeyo, D. O. (2007). Effect of P and lime on maize yield and P-uptake and P-use efficiency in acid soils of western Kenya. PhD thesis, Chapter 3, Moi University

Phosphorus (P) deficiency is considered one of the major growth-limiting factors for plants in many natural ecosystems. The experiment was carried out with a view to evaluate the effects of phosphorus, and lime application under low soil pH and to determine the P-uptake and P-Use efficiency of Kenyan and exotic maize genotypes. Fifteen maize (*Zea Mays* L.) genotypes, 11 from Kenya and 4 from CIMMYT, were evaluated in acid soils of Bumala and Kuinet in Western Kenya. The experiment was set up in a randomized complete block design with three replicates. Each genotype received four treatments (+lime, +phosphorus, +lime and zero lime and zero phosphorus). The genotypes were planted to one-row plots of 35 plants spaced 0.3 m apart with an inter-row spacing was 0.75 m. Lime was applied at the rate of 4 t/ha while phosphorus was applied in form of Triple Super Phosphate (TSP) at the rate of 36 kg P/ha. The combined analysis of variance revealed that genotypes, treatments, sites and the interactions between site and genotype and site and treatments for the three parameters were significant. The mean number of days to anthesis ranged between 60 days in DH02 to 126 days in K15 at Bumala and from 84 days in DH02 to 126 days in K15 at Kuinet. The overall mean number of days to anthesis was 71 and 111 days for Bumala and Kuinet sites respectively. Results from both sites indicated significant differences when phosphorus, lime or both were applied compared to where none was applied. Application of phosphorus reduced the number of days to anthesis. The mean ear height ranged from 45.5 cm in DH02 to 115.9 cm in K17 at Bumala, and 213 cm in Cimcali 97BSA 3-1 and 92.6 cm in H614D at Kuinet. The overall mean ear height was 78.5 cm and 52.8 cm at Bumala and Kuinet respectively. Results from Kuinet show that there was no significant increase in ear height due to application of lime, phosphorus or both. However, in Bumala addition of phosphorus, lime with phosphorus had significant increase in ear heights. The overall mean grain yield was 1.42 and 2.26 t/ha at Bumala and Kuinet respectively. At Bumala, addition of P or L and L with P gave mean grain yields of 1.61, 1.35 and 1.46 t/ha respectively compared to a situation where neither P nor lime was applied (1.26 t/ha). At Kuinet mean grain yields of 2.40, 2.24 and 2.47 t/ha were obtained for similar treatments. Cultivar 2B4 had the highest mean grain yield among the hybrids and populations at Bumala (1.92 t/ha) while at Kuinet H614D ranked first (4.77 t/ha). Cimcali 97 BSA 3-1 had the highest mean grain yield among the inbred lines at Bumala (2.53 t/ha), while K17 with 2.74 t/ha ranked first at Kuinet. The fifteen maize genotypes were evaluated for their P-use efficiency. The external phosphorus (P) use efficiency ranged from -8.6 to 37.7 kg grain per kg of P applied at Bumala, but varied between 7.1 and 29.7 in Kuinet. Variety 5A, H623 and inbred line K15 had negative P use efficiencies at Bumala. The internal P use efficiency ranged from -352.9 to 270.5 kg per unit P uptake in Bumala while at Kuinet it ranged from 41.2 to 305.8. When phosphorus was combined with lime, two land races 4C3 and 306B had the highest external and internal P use efficiencies respectively at Bumala. At Kuinet inbred lines K17 and K15 had the highest external and internal P use efficiencies respectively. P contents in the plant tissue ranged from 0.17% to 0.40% and 0.18% to 0.52% at Bumala and Kuinet respectively. Cimcali 97 BA Chap 1 SA 4, which is an acid tolerant check, had the highest tissue P contents at both sites. Total uptake from 0.85 to 8.0 kg/ha in Bumala while in Kuinet it ranged from 2.18 to 12.38 kg/ha. Inbred line K17 had the highest total dry weight while Cimcali 97 ASA 3-1 and Cimcali 97 BSA 3-1 which are susceptible checks in acid soils with low P had the lowest total dry weights. Genetic variability for tolerance to low soil P exists among Kenyan germplasm and this could be exploited to develop P-use efficient varieties.

Ligeyo, D. O. (2007) Developing and evaluation of Al tolerance maize synthesis for use in acid soils of Kenya. PhD thesis, Chapter 4, Moi University

A large number of open pollinated varieties (Synthetics), hybrids and inbred lines have been developed in Brazil for use in acid and low-P soils and since very little work has been done on this aspect in Kenya there is need to characterize and evaluate these germplasm for inclusion into our maize gene pool. The experiment was done with the following objectives; to test the adaptability of the Brazilian synthetics for adaptability to Kenyan conditions, and to cross Brazilian germplasm to adapted Kenyan germplasm to introgress Al-tolerance and P-use efficiency. Aluminium tolerant and P-use efficient varieties from EMBRAPA, Brazil, were initially evaluated at KARI-Kitale for yield, adaptability and other agronomic attributes. The experiment was set up in a randomized complete block design with three replicates. Each genotype was planted to three-row plots of 11 hills each spaced 0.3 m apart. The inter-row spacing was 0.75 m, thus giving a plant population of 44,444 plants per hectare. Phosphorus was applied in form of Triple Super Phosphate (TSP) at the rate of 36 P per hectare. Top dressing was done six weeks after planting using Calcium Ammonium Nitrate (CAN) at the rate of 80 kg N per hectare. The grain yield ranged from 2.94 t/ha in Synthetic Aluminium (Tolerant variety) to 7.92 t/ha in BR 106. The overall mean grain yield was 5.93 t/ha. Some Brazilian synthetics and hybrids were high yielding, however, the only problem was the yellow grain colour and hence there may be need for conversion into white if they were to be used for the improvement of the Kenyan germplasm. The number of days to 50% pollen shed ranged from 91 in CAT-AL 237/67x1143 (Brazilian material) to 102 in BR 106 (Brazilian material), Gx82 and Gx44 (Kenyan materials). The mean number of days to pollen shed was 97, but generally most of the Brazilian materials matured earlier than the Kenyan germplasm. The ear height ranged from 79 cm in HS-L3x723726-45 (Brazilian material) to 207 cm in 82x97 (Kenyan material). The mean ear height was 117.06 cm. The plant height ranged from 200 cm in synthetic aluminium form Brazil to 359 cm in 82x97

from Kenya. The mean plant height was 254.75 cm. The rust scores ranged from 1.5 to 3.0 while the blight scores also ranged from 1.5 to 3.0. Two Brazilian materials (HS-26xL3 and HS-L3x723726-45) had rust scores above 3.0 while HS-L3x5046 also from Brazil had a blight score of 3.0. In the second experiment the materials were evaluated under acid soil condition in western Kenya. The mean grain yield was 6.20 and 4.32 t/ha at Bumala and Kuinet respectively. The mean plant height was 258.23 and 215.92 at Bumala and Kuinet respectively while the mean ear height was 105.62 cm and 111.0 cm at the two sites respectively. The Brazilian materials seem to be adapted to medium agro-ecological zones of Kenya and the Al tolerance and P-use efficiency traits should be introgressed into the Kenyan germplasm. In addition, the Brazilian material could be useful in improving early maturity, reduced plant and ear height of the Kenyan germplasm

Okonda B.O. (2007). Effect of liming and inorganic fertilizer application on seed iron and zinc concentration and grain yield of common bean (*Phaseolus vulgaris* L.). Msc. Thesis, University of Nairobi, Kenya

Biofortification of staples with micronutrients and agronomic management practices such as amounts, timing, placement and forms of fertilizers applied in production of these crops have the potential to influence their grain micronutrient density. It has been hypothesized that the amount of iron and zinc in grain can be increased through agronomic management (fertilization practices) and plant breeding. However, comprehensive agronomic approaches, including specific fertilization strategies with macronutrients and micronutrients aimed at enhancing grain mineral concentration for grain destined for human consumption are not well known, hence this work. The objectives of this study were to determine the effect of N, P, K, liming, Fe and Zn fertilization on grain yield, seed iron and zinc concentration in beans and to identify bean genotypes with high seed Fe and Zn concentration grown under four environmental conditions in Kenya. Six trials were conducted at four locations in Kenya (Kabete Field 16, Kabete Field 10, Thika and Kakamega) over two seasons. Treatments were four levels of N (0, 50, 100, 150 Kg N/ ha), P (0, 25, 50, 75 Kg P/ha), K (0, 50, 100, 150 Kg K/ha) and lime (0, 7, 14, 21 t/ha). Fe was applied in soil (0, 2, 4, 6 Kg/ha) using Fe-EDDHA (6% Fe) and foliar (0, 75, 150, 300 litres/ha) using 0.2% $FeSO_4$ while Zn was applied at 0, 2, 4 and 6 Kg/ha into the soil using $ZnSO_4$, agricultural lime ($CaCO_3$), Fe EDDHA (Ethylene diamine di (O-hydroxy-phenyl acetic acid), ferrous sulphate ($FeSO_4$), and zinc sulphate ($ZnSO_4$) were used as nutrient sources. In each trial, the experiment was laid out in a split-plot design with three replicates. Nutrient levels were the main plots and varieties were the subplots. The bean genotypes used were nine micronutrient dense lines (AND 620, MLB 49-98A, VNB 81010, Maharagi Soja, GLP 2, TY 3396-12, Gofta, Roba-1 and Nakaja) and a low nutrient dense variety (M211) as check. A plot consisted of four, 3-m rows. Spacing was 45cm between rows and 10cm within rows. Data were analyzed statistically using Genstat Software. Mean bean grain yield increased significantly with increasing levels of N up to 100 Kg N/ha. Mean seed Fe and Zn concentration increased significantly ($P<0.05$) with increasing levels of N up to 100 Kg N/ha. In the N trial, highest significant mean yields were achieved from AND 620 (2807 Kg/ha) grown in Kakamega. The same variety grown in Kabete Field 10 had highest significant mean seed Fe concentrations (137.1 ppm). Highest significant seed Zn concentrations were obtained from VND 81010 (36.8 ppm) grown in Kabete Field 10. Mean bean grain yield increased significantly with increasing levels of P up to 25 Kg P/ha. Mean seed Fe and Zn concentration increased significantly ($P<0.05$) with increasing levels of P up to 50 Kg P/ha. In the P trial, highest significant mean yields were achieved from GLP 2 (2747 Kg/ha) grown in Kakamega, while highest significant mean seed Fe concentrations were obtained from AND 620 (123.4 ppm) grown in Kabete field 10. Highest significant increase in seed Zn concentrations were obtained from VNB 81010 (49.1 ppm) grown in Kabete Field 10. Mean bean grain yield increased significantly with increasing levels of K to 100 Kg K/ha. Mean seed Zn concentration increased significantly ($P<0.05$) with increasing levels of K up to 150 Kg K/ha. In the K trial, highest significant mean yields were achieved from MLB 49-98A (2856 Kg/ha) grown in Kabete Field 10. Highest significant seed Zn concentrations were obtained from VNB 81010 (34.3 ppm) grown in the same field. Mean bean grain yield increased significantly with increasing levels of lime up to 7 t/ha. Mean seed Fe and Zn concentration decreased significantly ($P<0.05$) with increasing levels of lime. In the lime trial, highest significant mean yields were achieved from GLP 2 (2744 Kg/ha) grown in Kakamega, while highest significant mean seed Fe concentrations were obtained from AND 620 (81.8 ppm) grown in Kabete Field 10. Highest significant seed Zn concentrations were obtained from VNB 81010 (29.2 ppm) grown in Kakamega. Mean bean seed Fe concentration increased significantly ($P<0.05$) with increasing levels of Fe up to 4 Kg Fe/ha and foliar Fe up to 150 L Fe/ha. Mean seed Zn also increased significantly with increasing levels of soil Fe up to 4 Kg Fe/ha and foliar Fe up to 150 L Fe/ha. In the Fe trial, highest significant mean seed Fe concentrations were obtained from AND 620 (152.0 ppm) grown in Kabete Field 10, while highest significant seed Zn concentrations were obtained from VNB 81010 (33.0 ppm) grown in the same field. Mean bean seed Fe concentration increased significantly ($P<0.05$) with increasing levels of soil Zn up to 4 Kg Zn/ha and foliar Zn up to 4 Kg Zn/ha and foliar Zn up to 100 L Zn/ha. In the Zn trial, highest significant mean seed Fe concentrations were obtained from Maharagi Soja (91.2 ppm) grown in Kabete field 10, while the highest significant seed Zn concentrations were obtained from VNB 81010 (68.2) grown in the same field. The results obtained indicate that adequate levels of N, P, K, Fe and Zn have the potential to increase bean yields, seed iron and zinc concentrations. However adequate levels of lime increased bean yields, but reduced seed iron and zinc concentrations. N, P, K, Fe and Zn application would therefore have an added advantage in increasing seed Fe and Zn concentration in the common bean in order to alleviate micronutrient deficiencies affecting vast human populations around the world, particularly medium and low income households in the developing countries, Kenya being one of them.

Thuita M.N. (2007). A study to better understand the 'MBILI' and convectional intercropping systems in relation to root characteristics, nutrient uptake and yield of intercrops in western Kenya. Msc. Thesis, Moi university school of Agriculture and Biotechnology

In Kenya and most sub-Saharan African countries smallholder farmers practise maize-legume intercropping systems. In most cases they are assured of a legume crop in the event of inadequate rains resulting in maize crop failure. However, low nutrient levels in soils result in low yields for both crops. It is common practise to plant both maize (staple) and beans in the same hill or between maize rows. Light competition vital for photosynthesis for such practice also contributes significantly to overall low yields. In recently introduced, Managing Beneficial Interactions for Legume Intercrops (MBILI) intercropping system, two rows of maize and two rows of beans (legume) are planted. The row rearrangement allows the farmer to focus on the cultivation of high value legumes like groundnut, green gram and soybean. On farm experiments were carried out in four districts of western Kenya (Bungoma, Siaya, Trans Nzoia and Uasin Gishu in 2005/6) in 3×2×2×2 factorial experiments arranged in a randomized complete block design with three replicates. The experiment consisted of three intercropping systems (MBILI, Hill and convectional), maize and two legumes per site (Bean with soybean or groundnut) and two fertilizer levels; 0 and 27 kg of P/ha. Soil and plant samples were taken at different stages of the experiment and chemically analyzed. Rooting patterns of intercrops were also studied. Harvesting of crops was done at maturity to determine yields and nutrient uptakes. Statistical analysis was done using the GLM procedure of SAS system V8 for all data obtained to determine treatment effects. There were significant differences on the amounts of nitrates available at 0-15 and 15-30 cm depths as a result of the intercropping systems for all sites. Higher levels of nitrates were found in the 15-30 cm depth in both the convectional and Hill intercropping systems for all sites while MBILI intercropping had most of the nitrates in the 0-15 cm depth favouring N uptake from MBILI. The legumes used did not have significant effect on the amount of nitrates on thru two sampling depths. MBILI intercropping system had the highest root length density, while Hill intercropping had the lowest densities in all sites regardless of the legume planted. This was due to better root distribution per unit area in MBILI intercropping. The highest yields for grain legumes were from MBILI intercropping with fertilizer for all sites. Bungoma had the highest groundnut yields for both long rains 2005 and 2006. This site further gave the highest bean yield under MBILI intercropping (1.4 t/ha) above the farmers yields of below 0.25 t/ha. Kitale gave the highest soybean yields ranging from 180 kg/ha for Hill intercropping without fertilizer to 583 kg/ha from MBILI with fertilizer. There were significant differences ($P<0.01$) in maize yields due o fertilizer application and intercropping systems. MBILI intercropping gave the highest maize yields (5 t/ha) in all sites except Sega, while the controls gave low yields (1 t/ha) in all sites compared to the fertilized intercrops. In the legumes, MBILI intercropping had the highest amount of nutrient uptake while Hill had the lowest amounts in all sites. The higher nutrient uptake by MBILI legumes was mainly due to thru higher root length density. The legumes under MBILI intercropping had a dense canopy, which gave good ground cover thus minimizing NO_3-N losses and this possibly favoured N uptake. Intercropping systems influenced agronomic P and N use efficiency with MBILI system having the highest amounts and Hill intercropping the lowest. Economic analysis showed that MBILI gave the highest returns on capital in all sites except in Sega. The distinct finding is that MBILI gave increased and superior maize and legume yields. The findings in this study have a practical implication in popularizing the MBILI intercropping system and a pose a challenge to develop a technology for planting the intercrops to save on labour. Further studies are suggested to determine the influence of intercropping systems on highly mobile nutrients in the soil e.g. potassium.

Vanlauwe B., Tittonell P., Mukalama J. (2007). Within-farm soil fertility gradients affect response of maize to fertilizer application in western Kenya. In: Bationo et al (Eds.) *Advances in integrated Soil Fertility Management in Sub-Saharan Africa: challenges and opportunities.* pp. 121-132

Different fields within a farm have been observed to have different soil fertility status and this may affect the response of a maize crop to applied N, P, and K fertilizer. A limiting nutrient trial was carried out at six farms each, in three districts of western Kenya. In each of the farms, the following treatments were laid out in three fields with different soil fertility status at different distances from the homestead (close, mid-distance, remote fields): no inputs, application of NPK, NP, NK or PK fertiliser (urea, triple superphosphate, KCl) to maize. Total soil N decreased at all sites with distance to the homestead (from 1.30 to 1.06 g/Kg), as did Olsen-P (from 10.5 to 2.3 mg/Kg). Grain yields in the no-input control plots reflected this decrease in soil fertility status with distance to the homestead (from 2.59 to 1.59 t/ha). In the NPK treatments, however, this difference between field types disappeared (from 3.43 to 3.98 t/ha), indicating that N and P are the major limiting nutrients in the target areas. Response to applied N was related to the soil total N in Aludeka and Shinyalu, but not in Emuhaia, probably related to the high use of partially decomposed organic inputs with limited N availability. Consequently, response to applied N decreased with distance to the homestead in Aludeka (from 0.95 Kg/kg relative yield to 0.55 Kg/Kg) and Shinyalu (from 0.76 Kg/Kg to 0.47 Kg/kg), but not in Emuhaia (from 0.75 Kg/Kg to 0.68 Kg/Kg). Response to applied P was related to the soil Olsen-P content at all sites. While for farms with a relatively high Olsen-P gradient, response to applied P decreased with distance to the homestead (from 0.99 Kg/Kg to 0.68 Kg/Kg), large variability in Olsen-P gradients across field types among farms within a specific site often masked clear differences in response to P between field types for a specific site. Clear scope for field specific fertiliser recommendations exists, provided these are

based on local soil knowledge and diagnosis. Scenario analysis, using farm-scale modelling tools, could assist in determining optimum allocation strategies of scarcely available fertiliser for maximum fertiliser use efficiency.

Barkutwo J.K., Ndungu K., Onyango R., Koech M., Mkamdi M. Wanyonyi Ombakho G. A (2006). Response to nitrogen and phosphorus of KARI maize Hybrids for the Highlands and most Transitional zones. KARI-Kitale Annual Report. pp 49-52

Maize (*Zea mays* L.) is the most important staple food crop in Kenya. However its production is low in tropics requires twice as much as that of a temperate environment in order to obtain the same yields. An attempt to raise maize yields in some areas in Kenya is hampered not only by low moisture availability the proportion of moisture from rainfall that is retained in soil after evaporization but also by nitrogen N and phosphorus P deficiency. In north rift valley as in many parts of Kenya, the common land fragmentation has led to continuous cultivation on the same pieces of land. The practice has depleted the soil of nutrients thereby leading to low soil fertility. Therefore there is urgent need to develop strategies to enhance soil fertility by the use of appropriate rates of N and P fertilizers. A wide range of maize hybrids have been developed and release to farmers. However the fertilizer rates have not been verified to exploit the highbrid yield potential and hence maximize production particularly for the new released highbrid developed to the blanket recommendations practiced. The study undertaken was to verify the yield potential of newly released highbrids under different fertilizer regimes in order to come up with suitable fertilizer recommendations that can be utilized by farmers.

Dirk van der Eijk, Janssen, B. H., Oenema O. (2006). Initial and Residual Effects of Fertilizer Phosphorus on Soil Phosphorus and Maize Yields on Phosphorus Fixing Soils. *Agriculture, Ecosystems and Environment Journal*, Elsevier B.V (116) 104-120

The objective of this article is to provide experimental data and new insights about the best P fertilization strategy for phosphorus (P) fixing soils in the tropics. Two controversial strategies to manage soils with high phosphorus (P) fixation capacity were compared with regard to effects on maize (*Zea mays* L.) yields and the fate of fertilizer P in soil. One strategy was broadcasting and incorporation of fertilizer P to quench P-fixation of the whole topsoil; the other strategy was subseed placement of fertilizer P to each crop to quench P-fixation in small volumes just below the plant. Field trials with maize as test crop were carried out on granite, rhylolite, basalt, felsite-andesite and volcanic ash soils in south-west Kenya during three growing seasons. Incorporation rates ranged from 66 to 2096 kg P /ha, and placement rates from 11 to 131/kg. Fertilized soils were analyzed regularly over a period of about 600 days. Grain yields respond strongly to P, except on the P-rich volcanic ash soil. Among other soils, felsite-andesite had the least response to incorporated P as well as to place P. In fertilized soil layers, a total P was higher for placed than for incorporated P. The ratio of P-Olsen/total P did not change over time. It was lower in P-fixing felsite- andesite than in non-fixing volcanic ash, and higher for place P than for incorporated P. The crop's response was related to volumes of P-enriched soil. Placement gave yields than incorporation of P rates 50 kg/ha, especially on soils with low yield. The residual effect was high because P-Olsen in the fertilized soil remained far above the values required for optimum growth. It was somewhat lower for placed than for incorporated P. Placement of P at low rates repeated in each season was better than a single placement at higher rates in the first season only, because placed fertilizer was in subsequent sessions not as close to the roots as in the first season. In conclusion, high P retention of soils did not adversely affect the response to fertilizer. P Low-input is preferred above high-input is preferred above high input because of higher P use efficiency, less weed growth, and easier adoption by farmers.

Jama B., and Van Straaten P. (2006). Potential of East African phosphate rock deposits in integrated nutrient management strategies. Anais da Academia Brasileira de Ciências (2006) 78(4): 781-790 (Annals of the Brazilian Academy of Sciences) ISSN 0001-3765; www.scielo.br/aabc

Phosphorus deficiency affects around 80% of the acid soils of western Kenya, but fertilizer use is limited due to high prices. This paper explores the potential of local phosphate rocks (PR) as a remedy within the context on an integrated soil fertility management approach. A promising phosphate rock is Minjingu PR (MPR, Tanzania), a sedimentary/biogenic deposit which contains about 13% total P and 3% neutral ammonium citrate (NAC) soluble P. On-farm trials in P-deficient soils in western Kenya demonstrate MPR to be as effective as triple superphosphate (TSP, 20% P) at equal P rates. The benefits are most pronounced with the integration of agroforestry technologies that improve soil fertility. Besides Minjingu PR, Busumbu PR from Uganda (BPR) is potentially another source of P. It is typical of the abundant but unreactive igneous PRs in eastern, central and southern Africa. Agronomic performance of BPR is poorer, though its lower cost and location near to P-deficient areas in western Kenya make it attractive in some situations. The policy implications of these findings are discussed further in the paper. **Key words:** fertilizers, maize, improved fallows, *Tithonia*, East Africa.

Kanyanjua S. M. (2006). Influence of soil parent materials on potassium availability to maize in western Kenya. PhD. Thesis, University of Nairobi, Kenya

Potassium (K) deficiency is an emerging problem in intensively cropped soil of Kenya; which contradicts a hitherto existing belief that Kenyan soils have adequate K to meet crop needs. The emerging K deficiency is attributed to a net negative K balance in soils, as a result of greater losses than gains. Weathering of parent materials is an important nutrient input pathway, which has hardly been studied in Kenya. This study was conducted to test the general hypothesis that there is a relationship between the mineralogy and geo-chemical properties of parent rocks and plant available K in soils. The four specific objectives used to test the general hypotheses were : (i) to establish whether areas in Kenya with an emerging K deficiency can be mapped from existing soil and climatic databases, and validate the map so-developed; (ii) to determine the relationship between mineralogical and geo-chemical properties of parent rocks, and amount of clay, clay mineralogy and potassium status of overlying soil; (iii) to determine the relationship between the amount of clay and clay mineralogy and the distribution of soil K in various pools and K availability to maize plants; and (iv) to determine the agronomic and economic benefits of K fertilizer application in maize optimally fertilized with N and P in field soils with an emerging K deficiency. Areas likely to have K deficiency were mapped in Geographical Information Systems (GIS), using geo-referenced database in the Almanach Characterization Tool (ACT). Studies were done at six sites, located in two major geomorphic areas in western Kenya. Three sites: Ebukanga, Yala and Kabula, were in the northern geomorphic area (NGA), and three sites: Itare, Keumbu and Ndanai in the southern geomorphic area (SGA). Hand specimens of rocks and soil samples were analysed for physical, chemical and mineralogical properties; and results used to test their relationships. The soils were exhaustively cropped with maize in the greenhouse and analysed for dry matter and K uptake. Field experiments were conducted in farmers' fields, to determine the effect of increasing K (0, 25, 50 and 75 Kg/ha) in one factor, randomised complete block design (RCBD), receiving 75 Kg of N and P_2O_5 /ha, as top-, and basal- dressing respectively. Mapped region covered about 13% of the land area in Kenya (about 7.5 million hectares). Exchangeable K ranged from 0.2 -1.6 cmol/Kg in soils from farmers' fields and was consistently deficient in the NGA, due to low soil organic matter. Soils from the SGA were not deficient in K due to high organic matter. This fact is confirmed by the high correlation obtained between exchangeable K and organic C ($r^2 = 0.859$, $P = 0.015$). The map developed from climatic data requires revision; in view of new insights obtained from this research work. The mafic (ferromagnesian) - to - felsic (quart, feldspar rich), mineral ratio in rock samples ranged from 0.05 to 2.33 and decreased with increase in SiO_2 content. Clay content of studied soils ranged from 35.5 -65.5%, but was not significantly related to mafic/felsic ratio in rocks, perhaps because of incongruent weathering of parent rocks, colluvial clay deposits from higher grounds to soils in Kabula and Ndanai, and plinthitization of soils in kabula. Observations made in the field confirmed these with increase in mafic: felsic mineral ratios of rocks, due to extreme weathering of mafic- rich parent rocks. Total K in rocks did not influence the exchangeable K in studied soils significantly, probably because of K release from organic matter; relative biotite/ orthoclase content in rocks, which have different susceptibility to weathering; and colluvial addition of K in Kabula and Ndanai soils. In studied soils; total K ranged from 10.7 - 48.5 cmol (p+)/kg, exchangeable K from 0.1 -0.35 cmol (p+)/kg, and solution from 0.0048-0.0182 cmol (p+)/kg, all of which decreased with increase in clay content of soils. The decreases were attributed to observed decrease in orthoclase in sand fraction, decrease in 2:1 clay minerals as clay content increased in soils, and assumed low diffusive flux in clayey soils. Average K uptake by maize plants ranged from 0.24 - 0.79 g/pot, and decreased with increase in clay content due to the limited labile K in fine textured soils. Maize response to increasing rates of K from 0-75 Kg K/ha (as KCl), was not significant, possibly because; the three-season testing period was too short, fixation by illites identified in this study, high incidence of striga weed and Ca and Mg deficiency found in soils from the NGA. The probability of response to K fertilizers increased with seasons, as readily available K got depleted in soils. Economic returns to K fertilizer application were positive and K fertilizer was recommended at 25 Kg K/ha in 40% of the farms in both NGA and SGA. Response to K fertilizers is expected to increase as more N and P fertilizers are applied in maize to increase yields, in an effort to fight hunger and reduce poverty among the Kenyan people, as stipulated in the millennium development goals, that Kenya has committed herself to meet by 2015.

Ndungu K. W., Koech, M. N, Mwangi, T. J, Onyango, R., Wanyonyi M., Mwangi M., Barkutwo J. and Kamidi M (2006). Testing of fertilizer with broad base of Nutrients in north rift valley. KARI-Kitale Annual Report. pp. 44-48

Soil nutrient balance studies in Africa show evidence of wide spread nutrient mining which has led to sever nutrient deficiencies across many ecological zones. There is sufficient evidence of declining maize yields in Kenya despite increasing knowledge on farm input use requirements, stable acreage under maize and sufficient rainfall. Nitrogen N and phosphorus P limitation to crop productivity are widely reported in western Kenya region potassium K has also been reported in 25% of the farms in Western Kenya. In addition to N and P other secondary and micronutrient deficiencies have also been observed as soil organic matter become depleted and also acidity increases. More than 50% of farms in Trans Nzoia are deficient in exchangeable bases including K calcium (Ca) and Magnesium (Mg). In Uasin Gishu are acidic with pH ranging from 3.42-5.82 and are characterised by increasing aluminium (Al) and Manganese (Mn) ion solubility and inadequacy of key elements particularly P, Ca,

N and Molybdenum (Mo). The low pH levels of these soils and high Al and iron Fe contents limit P availability through increased P fixation. Therefore there is an urgent need to use fertilizer with a broad base of nutrients to correct multiple nutrient deficiencies in these soils. Apart from supplying P minjingu phosphate rock (MPR) contains Mg Ca and eight more essential micronutrients. In addition MPR also contains P sulphur S and other essential micronutrients including boron (B), Manganese (Mn) Zinc (Zn) Molybdenum (Mo) and Copper (Cu). Single super Phosphate (SSP) also contains Ca and S and neutralizes toxicity from hydrogen (H) and AL ions. Apart from correcting N and P deficiencies mavuno fertilizer also has K, Ca Mg, in addition to P. Some of the compound fertilizers such as N-P-K (7-17-17) that contain K in addition to N and P would be expected to correct K deficiencies in depleted soils. Unlike CAN top dress fertilizer types of basal fertilizer in combination with proper top dress fertilizer can correct a wide range of nutrients in depleted soils. The major objectives of this study are to correct a wide spectrum of nutrient deficiencies of some of the new fertilizers formulations on maize grown in different soils across various agro-ecological zones.

Njunie M. N., Wagger M. G., Ali A. R. (2006). Development of appropriate maize and cassava legume production systems in coastal lowland Kenya. *North Carolina State University-Raleigh, Journal*, USA pp.97-170

Poor soils and erratic rainfall limit crop yields in the coastal lowlands of Kenya. Legumes as cover crops and intercrops have potential to improve land productivity by increasing N supply through biological nitrogen fixation and the recycling of nutrients via legume foliage used as green manure and/or ground surface mulch. A case study for developing appropriate maize (*Zea mays* L), cassava (*Manihot esculenta* Crantz) and legume production systems is reported for Coastal Kenya. Studies on forage legume management and the effects of commercial fertilizer on crop yields in maize and/or cassava production systems were carried out for two years. Fertilizer nitrogen (N) applied at 60 kg N/ha as calcium ammonium nitrate (26%N) to the maize in two splits and 20 kg P/ha as triple superphosphate applied at planting increased maize grain and stover yields by 70% over maize grown without fertilizer inputs. Intercropping maize with Dolichos increased grain yield by values ranging from 24 to 80%, compared to maize monocrop without fertilizer inputs. Intercropping maize with clitoria increased maize grain and stover yield during the long rain season, but decreased maize yield during the short rain season. Cassava monocrop resulted in the greatest tuber yields (9 t/ha), while intercropping of cassava with legume reduced tuber yield by 21%. To increase and sustain maize grain and cassava production in the region, inorganic fertilizer use and strategic harvesting management of forage legumes in cassava and/or maize and cutting the legume for mulch indicated an improvement in biological efficiency in the use of space and time in the region, by showing area by time equivalent ratio (ATER) values greater than unity. Measures that would minimize nutrient losses from the different cropping systems merits further research, such as synchronizing nutrient release with principal crop demand.

Okalebo J. R., Othieno C. O., Nekesa A. O., Ndungu-Magiroi K. W., Kifuko-Koech M. N. (2006) Potential for agricultural lime on improved soil health and agricultural production in Kenya. *African Crop Science Conference proceedings* Vol. 9 pp.339-341

Soil acidity is widespread globally, accounting for about 40% of total arable soils. In the tropics, substantial weathering of soils over millennia has resulted in the leaching of crop nutrient bases (mainly K, Mg and Ca) followed by their replacement by H, Al, Mn cations which contribute to acid related stresses on crop production. The practice of liming acid soils is not common in Sub-Soil acidity is widespread globally, accounting for about 40% of total arable soils. In the tropics, substantial weathering of soils over millennia has resulted in the leaching of crop nutrient bases (mainly K, Mg and Ca) followed by their replacement by H, Al, Mn cations which contribute to acid related stresses on crop production. The practice of liming acid soils is not common in Sub-Saharan Africa, perhaps as a result of limited knowledge on lime effectiveness, availability and high hauling costs of liming materials. A field study in western Kenya in 2005-2006 showed significant effects ($p<0.05$) of lime at 2 t/ha combined with phosphorus at 26 kg P/ha and nitrogen at 75 kg N/ha. The soil pH was raised to the range of 5.8 to 6.5 (by lime), while available phosphorus increased above 10 mg P/ha (the critical level). This input combination also resulted in significant maize yield increases to 6 t/ha, compared to the small scale farmers' yield of 0.5 t/ha. In addition to N and P inputs, liming is a practice with potential to improve crop yields on acid soils that are predominant in western Kenya.

Kamau D. M, Owuor P. O., Wanyoko J. K. (2005). Long term effects of nitrogenous fertilizers on tea yields, nutrient uptake and some soil chemical properties. *The Soil Science Society of East Africa, Proceedings of the 21st annual conference* 1st -5th Dec. 2003, Eldoret, Kenya. pp 281-289

A field experiment was set up to determine long-term responses of different rates of nitrogen fertilizers namely used in tea, NPKS 25:5:5:5 and NPK 20:10:10, on tea yields, nutrient uptake and soil chemical properties. The experiment also aimed at establishing whether tea plant would benefit more from NPK 20:10:10 or NPKS 25:5:5:5 fertilizer formulation. Mean tea yields and leaf nitrogen over the sixteen year period, 1986 to 2001, were

not affected by fertilizer formulation. Similarly, leaf sulphur content was unaffected by fertilizer type. However, leaf and soil phosphorus and potassium contents were significantly higher in the NPK 20:10:10 formulation compared to NPKS 25:5:5:5. The NPKS 25:5:5:5 formulation acidified the soil more than the NPK 20:10:10 at up to the 60 cm depth. Soil available phosphorus and potassium were higher in the NPK 20:10:10 fertilizer at all the four depths. Nitrogen fertilizer rates gave significant quadratic yield responses with peak yields at the 300 kg N/ha rate in both fertilizer types. Nitrogen uptake from the leaf nutrient data had a similar pattern and indicated that beyond the 300 kg N/ha rate, the nitrogen levels did not change implying that the extra nitrogen added was not utilized as efficiently by the tea plant. While leaf phosphorus and potassium decreased in a quadratic manner with nitrogen fertilizer rates, leaf sulphur content was not affected. The implications of using either of the two fertilizer formulations in tea production are discussed.

Muriuki W. S. (2005). Assessment of long-term impacts of organic and inorganic fertilizers on soil extractable phosphorus and carbon in machang'a, Mbeere district, Kenya. Msc. Thesis, Kenyatta University

Decline in crop yields is a major problem facing smallholder farmers in semi-arid Kenya and the entire Sub-Saharan region. Soil organic matter is rapidly declining and phosphorus (P) and Nitrogen (N) deficiencies are important constraint to food production in semi-arid areas. Inorganic fertilizers are unaffordable to most smallholder farmers at current producer prices, limiting their use on farms. While N can be replenished through biological fixation; there are no equivalent processes for the introduction of P in soils. Consequently, phosphorus deficiency has become a major constraint to food production. To try to solve this problem, two long-term field experiments were established at Machanga's site to asses long-term effects of manure and inorganic P fertilizers on soil extractable P and organic carbon (OC).The first experiment began in 1989 and treatments were; control continuous manure at 5 and 10 t/ha/yr. This trial had 14 years of annual manure application. The second experiment began in 1994 and was planned to supplement the first experiment by giving information on the effects of a onetime application of 250 kg/ha TSP on long-term P availability. Diffuse reflectance spectroscopy was used for rapid assessment of soil quality. While common wet laboratory methods for soil nutrient analysis are laborious, time consuming and costly, diffuse reflectance spectroscopy method was explored as an alternative analytical method. Since the current study was part of an explored as an on-going project. Data accumulated from the project was used for purposes of current study. Soil sampling began in 1993 and samples analysed for OC and extractable phosphorus. Sub-samples of these soils were scanned using reflectable spectroscopy. Samples collected in year 2002 were analyzed for sequential P fractions using a modified Hedllley's method. Laboratory data was analysed for variation by Genstat (1995), while the near infrated (NIR) spectral data was analysed using multivariate exploratory statistics. Partial least squares regression, principle component analysis and discriminant analysis were used to develop predictive, calibration models. Results indicated that repeated manure application at 10 t/ha/yr significantly increased the level of plant available P and maintained high OC. Residual manure did not have profound effects on P and OC compared with continuous manure. Though inorganic fertilisers raised the level of bioaviable P fractions, they had negligible influence on OC. The residual value of a onetime application of 250 kg/ha TSP was observed to maintain high soil P-test values for close to 10 years. Robust near infrared calibration models developed, well predicted the level of OC by the various treatments. However, poor calibrations were obtained for soil extractable P. It is not expected that NIR spectroscopy will replace the nutrients analysis used in convention soil fertility assessment. However, infrated methods have potential to rapidly and non-destructive predict soil quality changes caused by various management regimes, thus adding considerable value to soil analysis. The method is also economically attractive due to the low costs associated with it.

Tabu I. M, Obura R. K, Bationo A., and Nakhone L. (2005). Effect of farmer's management properties land maize yield practices in soil. *Journal of Agronomy*. Asian network for scientific information 4(4):293-299,

Variation in soil fertility and crop yield in famer's field is a factor responsible for the low farm productivity and adsorption of agronomic recommendations .A study was conducted to characterize the soil fertility management zones using participatory rural appraisal conventional survey methods and maize yield. Farmers identified the soil types using colour, texture and productivity. The red soil (Rhodic ferralsols) were rated to be less fertile than darker Humic acrisols and Mollic gleysols. Farmers also identified the soil fertility management niches in terms of soil topography, physical discontinuities, managements and classified them as productive or unproductive. The productive niches occupied between 0.25 and 0.30 ha and were used for maize, bananas and vegetable production. Non-productive niches were between 1.5 and 6.0 ha and were either left fallow or used for maize and sweet potato production. Productive niches had a pH of 5.3% C of 2.3 and silt fraction of 232 g/kg and maize yield of 4.3 t/ha. Non-productive niches had a PH of 3.99% C of 1.9 and a silt fraction of 193 g/kg and maize yield of 2.8 t/ha. Management should target processes that enhance these variables in addition to incorporate the farmer's local knowledge.

Aluga C.M. (2004). The effect of nitrogen and phosphorus application on growth, yield and nutritional quality of vegetable Amaranth (*Amarantus Hybridus*). Msc. Thesis, University of Nairobi, Kenya

Two field studies and laboratory experiments were carried out at Kabete Campus, University of Nairobi, between November 1994 and October 1995. The aim of the study was to find out the effect of nitrogen and phosphorus applications on growth, leaf yield and nutritional quality of vegetable amaranth. There were four levels of each treatments and it was conducted on a split plot design with three replications. Growth parameters evaluated included plant height, number of leaves, leaf area index and stem diameter. Fresh weight and dry weight were taken to determine yields. Nutritional quality of leaves was evaluated by analysing for crude fibre, crude protein, dry matter, beta carotene, calcium, iron, phosphorus as well as oxalates and nitrate contents. It was observed that applying seventy five kilogram's of nitrogen in one hectare gave a maximum height of thirty three centimetres. A height of thirty two point six centimetres was achieved with the application of sixty kilograms of phosphorous n one hectare. Nitrogen application gave a significant effect on stem diameter. Phosphorous application gave a significant effect on leaf area index. Both fresh weights and dry weight were significantly increased with increased application of nitrogen and phosphorus. The nutritional qualities of leaves were modified by the application of nitrogen and phosphorus. Crude protein and beta carotene contents increased with the application of nitrogen. The mineral contents of calcium, iron and phosphorus tended to increase with the application of nitrogen and phosphorus. However, the levels of crude fibre and oxalates were significantly reduced with the application of nitrogen and phosphorus. On the other hand, less nitrate N-concentrations have been reported in mature plants of Kales and Collards.

Kamwaga J., Okwaro H., Njau P., Kimurto P., Ndung'u P., Kimani E. (2004). Genotype-by-nutrient interaction in wheat grown in a marginal environment in Kenya. *Proceedings of the 12th regional wheat workshop for Eastern, Central and southern Africa*, 22–26 November 2004; Nakuru, Kenya

Six wheat (*Triticum aestivum* L.) cultivars (Chozi, Ngamia, Duma, Njoro BW1, K. Heroe and Chiriku) were grown in a marginal environment at two levels of fertilizer; 0:0:0:, 30:60:0 Kg/ha (N: P_2O_5: K) and at a seed rate of 125 Kg/ha to assess their response to fertilizer application and nutrient use efficiencies. Grain yield, spike numbers, harvest index (HI), nitrogen (N) uptake, N concentration and nitrogen use efficiency (NUE) were recorded. There were no significant differences in grain yield or spikes m-2 among varieties when averaged across fertilizer levels. Differences in HI between varieties were significant, with cv. Duma, a variety recommended for marginal environments, having higher HI than cv. K. Heroe. Fertilizer did not affect the HI. There were no significant differences among varieties in N acquisition, indicating similar nutrient uptake abilities, or in NUE, although this was reduced by fertilizer application, probably because the increased N uptake did not translate into a corresponding grain yield increase due to the poor growing conditions. Grain N content ranged between 2.2% in the fertilized plots and 1.8% in the unfertilized plots (averaged across cultivars) and 2.2% in Njoro BW1 and 1.9% in Ngamia.

Kimurto, P.K, Kinyua M.G., Ogola J.B.O, Macharia J.M, Njau P.N (2004) Physiological traits associated with drought tolerance in bread wheat (*Triticum aestivum* L) under tropical conditions. *Proceedings of the12th regional wheat workshop for Eastern Central and Southern Africa KARI/CIMITY.* pp 95-108

Although it is generally accepted that drought tolerance is a critical agronomic trait, efficient and predicable improvement in drought tolerance in bread wheat (*Triticum aestivum* L) has not yet been achieved .Evaluating the responses of physiological traits associated with drought tolerance in bread wheat varieties will enhance selection for tolerance in wheat varieties grown in marginal rainfall areas. This study assessed the drought tolerance that may be used for selection. Two experiments under the rain shelter and in the field) were carried out each for two seasons (2001/2002). The rain shelter experiment simulated rains at three watering regimes. low (210mm) medium (240mm) and high (270mm) significant genotypic variation ($P< 0.01$) was observed for water use efficiency (WUE) harvest index (HI) stomatal conductance, transpiration rates and CO_2 assimilation. Under dry conditions these genotypes. These trials could also be responsible for sustained survival and facilitated recovery after rewatering. Thus their use as selection criterion in breeding for drought tolerance is promising candidates with superior physiological traits and high grain yield. All of the genotypes were compared with the commercial checks Duma and Chozi. A need exists to determine the heritability of these traits to realize their potential usefulness in breeding program.

Kiramana J. K. (2004). Effects of nitrogen levels and spacing on growth, yields and quality of tomatoes (*Lycopersicon Esculentum* Mill.) grown in a greenhouse at high altitude in Kenya. Msc. Thesis, Egerton University, Kenya

Tomato (*Lycopersicon esculentum* Mill.) is popular both in fresh market and processing industries. Production of tomatoes under greenhouse conditions is gaining popularity in Kenyan Highlands. Its yields are limited by poor soil nutrition with nitrogen being the most limiting nutrient required in large quantities. Nitrogen fertilizer and spacing play a major role in yield and quality determination. This study investigated the effects of nitrogen levels and spacing on growth, yield and quality of tomatoes under greenhouse conditions at high altitude in Kenya. Plants were grown in a greenhouse on Tatton Farm of Egerton University, Njoro, Kenya. The study was conducted over a period of 10 months covering two seasons. The first season commenced in October 2002, and ended in February 2003, while the second one started in February 2003, and ended in July 2003. The nitrogen rates 0, 40, 80 and 120 Kg N/ha was each applied in two equal splits. Spacing was 40x30, 40x40, 50x30 and 50x40. The experimental design was a Split-Plot, arranged in a Randomized Complete Block Design, with three replications. Data on plant height were collected on a weekly basis throughout the entire growth period, beginning two weeks after transplanting. Fruit yield and quality data were taken after each harvesting. Nitrogen levels did not significantly ($p \leq 0.05$) affect plant height, but the effect of spacing was significant ($p \leq 0.05$) with spacing of 40x30 cm having the highest height in season 1 and 50x30cn in season 2. Wide spacing of 50x40cm had the highest fruit size, with lack of additional nitrogen having the lowest fruit size in both seasons. Total soluble solids were significantly ($p \leq 0.05$) lowered by lack of nitrogen application in both seasons. High nitrogen levels reduced fruit firmness in both seasons. Total soluble solids and fruit firmness in season 1 were not significantly ($p \leq 0.05$) influenced by spacing of 40x40cm and 50x40cm. Number of trusses was highest with close spacing of 40x30cm in both seasons. Spacing influenced days to flowering only in season 2. Fruit numbers and number of marketable fruits were significantly ($p \leq 0.05$) affected by spacing at 50x30cm in season 1 and at 40x30cm in season 2. Nitrogen level of 80 Kg/ha had the highest fruit numbers in season2. Nitrogen levels and spacing significantly ($P \leq 0.05$) affected fruit yields in season 1 with 80 Kg N/ha and spacing of 50x30cm having the highest fruit yield. In season 1, spacing at 50x40cm had the highest ($p \leq 0.05$) unit fruit weight and marketable unit fruit weight. Nitrogen level of 120 Kg/ha had the highest ($p \leq 0.05$) total leaf nitrogen content in both seasons. Less than 80 Kg N/ha and wide spacing 50x30 can be applied without adversely affecting the yields and total soluble solids and firmness of tomato fruits.

Macharia J. M. K., Njeru C. (2004). Effect of fertilizer on seed cotton yield, cotton plant height and boll count at Ithookwe, and Giaki during 2003/2004. Kenya Agricultural Research Institute, KARI Annual Report 2004; pp. 25-27

Cotton production in Kenya is mainly by small-scale farmers, labour intensive and characterised by low farmer's yields (500 kg/ha). Returns to the land and labour are low. Cotton production is therefore given a low priority and will only be planted after the farmers have completed planting of food crops like maize and beans. Despite the current fertilizer recommendations, most farmers will only apply fertilisers or manure to cotton only after applying other crops in Meru while in Kitui farmers believes that cotton does not require fertilisers and that fertilisers spoil soils. Yield responses by cotton to fertilisers have been contradictory and unreliable since it depends on such factors as rainfall, soil fertility and other crop management practices. Earlier research work showed that fertiliser application without pest control in cotton reduced the quality of seed cotton. There is need to evaluate the effects of the current fertiliser recommendations on cotton yield. On-station field trials were conducted at Giaki and Ithookwe to assess the influence of fertilisers (TSP, NPK 17:17:17 and CAN on quantity of seed cotton. Fertilizer had significant effect on cotton yield and height at Giaki ($p=0.022$) but not at Ithookwe.

Macharia J. M. K., Njeru C. (2004). On-farm evaluation of cotton plant density and fertilizer on cotton yield. Kenya Agricultural research institute, KARI Annual Report, 2004; pp. 23-25

Though the recommended optimal crop density of cotton in Eastern and Central is 33333 plants per hectare, at a spacing of 100cm*30cm with one plant per hole, most farmers continue to adopt lower densities. Reasons given for this that most farmers often intercrop with food crops, use oxen ploughs for planting and weeding and require less seeds and labour for planting. This trial aims to assess optimal density for HART89M under farmers managed trials in eastern Kenya. Four plant densities i.e. 27,777; 33,333; 55,555 and 74074 plants/ha were planted on five farmers' field at Giaki and Gaitu in meru during 2003-2004 cotton seasons. Fertiliser NPK 17:17:17 was applied during planting at 50 kg/ha and the crop later top-dressed with CAN at 100kg/ha. Farmers were provided with pesticides and the fertilisers but undertook the other management activities. Data on cotton yield was analysed using ANOVA and means separated by use Least Significance Difference (LSD) test. Results indicated a general increase in yield with increase in plant density as population increased from 27,777 to 74074 plants/ha. Densities of 55,555 and 74074 plants/ha) gave cotton yields higher by 40% and 54% than control (33333) plants/ha respectively. A population of 74,074 plants/ha had significantly ($P=0.099$) higher yield than 27,777 which was not significantly different from the control.

Malinga J., Kinyua M.G., Kamau A., Wanjama K., Njau P., Kamundia J.(2004). Evaluation of Kenyan bread wheat (*Triticum aevitum* L.) varieties for resistance to Russian wheat aphid in multi-location trials. *Proceedings of the 12th regional wheat workshop for Eastern, Central and southern Africa*. 22-26 Nov, 2004, Nakuru Kenya pp.117-124

Russian wheat aphid (RWA, *Diuraphis noxia*: kurdjumov) is a serious pest of wheat (*Triticum aestivum* L.) worldwide. The purpose of this investigation was to evaluate commercial bread wheat cultivars in different environments in Kenya to identify RWA resistance. Seven wheat cultivars (Pasa, Mbuni, Kenya Heroe, Kenya Fahari, Chozi Duma and Kwale) were planted at five locations over two years in Kenya in a split plot RCBD experimental design. The main plot consisted of insecticide treatment at two levels (untreated and insecticide treated). The subplot was the varieties. Results showed significant ($p<0.05$) genotypic differences across location. Effects due to insecticide year x location, and genotype x year x location interaction were significant ($p<0.05\%$) for thousand-kernel weight and grain weight. Positive correlation was observed between plant height and yield (r= 0.935 **), and thousand-kernel weight and yield (r = 0.876**). Significant negative correlations were recorded between RWA damage and plant height (r= -0.662**); and yield (-0.785**); and kernel weight (-0.667**). No significant association was observed for percentage plant height reduction and RWA damage. The first two principal components accounted for 83% of the variability. The study shows that K. Fahari, which has been previously reported to be resistant to green bug may have some resistance to RWA.

Mwangi H.G. (2004). Effects of Phosphorus and Copper on the performance of wheat (*Triticum aestivum* L.) genotypes in copper deficient soils. Msc. Thesis, Egerton University, Kenya

Low wheat yields in some parts of central Rift valley can be attributed partly to inherent low soil nutrient status, none or adequate or improper use of fertilizers including P and Cu. There is limited information on the effects of P, Cu and wheat genotype on the performance and yield of wheat. Three greenhouse studies using Cu deficient soil were initiated on, (1) the effects of P and Cu on wheat using 0, 10, 20 and 30 mg P/ Kg soil and 0, 2.5, 5 and 7.5 mg Cu/Kg soil, (2) the effects of P, Cu and genotypes on wheat using 0 and 20 mg P/Kg soil, 0 and 2.5 mg Cu/Kg soil and 4 wheat genotypes Pasa, Chiriku, Nyangumi and Fahari and (3), the effects of sources of Cu and methods of Cu application on wheat using sources as $CuSO_4.5H_2O$, $CuOCl_2$ and CuO and methods as foliar (1mg Cu/litre), seed dress (1mg Cu /Kg seed) and soil applied 1 mg Cu /Kg of soil. Grain yield (GY) and straw yield (SY), increased significantly (α= 0.05) with increasing P and Cu rates giving maximum at the highest rates of P and Cu i.e. at 30 mg P/ Kg of soil combined with 7.5 mg Cu / Kg of soil. High levels of Cu gave high grain Cu content. High P levels caused low grain Cu content (but not below critical level of 1ppm Cu). There was a significant (α= 0.05) interaction between P and genotypes on both GY and SY, showing that there are genotype differences in PUE as shown by Nyangumi. There were no differences observed between genotypes and Cu requirements. There was an interaction between source of Cu and method of application on GY. When foliar sprayed, $CuSO_4.5H_20$ produced significantly (α= 0.05) higher Gy than the conventional $CuOCl_2$ or CuO. The main effects of sources of Cu showed a significant difference with $CuSO_4.5H_2O$ giving the highest SY. The main effects of mode of Cu application showed a significant difference with foliar and soil applied giving the higher SY than seed applied.

Juma C. W. (2003) Phosphorus requirements of maize (*Zea mays* L) Genotypes in different soil types of Siaya district, western Kenya. Msc. Thesis, Egerton University

Maize (*Zea mays* L) is the staple food tor Kenyans. In many soils of Western Kenya, phosphorus and nitrogen deficiencies limit production of maize. Most of maize growers in region are smallholder farmers, who are often resource limited in the purchase of fertilizer inputs and recommended hybrid seed maize and therefore prefer growing local maize genotypes to hybrids. While significant progress has been made in research with regard to nitrogen use in the soils in this region, information on which to base fertilizer P recommendations for good maize growing is meagre considering potential differences in responses due to genotypes and soil types. A study was conducted in 1999 to determine external and internal P requirements, P use efficiencies, and recommendable P application rates for two landraces (Oking' and Ababari) and one hybrid maize (H513) genotype at four P deficient on-farm sites of Western Kenya. The genotypes were grown under four P fertilization regimes of 13, 26, 39 and 52 kg P/ha and a control (0 kg P/ha) in a randomized complete block design factorials arranged and replicated three times per site. The soils at the sites were ferric Alisols and haplic Ferralsols. Grain, total dry matter yields, total P uptake, P use efficiency, and soil P content were analyzed for each of the treatment combinations. Phosphorus application resulted in significant increases in grain yields by the genotypes at the four sites. It was found that the genotypes differed in their external and internal P requirements for grain production at the four sites. The external P requirements by the genotypes were achieved at P application ranges of 14-27, 20-29, and 25-40 kg P/ha for Ababari, Oking' and H513, respectively. The internal P requirements by the genotypes ranged from 7-24, 4-18, and 5-18 kg/ha for Ababari, Oking' and H513, respectively. Phosphorus application significantly increased physiological P use efficiency by the genotypes. The ranges of Physiological P use efficiency by the genotypes. The ranges of physiological P use efficiency by the genotypes (that coincided with their internal P requirements) at the sites were 111-314, 145-277, and 127-390 kg grain/kg P for Ababari, Oking' and H513, respectively. Hybrid

H513 genotype was most efficient in P use across the sites. The results obtained from this study underscore the need for specific fertilizer P use recommendations for maize at the different sites.

Mati G.N., Mburu W.K., Kurji P.N., Shibairo S.I. (2003). Effects of Nitrogen and Phosphorus fertiliser on growth and yield of Ironweed (*Vernonia galamesis*). *East Africa Agriculture and forestry Journal*. Vol. 69 (2) 109-118

Ironweed (*Vernonia galamensis*) is a promising new crop for industrial oil but information on its response to fertiliser is scanty. A field experiment was conducted at the University of Nairobi Field station farm during 2 seasons (January to May 1998, season 1 and March to August 1998, season 2) to determine the effects of Nitrogen (N) and Phosphorous (P) fertiliser on growth, photosynthetically active radiation (PAR) interception and seed yield of 2 vernonia galamensis cultivars (ethiopica and gibbosa). N was applied at 0, 75 and 150 kg N/ha, and P at 0, 45 and 90 kg P_20_5/ha. The experiment was a 2×3×3 factorial laid out in a randomized complete block design with 3 replications. N and P application significantly increased total dry matter (TDM), photosynthetically active radiation (PAR) interception and leaf area index (LAI) of both varieties in late vegetative and reproductive stages. Gibbosa had consistently higher TDM, LAI, PAR and was taller compared to ethiopica throughout the growing season. Average seed yield of gibbosa was 2.3 times higher than that of ethiopica in both experiments. The highest TDM, LAI and seed yields were obtained at the highest N and P levels. Gibbosa had a significantly higher number of capsules/plant but a lower harvest index (HI) compared to ethiopica

Mwangi, T. J. (2003). Yield and Nitrogen Fixation Response by Drought Tolerant Tepary Bean (*Phaseolus acutifolius* A. Gray Var. Latifolius) in Sole and Maize Intercrop Systems in Semi-arid Kenya. *Pakistan Journal of Agronomy* Vol. 2(3) pp 126-137

Tepary bean (TB), a drought tolerant bean variety has become popular among poor small-scale farmers in semi-arid Kenya, where it is predominantly intercropped with maize. Field experiments were conducted on effect of intercropping TB and maize on nitrogen fixation and crop yield in semi-arid Kenya over two cropping seasons. Experimental design was randomized complete block with eight treatments: TB sole crop not inoculated with Rhizobium (R3254) and without N fertilizer (N), TB sole crop not inoculated with R3254 with or without N, TB sole crop inoculated with R3254 without N, TB with maize intercrop not inoculated with R3254 with or without N and maize sole crop with or without N. Each treatment was replicated four times. Significant differences (≤0.05) were observed in total plant dry weight in treatment R3254 at both 21 and 42 days after emergence (DAE). TB yields were significantly reduced in uninoculated intercrop. Inoculated TB treatments had significant higher seed dry weights and yields/ha, intercropping TB and maize suppresses the yield of the former under semi-arid conditions. Inoculating TB with Rhizobium strain R3254 was ineffective, effective and significantly improved TB yields in sole and intercrop. Soil analysis after the two cropping seasons showed enhancement of soil N in sole TB plots above pre-planting levels. Maize plots exhibited a decline in soil N. Total N concentration in plant tissues was significantly enhanced in treatment R3254. There was a marked increase in soil P in all treatment plots following amendment.

Okalebo J.R. (2003). Inorganic resources management for sustainable soil productivity. *East African Agricultural and Forestry Journal*. Vol. 69 pp. 99-108

A field study was carried out for 2 seasons (November to February 1999 and April to August 2000) to investigate the influence of irrigation on maize growth, nitrogen uptake and yield. The experimental design was randomized complete block design laid out as split plot with water regime as main plots (irrigated, rainfed), and factorial combinations of N (0, 50, 100 Kg N/ha) and P (0, 25 Kg P_2O_5) as subplots. Data collected included leaf area index (LAI), photosynthetically active radiation (PAR) interception, total dry matter (TDM), nitrogen uptake and maize grain yield, so the data were pooled for P. In the wet (350 mm rainfall) Short Rains, 1999 (SR99), irrigation had no effect on LAI and fractional PAR interception but significantly increased total N uptake, TDM and grain yield by 50 to 100%. Under low rainfall (143 mm) in the Long Rains 2000 (LR00), irrigation increased LAI and PAR interception by 50 to 100% and N-uptake, TDM and grain yield by 10, 10 and 34 fold respectively. However there was no significant response to N fertiliser application without supplemental irrigation. Nitrogen application above 50 Kg/ha did not improve maize growth and yield in both seasons. Supplementary irrigation can therefore increase maize yield even at low fertiliser input level in semi-arid Kenya.

Okalebo J. R., Mukhwana E. J., Woomer P. L., and Kimenya L (2003). Effects of minjingu phosphate rock on maize yield and changes on soil phosphorus under improved fallows in western Kenya. The Rockefeller Foundation Forum on Agricultural Resource Husbandry; evaluation of selected soil fertility management technologies in Western Kenya (''BEST-BELTS''); ''Working towards food security through adopting Farmer-Friendly technologies'' Final technical Report 2003

Increased P release was observed with increase in rates of MPR. These increases varied with site and rates of MPR applied. Therefore, a blanket, recommendation of rates of supplemental P may not be effective in mitigating P deficiency. These recommendations should therefore be site specific. Crop rotation should be encouraged as this was found to contribute to increased financial returns. The most economical rate of MPR to use and the conclusive recommendation, a relatively longer term experiments with more than one farm per site to generate more data should be set up.

Ngoze S. O. (2002). Agronomic evaluation of Tanzanian and Ugandan phosphate rocks in western Kenya. Msc. Thesis, Moi University Department of Soil Sciences

Soil phosphorus (P) deficiency in western Kenya is a major cause of low maize yields, but commercial phosphorous fertilizers are unaffordable for most smallholder farmers. Local phosphate rocks (PRs) are an alternative phosphorous source, but most are uncreative. Surveys of natural phosphate resources in East Africa reveal availability of large amounts of phosphates from Uganda (Bukusu and Butiriku carbonite complexes) in eastern Uganda. Small-scale, appropriate technologies were developed for grinding and sieving the collected phosphates, concentrating the phosphate by removal of impurities through magnetic separation and blending the concentrate with soluble P fertilizers. A number of concentrates and blends were prepared for agronomic evaluation. Several East African PRs in one field and two pot studies using maize (*Zea mays*) as a test crop were carried out as follows: four Ugandan phosphate rocks (Busumbu hard and Busumbu soft, Bududa and Bukiribo) with citrate solubility 0.3 to 1.1%, Busumbu PRs (soft and hard) blended with triple superphosphate (TSP) or monoammonium phosphate (MAP) at various ratios and Minjingu phosphate rock from Arusha Tanzania with a citrate solubility of 3.4%. The materials were tested to evaluate their effectiveness as a P source for maize. Total P rates were 80 kg P/ha and 100 mg P/kg soil for the field and pot studies respectively. The soils collected from Nyabeeda, Kondik, Khwisero and Malava, which are acid, P-deficient Oxisols received nitrogen (N) and potassium (K). The field trial at Nyabeda was carried out for two seasons. Pot studies were done using soils sampled from the four sites. Results from these studies indicate that maize responded positively to increasing levels of P applied as TSP in the field study while maize response to applied TSP in the pot experiment showed two responses phases (0-50 mg P/kg soil and 50-300 mg P/kg soil).Maize growth with Ugandan BPR soft alone was not different ($p=0.05$) from the control both in the field and pot studies. The Uganda BPR hard alone was significantly different ($p=0.05$) from the control, the other Uganda Bukiribo (BUK) PR was significantly different ($p=0.05$) from the control in the pot studies. The relative Agronomic Effectiveness (RAE) of hard BPR relative to TSP was 55% and 61% while that of MPR was 75% and 91% for the long rains (LR) and short rains (SR) respectively. In pot experiments, the RAE for Ugandan PRs ranged from 10% to 32%, while for MPR averaged 92%. Addition of tithonia to BPR did not increase maize grain yield when compared to control treatment. In the pot studies, TSP: BPR (10:90 and 20:80) and MAP:BPR (10:90 and 20:80) blends on Kondik soil significantly ($p<0.05$) increased maize biomass yield above that expected from additive linear effects of unblended BPR soft and TSP/MAP alone at the rate occurring in the blends. Although the soluble fertilizers (TSP, DAP and MAP) gave the highest maize yields, the positive yields increments with hard BPR, BUK, BUD and blends of BPR (hard and soft): with small amounts of soluble P fertilizers merit further investigations especially economic analysis to test their suitability as alternative to TSP, MAP and DAP.

Onyando R. N. (2002). Effects of nitrogen and plant density on yield and quality of sweet potatoes. Msc. Thesis, University of Nairobi

A field experiment was laid out to investigate the effect of nitrogen levels (0, 45, 90 kg N/ha) and plant density at (41600 plants/ha) and (83200 plants/ha) on production of vines and storage roots in the variety Helena. The experiment was conducted during two seasons using a factorial design, during each season vines were harvested at 90, 140 and 190 Days after planting (DAP. Storage roots were harvested and weighed at the end of each season. Crude protein and crude fibre content of the vines was determined by proximate analysis. Results during the first season showed an effect of the interaction nitrogen X density on vine fresh weight yields at 90,140 DAP and total vine fresh weight. Planting at high density and fertiliser at 90 KgN/ha increased vine fresh weight to a maximum of 14 t/ha and total vine fresh weight at three harvesting intervals to33.7t/ha. In the second cropping season, at 190 DAP, high density and 45 KgN/ha increased vine dry matter yields from 0.1 to 0.4 t/ha compared to no nitrogen application. Density, nitrogen and their interaction had no effect on the vine dry matter yield at 90,140 DAP and total vine dry matter yields. High density increased storage root yields with application of 90 KgN/ha during the first season. There was no effect of nitrogen, or the interaction. In the second cropping season there was no response to nitrogen, density or their interaction. Yield of storage roots was higher during the first season than the second season at all nitrogen levels. Across all nitrogen levels, crude fibre was higher at 190 than 140 DAP

during the first season at both normal and high density and at normal density during the second season. Crude fibre content increased with nitrogen rate at 190 and 140 DAP at high density during the first and second seasons respectively. During the first season, crude protein was not different for all nitrogen levels at normal density. At the high density, Crude protein decreased with increase in nitrogen levels both 140 and 190 DAP. In the second season, crude protein content decreased with increase in nitrogen levels at 140 DAP at normal plant density. At high plant density, crude protein reached a maximum of 20.1% at 140 DAP when 45 KgN/ha was applied. However at 190 DAP, crude protein reached a maximum of 23.0% when 90 KgN/ha was used at high density. Generally, the experiment showed that the density and the interaction density x nitrogen increased the storage roots, fresh vine and dry matter yields during the dry season. Higher storage roots, fresh vine, dry matter yields, crude protein and fibre were recorded in the wet season. Nitrogen had no effect on the measured parameters. This means that higher yield of both fresh roots and vines for human and livestock can be achieved by balancing plant density and time of harvesting of dual-purpose sweet potato Helena.

Onyango C. O. (2002). Bypass flow nitrogen losses in vertisols in tropical environments. Msc. Thesis, Egerton University

Bypass flow is one of the main avenues of fertilizer nitrogen (N) loss in agricultural fields. The magnitude of fertilizer N carried in bypass flow is influenced by soil characteristics, nitrogen species i.e. (NH_4 or NO_3) and rainfall patterns, inter alia. The current study was designed to quantify the effects of fertilizer N source and rate, the onset of rains in relation to fertilizer application (i.e., wetting and no wetting before fertilizer application) on the fertilizer N recovered in bypass flow in a Vertisol. Besides, the ammonium and nitrate N adsorptive capacities of various Vertisols and non Vertisols were quantified. The experiments were conducted for the purpose .Experiment 1 comprised no wetting and pre wetting of soil prior to fertilizer application, 2 rainfall intensities, and 3 sources of fertilizer N. Experiment II involved 3 nitrogen sources, 3 N rates and 3 levels of rainfall frequencies. The bypass flow was collected, filtered and analyzed for mineral N. Treatments in Experiment III comprised 6 Vertisols and 2 non Vertisols (i.e. Ferralsol and Nitisol). The soil charges (i.e. NH_4 and NO_3 adsorptive capacities) were determined using the batch equilibration method. Wetting the soil prior to fertilizer application resulted in significantly ($p<0.05$) higher bypass flow and mineral N recovered in the effluent that did the no prewetting treatments. Both ammonium and nitrate-N recovered in the bypass flow increased with rainfall intensity and frequency. Nitrogen source and rate also resulted in significantly $p<0.05$ different amounts of mineral N in the effluent. The effect of N source on ammonium- N in the effluent were in the order urea>ammonium sulphate>calcium nitrate, while the effect of N sources on nitrate- N were in the order calcium nitrate>urea>ammonium sulphate. The increase in nitrate- N in the effluent due to fertilizer rate were in the order 200>100>50 kg N/ha, Ammonium -N losses were low being in the range 0.1 to 1% while nitrate-N losses were high, being in the range 0.02 to 21% of the applied fertilizer. It is concluded that bypass flow is a major avenue of loss of nitrate-N in Vertisols.

Chui J. N., Keter J. K. A. (2001). Effects of nitrogen fertilizer and bean (*phaseolus vulgaris* L.) residue on yield of beans in different cropping systems. *East Africa Agriculture and Forestry Journal*. Vol. 67(1) pp 37-46

The amount of nitrogen fixed by legumes varies with legume species and may supply a major part of the entire N needed by the crop. However, inorganic N fertilizers are sometimes essential, especially where symbolic N fixation by rhizobia is negligible and N is severely deficient in the soil. A study was carried out in Machakos to investigate the N requirement by beans in different cropping systems: continuous sole cropping, rotation, and intercropping systems with maize, and to determine the value of bean residue in bean production in semi-arid region. The results showed that the effects of N rates 0, 25, 50 and 100 kg N/ha application significantly increased bean grain yields by up to 1.08 t/ha in sole cropping, 1.45 t/ha in rotation and 0.55 t/ha in intercropping thus indicating that N was deficient in the soils. Generally, bean grain yield response to N was quadratic, except in a few cases which were linear where bean residue was not removed from the plots. The highest response occurred in rotation probably because of depletion of N by preceding maize crop while the least was observed in intercropping rate with the highest bean response in continuous sole cropping and those in alternate rows was 50 kg/ha, but for those in rotation it was 75 kg/ha while for beans in the same rows with maize they were 75 and 100 kg N/ha at Kimutwa and Masii, respectively. Greater yield response to N occurred in the Acrisol than in the Nitisol. Number of pods/plant and relative yields were not significantly affected by N. Intercropping significantly lowered the number of pods/plant, grain yields and relative yields. Beans intercropped in the same row with maize gave significantly higher grain yields and relative yields than those in alternate rows. Beans in rotation gave significantly higher grain yields than those in sole cropping and intercropping systems. Return of bean residue significantly reduced grain yields and tended to lower the number of pod/plant. Higher grain yields were obtained during the Long rains than the short rains at Kimutwa while the opposite was true of Masii locations in Machakos district.

Njoroge P. K. (2001). Effects Of Nitrogen and Phosphorus Fertilizers on Growth and Yield of Snowpeas (*Pisum sativum L.* Var.Oregon Sugar pod II). Msc. Thesis, University of Nairobi,

Two field experiments were carried out concurrently at the Faculty of Agriculture, Field station farm, University of Nairobi in March -July 2000 (season 1) and June-September 2000 (season II) to determine the effect of application of different levels of either nitrogen (N) or phosphorus (P) fertilizer on growth and yield snowpea (*Pisum sativum* L. var.Oregon sugar pod II). The experiments were laid out in a complete randomized block design with three replicates. Four levels of N (0, 50, 100 and 150 kg N/ha) were split applied in equal halves as CAN (26% N) at 29 and 58 days after sowing (DAS). In the parallel experiment, four levels of P (0, 57, 114, 171kg P_2O_5/ha) were applied at planting. Plant heights were measured at 31, 38, 45, 58, 71, 84 and 97 DAS. Leaf area index and above ground dry mass were determined at 29, 43, 63, 77 and 94 DAS. Harvesting of pods was done at 68, 72, 75, 79, 82, 86, 89, 93, 96 and 100 DAS). Nitrogen application did not affect plant height, leaf area index, total above ground dry matter accumulation, number of pods and pod dry mass/plant in both seasons indicating that the snowpeas growth and yield did not sustainably benefit from N fertilizer application. It is possible that either snowpeas were able to fix enough N to meet their requirements or these N requirements were met from the soil supply. Pod yields in this study were not affected by N probably through its lack of effect on growth and development. It is therefore recommended that less N be applied for growth and yield snowpeas. In the parallel experiment on P fertilization, significant ($P<0.05$ increases in plant height leaf area index, and total above ground dry matter accumulation in both seasons were observed. Number of pods/plant showed a quartratic trend with increasing P at 68, 89, and 93 DAS in season I. Linear and quadratic increases in number of pods/plant were observed at 96 DAS and on total number of pods/plant. At 100 DAS, only linear increase was observed. Pod dry mass/plant showed a quadratic increase at 68, 89, 93 and 96 DAS. At 100 DAS, linear increase in pod dry mass/plant was observed. Linear and quadratic increases were observed in total pod dry mass/plant. P application did not affect both the number of pods and pod dry mass/plant in season II because of the low amount of rainfall. Application of 57kg P_2O_5/ha resulted in dry pod yields of up to 9.75 tons/ha which is higher than the national dry mass averages of 5 to 6 tons/ha. It is therefore recommended that judicious levels of P be applied for growth of snowpeas.

Shepherd G., Buresh R.J., Gregory P.J. (2001). Inorganic soil nitrogen distribution in relation to soil properties in smallholder maize fields in the Kenya highlands. *Geoderma Journal*, Elsevier B.V 101 : 87-103

We investigated the influence of soil charge properties on the distribution of inorganic soil N in maize (*Zea mays*) fields on small holder farms in the subhumid highlands of Kenya. There was little or no fertilizer use in these subsistence farming systems. Soil NO_3^- was measured to 2m depth in maize fields on 96 farm, sampled in transects at three physiographic positions (ridge top, midslope and lower slope) in each of six soil map units (4 or 8 transects per soil map unit) covering four parent materials: acid igneous, various igneous, basic igneous, and sedimentary. Soil NO_3^- concentrations varied from <0.1 to10 mgN/kg in the top soil 0.25 m and from <0.1 to 16 higher in two soil map units (means ranged from 20 to 30 kgN/ha). Subsoil NO_3^- concentration was not related to effective anion exchange capacity (AEC), Plant N content (taken as an indicator of plant N demand) or anaerobic N mineralization (taken as an indicator of N supply). Effective cation exchange capacity (CEC) of ≤ 7.3 cmol C/kg clay correctly classified 79% of the farms with high subsoil (0.5-2.0) NO_3^- contents of > kgN/ha. It may be difficult to accurately predict the spatial distribution of subsoil nitrate accumulation in maize from routinely measured soil variables, but our results indicate that information on the parent material and subsoil CEC and clay content may help provide broad generalization.

Hamertemink A. E., Buresh R.J., Van Bodegom P.M., Braun A.R., Jama B., Jansen B.H. (2000) Inorganic nitrogen dynamics in fallows and maize on an oxisol and alfisol in the highlands of Kenya. *Geoderma* 98 (2000) 11-33

Fallows with naturally regenerated or planted vegetation are important in many subsistence agricultural systems of tropical regions, but the underlying soil processes in fallows are not properly understood. We investigated N dynamics under different fallow vegetation on a Kandiudalfic Dutrudox (2372-mm rain in 16 months) and a Kandic Paleustalf (1266-mm rain in 15 months) in the Kenya Highlands. The treatments, which extended for three cropping seasons (15-16 months),were *Zea mays* (maize), natural regrowth of vegetation (natural fallow), planted *Sesbania sesban* (sesbania fallow) and uncultivated soil without vegetation (bare fallow). In organic N (nitrate+ ammonium -N) to 2-m depth under bare fallow increased by 242 kg N/ha/year on the oxisol and 54 kg N/ha/year on the Alfisol, indicating that N mineralization exceeded N losses. Subsoil inorganic N (0.5-2.0m) remained relatively unchanged after three crops of unfertilized maize, which produced limited total biomass because of P deficiency. Inorganic N decreased during natural and sesbania fallows, and both fallows similarly depleted subsoil inorganic N. The fallows depleted inorganic N at 0.5-2.0 by 75-125 kg N/ha/year down to a minimum N content between 40 and 80kg N/ha. After slashing sesbania and incorporating the above-ground biomass with 154-164 kg N/ha, soil inorganic N increased within 2 months by 136 kg N/ha on the Oxisol and 148 kg N/ha on the Alfisol. Inorganic N decreased after cropping the bare fallow on the Oxisol with maize, indicating that inorganic N was prone to leaching during heavy rains when the maize was small. A considerably part of the N in biomass of the

natural fallow was recycled. Much of the total N accumulated by the sesbania Alfisol. We conclude that sesbania fallows can retrieve considerable subsoil inorganic N on deep soils with high subsoil N and effectively cycle this N through its rapidly decomposable biomass to subsequent crops.

Mati N. G. (2000). Effects of nitrogen and phosphorus fertilizers on growth and yield of *Vernonia galamensis*. Msc. Thesis, University of Nairobi

Vernonia galamesis is a promising new crop for industrial oil but information on its performance response to fertilizer is scanty. Two field experiments were conducted at the University of Nairobi, Kabete field station in January to May 1998 and March to July 1998. The objectives were to determine the effects of different nitrogen (N) and phosphorus (P) fertilizer rates on growth, solar radiation (PAR) interception and seed yield of two vernonia varieties (ethiopica and gibbosa).N was applied as calcium ammonium nitrate (CAN) AT 0, 75, 150 kg N/ha, and P as triple superphosphate (TSP) at 0, 45, and 90 kg P_2O_5/ha. The experimental design was a factorial laid out as randomized complete block with three replications. Number of leaves/plant and number branches/plant was not significantly (P = 0.05) influenced by N and P application in the two varieties throughout the growing season. N and P application significantly (P=0.05) increased total dry matter (TDM, g/plant), photosynthetically active radiation (PAR) interception and leaf area index (LAI) of both varieties in late vegetative and reproductive stages. Gibbosa consistently had higher TDM and LAI compared to ethipica throughout the growing season. Gibbosa was taller and intercepted more solar radiation (PAR) than ethiopica throughout the growing season. Average seed yield of gibbosa was 2.3 times higher than ethiopica (averaged over all N and P levels) in both experiments. The highest seed yield was obtained with the highest N and P levels. Gibbosa had significantly (p=0.001) higher number of capsules/plant and harvest index (HI) compared to ethiopica. Both N and P increased seed and dry matter.

Mutuo P. K. (2000). Influence of Phosphorus Fertilization on Soil phosphorus Pools and their Relationships to Maize Yield in Western Kenya. Msc. Thesis, Moi University

In Western Kenya, the nutrient depleting effects of long-term cropping as well as low native soil P and fixation of P contribute to P deficiency. The study was conducted on such a soil between March 1996 and January 1997 to determine the fractions of soil P (inorganic and organic P) that released P to crops following P fertilization and were related to maize yield. The experiment was laid out in a randomized block design with four replicates and 10 treatments. The treatments were a factorial combination of 5P treatments (no added P, triple superphosphate at 50 and 250 kg P/ha and Minjingu PR at 50 and 250 kg P/ha) and 2 N sources at 60 kg N/ha (urea and tithonia biomass). The experiment went on for two seasons where maize was grown. Soil sampling at a depth of 0 to15cm was done four times over the two growing seasons and samples analyzed for fractions of P, Potassium (K) and calcium (Ca). The maize yield and soil data were statistically analyzed by Genstat 5 (release 3.2). Inorganic and organic P pools were affected (P<0.05) by only P treatments. Changes in inorganic P fractions after P pools were affected (<0.05) by only P treatments. Changes in inorganic P fractions after P application exhibited the initially rapid decrease but ultimately slow, gradual decline in available P after a soluble fertilizer addition, While PR treatments showed gradual increases in Pi pools. Trends in $NaHCO_3PO$ and NaOHPO fractions followed closely the trends in their inorganic counterparts. At the different sampling dates levels of exchangeable Ca were higher (3.2-4.5 cmolc/kg) when P was applied at 250 kg P/ha than application of P at 50 kg P/ha (2.8 to3.3 cmolc/kg). Extractable K was only affected by N source, up to seven months after treatment application as a result of applying high K- content tithonia. Levels of exchangeable K in Tithonia-treated soil ranged between 0.07 and 0.18 cmolc/kg while urea-treated soil ranged between 0.05 and 0.10 cmolc/kg. Grain and total yields were affected by P treatments depending on the amount of P that was available to the growing crop at early stages of growth. The RAE of Minjingu PR (84-98%) indicated that there might be an economic incentive for using Minjingu PR over TSP in western Kenya. Application of N as Tithonia increased total yearly grain yield (3.3 t/ha) more than N application as urea (1.6 t/ha). Other nutrients such as K from tithonia affected grain yield, showing that in addition to P, K was also limiting. Considering all treatments, fractions of P were not related to yield, partly because of K limitation in urea treatments and partly because P was not limiting plant growth at 250 kg P/ha. However, in treatments without K limitation and with P limitations to maize growth. Resin P and hydroxide Pi were well related to maize yield with coefficients of determinations (R^2) of 0.61 and 0.78, respectively. The replenishment of soil P using Minjingu PR and N using Tithonia is a viable option for increasing productivity considering the environmental consequences of using soluble must be accompanied with management to overcome other nutrient limitations and crop fertilizers such as TSP and urea.

Ogola A. H. and Ndiema A. (2000). The effects of Urea-foliar application on wheat yield. *Proceedings of the 15th Annual General meeting of the Soil Science Society of East Africa*, August, 19th - 23rd 1996, Nanyuki, Kenya Pp 44-48

A study on the suitability of Urea foliar application on wheat was conducted at Njoro Research Centre to determine the effect on wheat yield. Seven rates of Urea were applied on the crop which has been planted with a blanket rate of phosphorus (60 kg P_2O_5/ha). The foliar was given in two splits of half dose each at 4 and 8 weeks after emergence. Three wheat varieties namely: K. Mbuni, K. Kwale and K.Pasa were used in the experiment. The results indicated significant (P=0.05) increase in grain yield at 6, 12, 18, 24 and 30 kg N/ha. However, 1000 grain weight was not affected by the treatments in all the varieties. The observed increase in the grain yields, with fertilization, were attributed to the increase in grain fillings. Interaction of other yield components with foliar are also discussed.

Opiyo A. M. (2000). Effect of nitrogen application and plant age on edible leaf yield and quality of black nightshade (*Solanum nigrum* L.) plants. Msc. Thesis, University of Nairobi, Kenya

Two experiments were carried out to investigate the effects of nitrogen application rates and plant age on the edible leaf yield and nutritive quality of black night shade (*Solanum nigrum* L.) plants. The first experiment was between February and June, and the second between July and November 1995, at Egerton University Njoro, Kenya. Nitrogen rates were 0, 26, 52, 78 and 104 Kg N/ha; applied either as one, two or three split applications. The experiment had 15 treatments arranged in a split plot design, replicated thrice. Nitrogen rates constituted the main plots, while the application methods constituted the sub-plots. Seedlings were transplanted when 8 weeks old. Edible shoots were harvested fortnightly starting from 8 weeks after transplanting, and continued up to 20 weeks after transplanting. Edible leaf yield increased with increasing nitrogen application rates. Increase in yield was not significant in season 1, but was significant in season 2. Nitrogen at a rate of 104 Kg N/ha gave the highest yield (15 t/ha) in season 2, but it was not significantly different from application rate of 52 Kg N/ha (14.8 t/ha) and 78 Kg N/ha (14.8t/ha). Leaf yield increased significantly with increasing plant age. Yield increased up to 14 weeks (2.4 t/ha) and 18 weeks (2.7 t/ha) after transplanting in season 1 and season 2 respectively, thereafter yields declined with successive harvests. Harvested leaves were dried, and analyzed for oxalate and phenolic contents. Plant age significantly affected oxalate content of the leaves during both seasons. Oxalate content decreased with increasing plant age from 611.0 mg/100g 8 weeks after transplanting to 480.7 mg/100g 20 weeks after transplanting, in season 1. In season 2 the lowest oxalate content of 652.7 mg/ 100g was recorded during the first harvest, i.e. 8 weeks after transplanting. At the last harvest (20 weeks after transplanting) the oxalate content was 707.1 mg/100g. The highest oxalate content during season 2 was 938.5 mg/100g, recorded 12 weeks after transplanting. Plant age had no significant effect on phenolic content in season 1; but its effect in season 2 was significant. The lowest phenolic content in season 2 (1153 mg/100g) was observed 16 weeks after transplanting, while the highest content (1507 mg/100g) was recorded at 20 weeks after transplanting. This study shows that nitrogen application at 52 Kg N/ha applied in a single dose is the most economical. It is also evident that nitrogen fertilizer does not increase oxalate and phenolic contents in *Solanum nigrum* to harmful levels.

Kihanda F. M., Mugendi D. N. (1999). Determination of Limiting Nutrients in Central Kenya Highlands Test Strips Approach. Kenya Agricultural Research Institute-Regional Research Centre-Embu. Annual Report 1999 pp 15-16

Nitrogen and phosphorus are reported to be the most limiting soil nutrients to crop productivity in the highlands of central Kenya. As a prerequisite, to carrying out soil fertility experiments, it is important to ascertain the most limiting nutrients in these areas. A quick method of knowing which nutrient is limiting is by laying out test strips with varying nutrient supply. A study was started with the main objective being to determine the most limiting nutrient in the two soil types namely, Ando-Humic Nitisol and Humic Nitisol. The experiment was initiated in two locations with different soil types and land use systems. The Major soil type in Kutus-Sagana area is the Humic Nitisol and maize production is the main agricultural enterprise. In Kianjuki area, the main soil type is the Ando-Humic Nitisol with tea and dairy production as the main agricultural enterprise. Varying levels of N, P, K were applied among 10 farms in each site. The results showed that nitrogen and phosphorus appeared to be the most limiting nutrients in the Sagana-Kutus area. Crop response due to fertilizer application was found to be closely related to laboratory soil analysis. It was also found out that, high levels of aluminium saturation in the Ando-Humic Nitisol of Kianjuki area had an effect on plant root development and hence poor response to applied fertilizer. In order to estimate the limiting nutrients in this area, it appeared necessary to remove/minimize the effects of aluminium toxicity through liming.

Mutuo P. K., Smithson P. C., Buresh R. J. and Okalebo J.R. (1999). Comparison of phosphate rock and triple superphosphate on a phosphorus- deficient Kenyan soil. Communications in Soil Science and Plant Analysis, 30:7-8, 1091-1103, DOI:10.1080/00103629909370270

Soil phosphorus (P) deficiency is a constraint to crop production in many regions of sub-Saharan Africa, which could be overcome through use of either soluble P fertilizer or sufficiently reactive phosphate rock (PR). A field study was conducted with corn *(Zea mays* L.) for three growing seasons (18 months) on a P-deficient, acid soil in Kenya to compare a soluble P source (triple superphosphate, TSP) and relatively reactive Minjingu PR from Tanzania. In the 18 months following application of 250 kg P/ha, bicarbonate extractable inorganic soil P (Pi) was higher for application of TSP than PR, but Pi extracted with a mixed anion-cation resin was comparable for TSP and PR. Inorganic P extracted by 0.1M NaOH, without prior extraction of resin and bicarbonate Pi, decreased during the 18 months following TSP application, but increased following PR application. After 18 months, about 7% of the added PR-P remained as Ca-bound P that was extracted with 1M HCl. The 1M HCl extractable P., however, underestimated residual PR-P that gradually dissolved and supplied plant-available P, as indicated by recovery of <40% of PR-P added to soil in laboratory incubations even though PR solubility in HCl was >90%. Minjingu PR was an effective source of P for corn. Corn yields were comparable for TSP and PR, and the relative agronomic effectiveness of PR averaged 107% in Season 1 and 79% in Season 3. Anion resin and mixed anion-cation resin appeared to be superior to bicarbonate and NaOH as a soil P test for use with both TSP- and PR-treated soils.

Njui A. N. (1999). Phosphorus use efficiency by maize (*Zea mays* L.) at selected sites in Siaya District, Western Kenya. Msc. Thesis, Egerton University, Kenya

A major objective of the National Food Policy for the Government of Kenya is the attainment of household and national food security. In line with this, improvement of household food security in Ukwala and Wadai divisions of Siaya District is a major priority. Fertilizer use with appropriate maize varieties is an important input necessary to achieve this goal. Phosphorus (P) deficiency is the main limitation to maize production but little is known about phosphorus use efficiency (PUE) by maize (*Zea mays* L) in this region. A study was conducted to determine how band P placement and P fertility levels affect production and P use efficiency by maize. Two on-farm trials were conducted. These comprised a varietal trial and a phosphorus rate trial. In the varietal trial, the performance of two maize hybrids (PAN5195 and H512) and two local maize varieties (local white and local yellow) was compared with and without an application of P fertilizer at 20 Kg P_2O_5/ha. The experimental design was Randomized Complete Block Design (RCBD) replicated three times. In the P rate trial, five P rates (0, 10, 20, 30 and 60 Kg P_2O_5/ha) were combined with two rates (12 and 40 Kg N/ha) of nitrogen (N). The ten treatments were laid in a RCBD with a split-plot arrangement. N was put in the main plots and P in the sub-plots. In the varietal trial, it was found that; grain yield was consistently higher with addition of fertilizer. Analysis of variance showed that there was no significant variety by fertility level interaction. At low P fertility level, the performance of unimproved varieties was similar with the hybrids. The best hybrid and local variety had 1.99 and 2.17 t/ha grain yields respectively. Total aboveground dry matter accumulation was highest for H512 and lowest for local yellow. PUE defined as kg grain per kg of soil available P (mineral-P in 0-20 cm depth + P rate) was better at low rates of P application as compared to high rates. In the P rate trial, basal N without P gave the highest PUE where rhodic Ferralsols had 478.14 and orthic Acrisol had 671.77. In the varietal trial, PUE was better for local varieties as compared with the hybrids. In this trial, PUE values of 355.60 and 336.70 were observed with Local white and H512 on orthic Acrisol and rhodic Ferralsol respectively where there was no P applied. Given the rapidly increasing prices of hybrid seed, farmers seem to be justified in selecting their own local seed for production under low input conditions. In the P rate trial, the combined grain yield effect of N and P application was much better than basal N only. The highest grain yield of 3.75 t/ha was obtained with the highest rates of N (40 Kg N/ha) and P (60 Kg P_2O_5/ha). This means that N topdressing is necessary for effective P response. It is therefore, recommended that at least 20-30 Kg N/ha be top dressed. Significant ($P<0.05$) response to P at 10 Kg P_2O_5/ha was observed. From economic analysis, this low rate of P proved profitable to the farmers. Therefore, it is recommended that 10-20 Kg P_2O_5/ha be applied during planting. Timely band P application should be practised for an economically self-sustainable system in high P sorption soils. The results indicate that there is potential for improvement of P use efficiency.

Kouko W. O, Owino-Gerroh C. (1998). Response of cotton (*Gossypium hirsutum* L.) to nitrogen phosphorus fertilisers in western Kenya. *Proceedings of the 6th KARI Scientific Conference* held at KARI Headquarters on 9-13th November, 1998. Pp. 576-580

The requirements for nitrogen and phosphorus fertilisers for growing cotton (*Gossypium hirsutum* L.) in Kenya are 26-kg N/ha and 27 kg P/ha respectively. Calcium ammonium nitrate (CAN) was recommended at the rate of 100 kg/ha for black cotton soils while double superphosphate (DSP) was recommended at the rate of 150 kg/ha on reddish brown clays. However, experiments conducted on major soil types on which cotton is grown in Kenya

showed that soil colour is not the best indicator of nutrients supply power of the soil. It was found that Verto-eutric planosols of National Fibre Research Centre-Kibos requires application of 13-kg/ha as CAN for optimal yields. Ferralo-eutric Acrisols of Alupe Agricultural Research Sub-Centre, Busia needed 26-kg N/ha and 9 kg P/ha to give high yields. At Siaya FTC 9 kg P/ha was adequate in providing the highest yields without nitrogen. Strict observation of recommended agronomic practices for growing cotton and good soil management practices for growing cotton and good soil management practices were observed a prerequisite for high response and efficient utilisation of fertilisers.

Masinde P. W. (1998). Influence of Nitrogen and Phosphorus application, and seed source on cumulative leaf yield, nutritive quality and premature flowering of collard (*Brassica oleracea* var *Acephala* D.C). Msc. Thesis, University of Nairobi Department of Plant Science and Crop Protection,

An experiment to study the influence of nitrogen (0, 4, 8,12 g N/plant), phosphorous (0, 3, 6 g P_20_5/plant) and seed source (local and imported) on leaf yield, nutritive quality and premature flowering of collard (*Brassica oleracea* var acephala D.C) was conducted in two seasons at JKUAT farm at Juja between October 1994 and October 1995. The experimental design was split-split plot replicated three times with the seed source as main plots, nitrogen as sub-plots and phosphorous as sub-sub plots. Harvesting of leaves began at 40 days after transplanting and was done at 14-days interval for 168 and 126 days in the short and long rains, respectively. Leaf weight and number were determined at each harvest. Leaf quality was determined by analysing for nitrates, crude protein, crude ash and phosphorous contents at 40, 68 and 96 days after transplanting. Premature flowering was recorded as percent flowered plants. Nitrogen application increased cumulative leaf weight. Application of 8 and 4 g N/plant (855.6 kg CAN/ha and 427.8 kg CAN/ha) were optimal for cumulative leaf weight in the short and long rains, respectively. Leaf number was not affected by nitrogen. Application of phosphorous increased cumulative leaf weight and number in both seasons with 3 g P_20_5/plant (205.6 kg TSP/ha) being optimal. Seed source did not affect leaf yield. Nitrogen and phosphorous interacted to increase leaf weight but not leaf number during the long rains. The effect of nitrogen on fresh leaf weight was observed for about 50% and 66% of the harvesting periods considered in the short and long rains, respectively but with phosphorous this was 67% and 89%. Leaf number was affected by nitrogen for 25% and 56% of the harvesting period in the short and long rains respectively while the phosphorous the effect was for 11% and 78%. Nitrogen application increased nitrate (petiole and blade), crude protein, crude ash and phosphorous (blade) content of the leaves while phosphorous content. Plants from the imported seed had significantly higher content of crude ash than those from the local seed. Nitrogen interacted on seed source and phosphorous for crude protein content of the blades during the long rains. However, during the short rains, the only interaction was between phosphorous and seed source for crude ash content of the blades. Seed source had a significant effect on premature flowering of the plants. Plants from the local seed flowered earlier and produced more flowers than those from the imported seed. Neither nitrogen and phosphorous application nor their interactions had any significant effect on premature flowering.

Nyachio S.G.(1997) Effect of chickpea (*Cicer arietinum* L. cv. Kabuli) and common beans (*Phaseolus vulgaris* L. cv. Rose coco) on wheat performance and soil fertility in a legume-wheat cropping sequence. Msc. Thesis, Egerton University, Kenya

Soil fertility is one of the most serious problems that limit wheat productivity. This is partly caused by wheat monocropping which leads to nutrient depletion especially nitrogen, which limits wheat productivity when in short supply. Legumes when incorporated into cropping systems improve soil fertility through their nitrogen fixing ability and consequently increase the yields of subsequent crops. Thus a study on the effect of two pre-wheat legumes (chickpea and beans) on wheat performance and soil fertility was conducted in the Egerton University, Agronomy field, during the short rain season of 1995/96 and the long rain season of 1996. Two cropping sequences, (C-W) and (B-W) were compared to (F-W) at the 0, 30 and 60 Kg N/ha rates of N application. The percent total N in wheat plants at different stages of growth, available N at three depths (0-15, 15-30 and 30-60 cm) and microbial biomass at 0-15 and 15-30cm depths were monitored. Incubation studies to determine potential N mineralization of the soil were also conducted in the laboratory for a period of 90 days. The results showed that cropping sequences had significant effect on wheat DM yield but not on the grain yield. The different rates of N application on the other hand had significant effects on the grain and DM yields. The fertilizer replacement value for C-W was 39.7 Kg N/ha whereas that for B-W was 24.0 Kg/ha. The total N in wheat grains and straw increased with increase in the rate of N application but still B-W and C-W cropping sequences had higher total N levels than F-W. However the total N content in wheat plants at different stages of growth declined from seedling to harvest due to either dilution effect as more plant biomass was produced or translocation of nitrogen to newly formed plant parts such as the grains. The C-W and B-W cropping sequences generally had higher levels of available N in the soil compared to F-W except at wheat planting and the rates of N application showed significant treatment effect on available N as from 30 DAS till harvest.

Ojiem J., Odongo O.M., Wakhonya H. (1997). Effect of fertilizer and variety on maize grain yields under Striga infestation in Yala, western Kenya. Kenya Agricultural Research Institute, Kakamega. Annual Report 1997 pp. 78-80

Striga hermonthica is one of the most important factors constraining maize yield in western Kenya, particularly in Siaya and Busia Districts. Hybrid maize varieties are recommended in these districts but their adoption is low (Hassan *et al*., 1994). The hybrid maize varieties are generally susceptible to striga, therefore farmers in these districts prefer growing their local maize varieties, which have been selected repeatedly under striga infestation and therefore have in some degree tolerance incorporated in them. The adverse effect of striga is often aggravated by low soil fertility. Improving maize production in the striga infested districts would therefore require tolerant maize varieties combined with improved fertility management. The two factors were investigated in this study.

Anjenjo D. (1996). Effects of Phosphorous and Nitrogen fertilizers on grain yield of common beans (*Phaselous vulgaris* L) Cultivar"Ros Coco". Msc. Thesis, Moi University

Common beans are important staple food worldwide and more important in developing countries because they are the cheapest source in protein. Production of common beans in Kenya is declining while the demand is increasing. The decline in production is partly attributed to the declining soil fertility and non use of fertilizers in production of the crop. There is a general untested conception that beans crop does not require fertilizers, especially nitrogen and phosphorus. Because of this conception most Kenyan farmers do not use fertilizers for their bean crop and this could be contributing to the decline in production of the crop. A field study was conducted to evaluate the response of grain yield of common beans (*Phaseolus vulgaris* L) cultivar "Rose coco" (GLP 2) to varying rates of Nitrogen (N) and Phosphate (P) fertilizer applications. The study was also to evaluate nutrient concentration and accumulation in the grain of the crop as influenced by N and P fertilizers. Simple economic analysis was also carried to determine monetary returns due to the use of N and P fertilizers. The fertilizers used were Calcium Ammonium Nitrate (CAN) and Triple Superphosphate (TSP) as sources of N and P respectively. Both fertilisers were applied in bands at sowing rates of 0, 20, 40, 80 kg/ha of N and P. Recommended cultural practices were followed in growing the beans. The study was conducted at the university of Eastern Africa, Baraton in Nandi district within the Rift valley province, Kenya during a short rainy season. Nitrogen fertiliser applied at 20, 40 and 80 kg P/ha significantly (P< or=0.05) increased grain yield by 35% and 53% respectively. Nitrogen fertiliser significantly (P<or=0.05) increased nitrogen, phosphorus, potassium, calcium and magnesium accumulation in the grain. The accumulation of these macronutrients increased with increasing rates of N application; however, the N fertilizer did not significantly increase the concentration of the macronutrients in the grain. Phosphate fertiliser significantly (p< or =0.05) increased accumulation of N and Mg only in the grain, but it did not significantly affect phosphorus, calcium and potassium accumulation in grain. The results however, showed that there was no significant interaction between two fertilisers. Even though the results showed that application of both N and P fertilisers to the common beans crop gave economic returns with the highest amounts being realised at 20 kg N/ha and 40 kg P/ha, the work was only done in one season. It is recommended that further work should be done at the same and higher rates of both fertilisers and also with different sources of P. The study should also involve planting during the late part of the long rainy season because early part of the long rains is always characterized by excessive soil moisture and low temperatures which are not conducive for growing beans.

Mugwanja P.N. (1996) The influence of phosphorus fertilizer application on growth and elemental composition and distribution in sunflower (*Helianthus annuus* L.) Msc. Thesis, University of Nairobi, Kenya

The effect of P fertilization on dry matter (DM) production and elemental composition and distribution in sunflower (*Helianthus annuus* L.) was studied at different stages of growth. Two varieties (H345 and Issanka) were used in the study. Phosphorus fertilizer significantly increased DM production in the leaves but had no significant effect on DM accumulation in roots, stems and heads. Phosphorus fertilizer application affected seed yield and oil concentration significantly in both varieties. The highest seed yields were obtained with the application of P at 31.5 and 63.0 Kg/ha in Issanka and H345, respectively. The highest oil content in both varieties was obtained with the application of P fertilizer at 63.0 Kg/ha. Calcium concentration in the leaves was increased significantly by P fertilizer application. Similarly, P concentration in the stems of H345 was significantly higher than in plots applied with P fertilizer than those with no P fertilizer application. In other plant parts, P fertilization did not have significant effect on P and Ca concentrations. Nitrogen concentration in the leaves, stems and heads was significantly reduced by P fertilizer application but not in the roots. Also, K concentration in the stems was significantly reduced by P fertilizer application. With the exception of seedling stage of growth, the roots had the highest dry matter production and stems had the lowest. Leaves had the highest concentrations of N, Ca and Mg during most of the growing season. The heads had the highest P concentration from heading to maturity stage. Roots and stems had the lowest concentration from heading to maturity stage. Roots and stems had the lowest concentrations of N, P, Ca and Mg throughout the growing season. Seeds had the highest K and Ca concentrations when compared with other plant parts at maturity. Nitrogen, P, K, Ca and Mg concentrations in the roots declined during the growing season. Nitrogen concentration in the stems declined throughout the growing

season while P and K concentrations did not have a consistent trend during the early stages of plant growth but declined from flowering stage onward. Calcium concentration increased slightly during the early stages of plant growth but remained relatively constant from flowering stage to maturity. Magnesium concentration in the stems remained relatively constant up to the flowering time, then declined. Nitrogen, P, K and Ca concentrations in the heads declined throughout the growing season but Mg concentration increased slightly up to the flowering time, then declined. Nitrogen concentration in the leaves declined throughout the growing season while Ca concentration increased. Phosphorus and Mg concentrations remained relatively constant up to the flowering time, then declined at maturity in both varieties. Also, in the leaves K concentration increased up to flowering time then declined at maturity.

Ogenah V. E. (1996). Effects of diammonium phosphate and potassium application and deflowering on yield and quality of cowpea (*Vigna unguiculata* (l) walp) leaves. Msc. Thesis, University of Nairobi

The experiments were carried out during the short rains of 1992 and the long rains of 1993 at the University of Nairobi's Kabete campus Field Station to study the effects of; (1) diammonium phosphate (DAP) and potassium Fertilisers application on yield and crude fibre content and (2) DAP and potassium fertilisers application and deflowering on yield and leaf senescence of cowpea leaves. For the first experiment, 16 treatments which were factorial combination of four fertilizers rates each DAP and potassium were used in a randomised design (RBD) experiment with 3 replications giving a total of 48 plots. For the second experiment, there were 32 treatments which were a factorial combination of four rates each of DAP and potassium and deflowering or not in a CRD experiment with 3 replications. Diammonium phosphate application significantly increased the fresh leaf yield during the second season only. Potassium application had no significant effect on yield during both seasons. The interaction between phosphorus and potassium for yield was not significant. Diammonium Phosphate and potassium application or their interaction had no significant effect on cowpea leaf numbers and leaf senescence in both seasons. Deflowering significantly ($P \leq 0.01$) increased both fresh lea yield and leaf number and decreased leaf senescence in both seasons. The interaction between DAP application and deflowering for leaf senescence was significant during both seasons. Diammonium phosphate application and deflowering reduced leaf senescence. The interaction between potassium application and deflowering for leaf senescence was only significant during the first season when potassium application and deflowering reduced leaf senescence. The interaction between potassium and phosphorus application for leaf senescence was not significant in both seasons. Diamonium phosphate and potassium application did not significantly affect crude fibre content. However, leaf fibre content increased significantly with increasing plant age. The study therefore was provided information that may directly or indirectly be utilised to enhance cowpea production. Farmers growing cowpeas for leaves could directly apply the results of this study to improve their production either by applying diamonium phosphate or by deflowering the plants. The study also provided information that could be useful to those interested in further research on the crop.

Ogola, A.H, Kouko' W.O. (1996). Evaluation of the effects of fertilizer (N*P) on randomized rice varieties in Western Kenya. *Proceedings of the 5th KARI scientific conference*, 14th to 16th October, 1996, KARI Headquarters, Kaptagat road, Loresho. Nairobi. pp 226-436

A study on the response of fertilizer (N*N) was carried out on five rainfed rice varieties in Western Kenya to determine the response of the varieties to three different rates of phosphorus and four rates of nitrogen. The trial was conducted in five sites. Treatments were planted in a split plot design with varieties in the main plots, phosphorus in the sub-plots and nitrogen in the sub plots. Three replicates were used. Application of phosphorus at 23kg P_2O_5/ha significantly increased grain yield at Opapo site. While nitrogen application gave significantly better yield when applied at 26 kgN/ha at Kibos. Combined analysis showed that phosphorus application at the rate of 23 kg P_2O_5/ha significantly ($P \leq 0.05$) increased paddy yield at Opapo while at Yala Swamp and Lichota sites, the higher rates of phosphorus (46 kg P_2O_5/ha) significantly reduced grain yield from 4771 kg/ha to 3524 in Lichota. haveThere was less response to phosphorus application at Alupe and Kibos probably due to accumulated, residual soil phosphorus which may have been enough to meet the crop requirement over the season.

Nesbert Mangale (1995). Corn responses to nitrogen forms, ammonium/nitrate ratios and potassium in Iowa and Kenya. PhD. Thesis, Iowa State University,

Nitrogen in soil occurs in both the organic and inorganic forms; but a crop absorbs and utilizes mainly the inorganic forms. Of these inorganic N forms only the nitrate (NO_3) and ammonium (NH_4) forms are absorbed. In humid and sub-humid regions, NO_3^-N is lost from crop rooting zones by leaching and/or identification. Preserving fertilizer N in the NH_4^- N is not easily leached and is not denitrified. However, ammonium nutrition may be harmful to a crop especially when high amounts are used. There are, however, some indications that potassium (K) addition may prevent the injurious effect of NH_4 and NO_3 forms of N compared to either form alone, results in an improvement in plant growth and higher yields. This study, therefore was undertaken to determine whether NH_4^- N supplied at

a rate that is within economic reach of farmers is toxic or not and if it is, whether or not potassium addition could reduce the injurious effect of NH_4^- N. Also evaluated were the effects of mixtures of NH_4^- N and NO_3^- N and various levels of NH_4^- N. Also evaluated were the effects of mixtures of NH_4^- N with or without K addition on the yield and element composition of field grown corn. The study was in three parts. The first part evaluated the effect of the two forms of N (NH_4 and NO_3) combination ratios with or without K addition on corn yield were evaluated. The N rate used was 100 kg/ha and the K rate was 50 kg/ha. In the third part, the effect of various levels of NH_4^- N with or without K addition on corn yield was investigated. Rates used ranged from 0 to 150 kg/ha for N and 0 to 50 kg/ha for K for all soils except the Clarion series which received higher rates that ranged from 0 to 336 kg/ha for both N and K. Experiments were conducted on: Typic Hapludolls (Clarion and Marshall Series), Oxic Paleustalfs and Typic Paleudults soils. Corn yield was not negatively affected by NH_4^- N or NO_3^- N. In both Iowa and Kenya corn grown with NH_4^- N produced higher grain yield than that grown with NO_3-N. Potassium addition appeared not to be needed. There was no specific NH_4:NO_3 combination that was applicable to all the four soils used for high corn yield. Each soil type required a different NH_4:NO_3 ratio for higher corn yield plateau.

Owino-Gerroh C. (1995). Rehabilitation of soils formerly under tea using phosphorus sources as soil amendments. PhD. Thesis, University of Nairobi

Soil chemical factors responsible for stagnation and/or decline in yields of tea (*Camelia sinensis* L.), failure of alternative crops such as field bean (*Phaseolus vulgaris* L.) to establish in former tea soils and their amendments with phosphorus sources were investigated in laboratory, greenhouse and field studies. Ando humic nitisols from four sites, viz fields with moribund tea, teas planted in 1959 and 1979 and newly cleared forest in Kagaa, Lari Division Kiambu District Kenya were used. High aluminium (Al^{3+} concentration and saturation (>480g/kg), deterioration of soil nutrients balance, low phosphorus (P) content and high P- fixation capacity were found to be the most probable detriments. The addition of triple superphosphate (TSP) and Minjingu phosphate rock (MPR) fertilizers at rates 0 (Control), 30, 45 and 60 kg P/ha and 30 kg P/ha as TSP plus lime ($CaCO_3$) to the soils as sources of P and soil ameliorants and incubating for 1, 7, 14, 28 days showed that TSP and 30 kg P/ha (TSP) plus lime significantly increased Ca^{2+} and P and decreased Al^{3+} contents more than MPR did within one day of application. MPR significantly increased the soil reaction, Ca^{2+} and P and decreased Al^{3+} contents gradually within 14 days. The differences between the P sources was attributed to the higher solubility of TSP and also its ability to supply more P to the soils which reacted with Al^{3+} to form sparingly soluble compounds. The yields of field beans grown on the soils studied were also significantly increased by TSP and 30 kg P/ha (TSP) plus lime more than MPR fertilizer did when the above scaled rates of TSP and MPR fertilizers and 30 kg P/ha (TSP) plus lime were added to the soils. The differences were attributed to the abilities of the sources to supply sufficient quantities of P to satisfy both the soils high P- fixation capacities and also for the plant growth. Incorporating field bean tops (shoots) into the soils significantly increased the yield of subsequent field bean crop. The yields were also significantly increased when the above stated P sources were also added to the soils incorporated with field bean tops. Significantly higher increases were found when TSP and 30 kg/ha (TSP) plus lime were applied than with MPR fertilizer. This was attributed to low C:N (6.3) and lignin: N (1.3) ratios, low polyphenolic (2.7g/kg) and high N (50.4 N g/kg) contents of the bean plant. These enabled it to decompose rapidly thereby releasing both N and other essential plant nutrients to the soil for plant growth. The ability of TSP and 30 kg P/ha (TSP) plus lime to dissolve quickly and supply P to the soils which is good for higher microbial events led to the observed higher yields. Agronomically, TSP fertilizer was found to be superior to MPR as a source of P and also as a soil ameliorant for growing field bean in soils formerly under tea. This is because the former releases P more quickly thereby reducing the soil's high P-fixation capacity and also supplying highly deficient P for plant growth in the soil. The yield responses of tea (*Camellia sinensis* L. O'Kuntze) to 30, 45 and 60 kg) P/ha of TSP and MPR fertilizers, 30 kg P/ha (TSP) plus Lime ($CaCO_3$) and 25:5 5:5 NPKS fertilizer (Control) in moribund tea and 1979 planted tea fields were stastically not significantly different because of ''the complexation of AI'' tolerance mechanism of the tea plant to high AI and P content soils. Through this mechanism, the uptake of both P and Ca^{2+} by the tea plant is insignificantly reduced. In conclusion the study showed that for the tea plant, all the P- sources used are effective as sources of P but for the purpose of rehabilitation of moribund tea fields and also for sustainable productivity, 30 kg P/ha (TSP) plus lime and MPR should be preferred because they reduce the high soil acidity. AI content and saturation and also increases the available P content in the soil. This will reduce AI build up in the plant tissues which exert stress on the plant and eventually leads to the decrease in the plant's resistance to opportunistic diseases such as *Armilaria melea* and *Bypoxylon Serpens* hence vacancies and reduced yields.

Ngugi S. M. (1994). Effects of liming and phosphorus application on the growth and nodulation of soybeans (*Glycine max* (L.) Merr.) cv "Hill" in acid soils. Msc. Thesis, University of Nairobi, Kenya

A study on the effects of lime and phosphorus application on the growth and nodulation of soybeans (*Glycine max* (L.) merr.) cv "Hill" was conducted in a factorial experiment under green house conditions using two strongly acid soils (a umbric andosol from Gituamba and a humic nitisol from Kisii). The soils were limited with calcium carbonate ($CaCO_3$) based on the levels of exchangeable Al present in the soil. The phosphorus levels were 0, 50, 100 and 150 Kg P/ha, applied as triple superphosphate (TSP). Half the seeds were inoculated Rhizobium strain, NUM 508

before planting and half were not. The plants were harvested 51 days after planting and the variables measured were nodule number and nodule dry weight, total dry matter yield and uptake of N, P, K, Ca and Mg. Inoculating the seeds significantly increased nodulation. The nodule numbers and nodule dry weights increased significantly with initial liming. The application of 100 Kg P/ha significantly increased nodulation. There was no interaction between lime and phosphorus with respect to nodulation. Initial liming (3 meq $CaCO_3$/100g) increased the shoot dry matter yield significantly (p=0.05) in Gituamba soil. Further increases in lime application did not affect the yield significantly. In Kisii soil the application of 3 and 6 meq $CaCO_3$/100g increased the shoot dry matter yield significantly (P=0.05). Application of 9 meq $CaCO_3$/100g decreased the yield but not significantly. The highest shoot dry matter yield occurred at the highest level of phosphorus (150Kg P/ha). There was a positive interaction between lime and phosphorus with respect to dry matter yield in Kisii soil. The application of P increased the dry matter yield significantly at lime levels 3 and 6 meq $CaCO_3$/100g. At the highest level of lime application (9 meq $CaCO_3$/100g) the yields decreased though not significantly. The application of phosphorus significantly increased the uptake of N, P, K, Ca and Mg. The growth response to liming and phosphorus application was attributed to the reduction of exchangeable Al. Significant increases of dry matter yield with increasing levels of P application suggest that further investigations with regard to optimum P level would be advisable.

Wareku J.W. Z. (1994). The influence of nitrogen application on yield and quality of freshly harvested and stored carrot (*Daucus carota* l.var.'nantes') roots. Msc Thesis, University of Nairobi

Experiments were carried out in two seasons at the Field Station, Kabete Campus, between November, 1988 and May, 1989 to study the effect of nitrogen application rates (0, 26, 52 and 78 kg N/ha) on the yield and quality of fresh and stored carrot roots. Freshly harvested roots were stored at room temperature in perforated and non-perforated polythene bags for zix days. Carrot roots were analyzed for splitting, beta and total carotenes, ascorbic acid, dry matter, proximate chemical composition, nitrate accumulation and weight loss. The experimental design used for the field experiment was the randomized complete block design with three replicates while storage experiment was a 4x2 factorial experiment (four nitrogen and two storage levels) set out in a randomized complete block design with three replicates. The effect of nitrogen application on root yield and splitting was not significant differences between seasons in yield. Root yields and splitting were lower in the first season than in the second season. During the first season, nitrogen application significantly ($P<0.05$) increased the contents of beta carotenes in the carrot roots. Total carotene contents were not significantly affected. During the second seasons, nitrogen application did not affect beta carotene contents in the roots but significantly affected total carotene contents. During both seasons, crude protein was not affected by nitrogen top-dressing but crude fat, total ash and fibre contents were. These increased significantly with increasing rates of nitrogen application. Vitamin C content of roots was not affected by nitrogen application in both seasons. During the first season dry matter contents of roots were not affected by nitrogen application. However, during the second season, the dry matter of roots increased significantly with increasing nitrogen rates. In both seasons, nitrogen application significantly increased nitrate accumulation in the roots. Roots from the second season had accumulated significantly more nitrates than those from the first season. In the first season, there was a net significant increase in weight loss during storage. Roots that had been top dressed with nitrogen had significantly lost more weight than those that had not been top dressed at the end of the storage period. As expected the weight loss was higher in roots stored in perforated polythene bags than in those soted in non-perforated bags for all nitrogen rates in both seasons. The dry matter contents of stored roots was not significantly affected during storage in both seasons. In the first season, roots stored in perforated bags retained more total carotenes than those stored in non-perforated bags. In both storage methods, roots top dressed with nitrogen retained more beta and total carotenes than those that were not top dressed. Vitamin C contents were not affected during storage. Storage significantly decreased contents of nitrates in the roots. Roots in the perforated bags had more nitrates than those stored in non-perforated bags.

Nyaga L. N. (1993). The influence of nitrogen fertilization on growth, flowering and keeping quality of Alstroemeria 'Carmen' and 'Marina' Msc. Thesis, University of Nairobi, Kenya

The study was conducted in Limuru from June to November, 1990, to investigate the influence of nitrogen fertilization on growth, flowering and keeping quality of Altroemeria 'Carmen' and 'Marina' flowering plants. The number of total shoots/M^2 increased significantly with application of nitrogen in 'Carmen' but the increase was not significant in 'Marina'. The average fresh weight of 'Carmen' flowering and vegetative shoots increased significantly with application of 117 Kg N/ha. In 'Marina', the average fresh weight of vegetative shoots increased slightly with nitrogen application but that of the flowering shoots increased significantly with application of 78 Kg N/ha then decreased with higher nitrogen application. The average length of 'Carmen' vegetative and flowering shoots increased significantly with application of 156 and 117 Kg N/ha, respectively. In 'Marina' the average length of vegetative and flowering shoots increased with application of 39 and 78 Kg N/ha, respectively, but higher nitrogen fertilization decreased it significantly. The thickness of both vegetative and flowering shoots of 'Carmen' was not significantly affected by nitrogen application. The vegetative shoots of 'Marina' had a similar trend but flowering shoots from plants fertilized with 39 Kg N/ha were significantly thicker than those from other nitrogen treatments.

Nitrogen fertilization did not influence the number of leaves on flowering and vegetative shoots in both 'Carmen' and 'Marina'. The number of flowering shoots/M2 increased significantly with nitrogen application in 'Carmen' but slightly in 'Marina'. The percent of flowering shoots in 'Carmen' increased significantly with nitrogen fertilization but in 'Marina', it was not affected. Nitrogen fertilization did not affect onset to flowering of either 'Carmen' or 'Marina'. However, the number of cymes per inflorescence increased slightly with application of 156 Kg N/ha in 'Carmen' and 39 Kg N/ha in 'Marina'. Nitrogen concentration in leaves and stalks of both 'Carmen' and 'Marina' increased with increased nitrogen fertilization. It was highest in young leaves, intermediate in old leaves and lowest in stalks. Leaf chlorophyll content of cut flowers after harvest, on seventh and fourteenth day in vase remained high with application of 156 and 117 Kg N/ha in 'Carmen' and 'Marina', respectively. There was a more rapid leaf chlorophyll breakdown of cut flowers in both cultivars during the first week than the second week in the vase especially those from plants treated with high nitrogen levels. The average number of days to complete leaf yellowing in both cultivars increased significantly with nitrogen fertilization. The average number of days to half petal fall in 'Carmen' increased significantly with nitrogen application, but in 'Marina', it increased slightly. In 'Carmen', split nitrogen applications did not affect shoot growth, flowering, cupflower quality and keeping quality. However, 'Marina' plants fertilized with most nitrogen levels had more leaves on flowering shoots when nitrogen was applied in four splits than in two splits. 'Marina' cut flowers from plants fertilized with 39 and 78 Kg N/ha in four splits interval lasted longer before complete leaf yellowing in vase than those fertilized in two splits.

Odeny D. A. (1993). Response of sesame (*Sesamum indicum* L.) to nitrogen and phosphorus fertilization. Msc. Thesis, University of Nairobi, Kenya

The response of sesame to varying rates of nitrogen (0, 50, 100 and 150 Kg N/ha) and phosphorus (0, 30, 60 and 90 Kg P/ha) was studied in two experiments, at the Siaya Farmer`s Training Centre in Siaya District, during the short rains of 1991 and the long rains of 1993. Two local unimproved landraces, black-seeded and white-seeded grown by the majority of farmers in Kenya, were used in this study. Results showed that nitrogen and phosphorus fertilization did not significantly affect yield and yield components of sesame. It was concluded that the local landraces of sesame were not responsive to application of nitrogen and phosphorus fertilizers under the conditions of the experiment.

Kamau Ngamau (1992). Influence of level and frequency of nitrogen fertilizers on growth, flowering and postharvest quality of tuberose (*Polianthes tuberosa* L.). Msc. Thesis

University of Nairobi

This study was conducted to determine the influence of various levels of Nitrogen and frequency of application on growth, flowering and postharvest quality of tuberose. Nitrogen tended to stimulate an increase of leaf length in Kabete but did not influence the number of basal leaves. With the application of 0,21,25,42.5 and 85.0kg N/ha, leaf length increased from 38.2 cm to 39.2, 40.5 and 38.2 cm. However this increase was not significant. Nitrogen application promoted the increase of the spike and rachis length and spike diameter both at Kiambu and Kabete. However, only the spike diameter increased significantly with application of N giving the highest spike diameter at the highest N level. Split N application also positively promoted greater spike and rachis length and spike diameter. The spike growth rate and the number of leaves and florets per spike were not significantly influenced by N. level. The distal floret size and colour were not significantly by N level. However, the latter decreased while the former tended to increase with N levels. Increased N levels delayed the senescence of flower sepals and the yellowing and senescence of distal florets but is did not prevent their abortion. The application of 0, 21, 25, 42.5, and 85.0 kg N/ha significantly delayed senescence of sepals and the unopened distal florets giving the greatest delay at the highest N level. Split application of N did not significantly influence the period to senescence of sepals and the yellowing and senescence of the distal florets. However, the period to the wilting and senescence for the last open floret and the total number of open florets tended to decrease with split N application. Nitrogen application did not significantly influence the period to the wilting and senescence of the last open floret and the number of dry and senesced florets. Both split an application and the levels of N increased the number of spikes produced. However, the increase due to N levels was not statistically significant. The spike yield increased with split N application and rose from 17.5 to 18.0 and 23.8 stems per plot (m^2) at 4 wk, 2wk, and 1wk application interval, respectively. Nitrogen application increased production and quality of cut tuberose. A level of 42.5 kg N/ha application promoted optimum response for most observed parameters. Split N application was also found to improve yield and quality of cut tuberose with higher frequencies of application giving better results.

Maingi D.M. (1992). The effect of nitrogen and phosphate fertilizer management on the production and quality of true potato (*Solanum tuberosum*, L.) seeds from three commercial varieties grown in Kenya. Msc. Thesis, University of Nairobi

Three experiments were conducted in the field to study the effect of fertilizer management on True potato (*Solanum tuberosum*, L.) seed (TPS) production and quality. In the first experiment, the effects of split applications of Nitrogenous fertilizer (112.5 Kg N/ha) on flowering, pollen quality, berry production and TPS quality, were studied. In Experiment II, the effect of time of nitrogenous fertilizer application of a single dose of 112.5 Kg/ha on flowering, pollen quality, berry production and TPS quality, was studied. Experiment III, involved three commercial varieties, Kenya Dhamana, Anett and Kenya Baraka under four levels of the nitrogenous fertilizer (0, 100, 200 and 300 Kg N/ha) and 3 levels (60, 120, 180 Kg/ha) of a phosphate (P_2O_5) fertilizer in factorial combination. The parameters studied in Experiment III were, flowering, pollen viability, berry and tuber yields. In experiment I, additional split applications of N at hilling-up, and at flowering, gave a significantly higher mean flower number, pollen quality and berry yields. The treatments also had the highest mean number of TPS in 1000, in the large seed fraction. Tuber yields improved significantly, when N was split applied at planting and 30 days later at hilling-up. In experiment II, application of N at hilling-up resulted in a significantly higher flower number, pollen viability, berry yields and TPS quality. However, application of the N fertilizer at the onset of flowering (50 days after planting) resulted in a significantly greater number of TPS in 1000, being in the larger seed Fraction (LSF). Both applications of N at hilling up and at flowering (30 and 50 days after planting) resulted in higher total tuber yields, compared to application of N at planting or at berry development (75 days after planting). In experiment III, outstanding varietal differences among the three commercial varieties were noted in almost all parameters studied, except mean tuber yields. Kenya Dhamana had outstanding performance in flowering, pollen quality and Berry production. Anett and Kenya Baraka were not significantly different from one another with regard to these TPS production parameters. Variety and phosphate fertilizer interactions were significant. The general trend across all varieties was a decrease in flower numbers, pollen viability and berry yields. Variety and nitrogen fertilizer interaction was significant across all varieties in pollen viability. The varieties showed a good response in pollen quality with the application of N. The general trend was increased viability at higher levels of N application. Only the factor Nitrogen fertilizer levels showed significance in total tuber yield response. Kenya Dhamana showed highest yields at 300 Kg N/ha, and at 200 Kg N/ha level for Anett and Kenya Baraka. Low levels (i.e. < 180 Kg P_2O_5) combined with high levels of N may be useful in TPS production at Kabete. Considerable seasonal differences resulted in almost a total lack of flowering in the varieties Kenya Baraka and Anett.

Probert M. E. and Okalebo J. R. (1992). Effects of Phosphorus on the Growth and Development of Maize. Kenya ACIAR Proceedings: A search for strategies for sustainable dryland cropping in semi-arid eastern Kenya. Proceedings of a symposium held in Nairobi, Kenya. Vol. 41 pp 55-62.

It is now apparent that phosphorus deficiency is likely to be a limitation to crop growth on much of the croplands of the semi-arid areas of eastern Kenya. An experiment was carried out in eastern Kenya with the main objective of determining the effects of phosphorus on the growth and development of maize. The results showed that large responses can be achieved through correction of gross phosphorus deficiencies in both maize and legume crops. It was especially notable that application of nitrogen alone may give disappointing results. The treatment that received 40 kg/ha of P in the first season gave yields in the following season that were as high as where fresh P had been applied. It was also noted that time to 75% silking was delayed by up to 10 days on plants that had not received phosphorus. Calculation shows that applying the fertilizer to individual planting holes result in the volume of soil fertilized being considerably less than what may be optimum. Use fertilizer P up to 40 kg/ha increased maize yield but any application above that recorded no further yield increase.

Omwoyo D. O. (1991). The effect of Nitrogen rates on yield, quality and nodulation and storage temperatures on water and Ascorbic acid changes in Cowpea (*Vigna unguiculata* (L) Walp). Msc. Thesis, University of Nairobi

Two experiments were conducted between October and December 1988 and repeated between January and May 1989 at the field station, Faculty of Agriculture, Kabete Campus, University of Nairobi, Kenya, to investigate the effect of four nitrogen rates (0, 60, 80 and 100 kg N/ha) on cowpea leaf yield, dry matter, nutritive quality, nitrate accumulation and root nodulation for two varieties of cowpea (Vita-3 and K-80). Leaves from vita-3 variety were used in storage experiments in which water and ascorbic acid changes were studied under room (21±7°C) and refrigeration temperatures (4±1°C). Results showed the application of nitrogen had no significant effect on leaf yield of cowpea plants. Similar responses were observed for leaf dry matter, crude fibre, beta carotene, ascorbic acid and nitrate accumulation. Nitrogen application significantly reduced cowpea root nodule weight, but had no significant effect on average nodule numbers per plant. There were varietal differences in root nodule number. Root nodules per plant were consistently lower for Vita-3 than for K-80. Leaf protein tended to increase with increase in N-rates and it was significant in one experiment, in which leaf protein was 28.6% for cowpea plants had received the highest N-rate. Leaf ether extract content was significantly increased by application of nitrogen. The ash content of the leaves from plants that received nitrogen increased significantly. Slight increases were

observed for K+ and Ca++ at higher nitrogen rates. Most of the trace elements studied did not change significantly with applied nitrogen. Laboratory experiments showed that leaves lost fresh weight significantly both at room and refrigeration storage. Losses were however, less drastic in refrigerated storage relative to room storage. Significant losses in ascorbic acid occurred for cowpea leaves at room temperature storage. When refrigerated, the vitamin however, was not significantly altered.

Wanyoko J. K., Othieno C. O. (1991). Effect of slaked lime on soil chemical properties of highly acidic tea soils from different parts of Kenya. *Proceedings of the 10th Annual General meeting of the Soil Science Society of East Africa*, December, 3rd - 7th 1990, Arusha, Tanzania. Pp 29-35

In a laboratory study, air-dried low pH tea soils from different parts of Kenya were incubated with slaked lime at rates varying from 0 to 0.7% (w/w) at room temperature. Results showed that; soil pH values and soil exchangeable calcium increased with increasing lime rates while both soil exchangeable aluminium and manganese decreased. Soil extractable phosphorus, exchangeable potassium and sodium were not significantly affected by the lime treatment. Large differences in chemical properties between the various soils were observed.

Obiero F. O. (1990). The effect of time of nitrogen application on the growth, yield and nitrogen content of three maize (*Zea mays* L.) varieties. Msc. Thesis, University of Nairobi, Kenya

The study was conducted at the Kabete field station of the University of Nairobi, Kenya over two rainy seasons with the first crop planted in 1989 and the second in early 1990. The objective was to investigate the best time to apply N to maize (*Zea mays* L.) crop. Three maize varieties, Katumani composite B, Embu 511 and Kitale 614 were used as the test varieties. The fertilizer timing treatments were based on the maturity periods of each variety but in general the applications were made at planting, 1/3 and 2/3 the periods to flowering and at flowering. The results showed that the timing of N application was generally insignificant with regard to crop growth, grain yield and quality. However application at 1/3 and 2/3 periods to tasselling was generally superior to application at planting and the control (no N application). All the varieties portrayed a similar response to N application time and in fact there was virtually no interaction between variety and time of N application for all the considered parameters. In spite of all these, the long maturing Kitale 614 was generally superior to the short maturing Embu 511 which was in turn better than Katumani composite B both in terms of growth and grain yield.

Okalebo J. R, Njuho P. M, Gathua K. W. (1990). Effects of form and method of phosphate fertilizer application on maize, sorghum and millet growth in a semi-arid environment of Kenya. I. Effect on maize and Sorghum. *East Africa Agriculture and Forestry Journal* 1990 Vol.55 (4) pp 227-238

In a study to investigate maize and sorghum response to three types of phosphorus fertilizers (DAP, TSP and SSP), uniform crop emergence and rapid growth to maturity resulted mainly from adequate rainfall, evenly distributed over the major development stages (vegetative, flowering/silking and grain filling). At harvest, the crops attained the highest grain yield of 2,970 and 2,250 kg/ha for maize and sorghum respectively. Grain yield levels from banding or broadcasting P were statistically similar for the two cereals, which imply that a farmer may select any one of the methods for fertilizer P application. Phosphate fertilizers (DAP, TSP and SSP) did not give significant grain yield increases, possibly as a result of adequate available P levels in soils on the test site (31 ppm P by Bray No. 2 extraction). Moreover, with sorghum, grain yield reduction from fertilizer applications were observed and the cause of yield depression has to be sought. The differences in performance of three P sources with respect to maize and sorghum production were evident mainly from the vegetative to flowering/silking stages of growth. In this period, rapid uptake of P and subsequent high dry matter yield of tops were observed from the highly soluble DAP. But the use of superphosphate (TSP and SSP) seemed to give higher final grain yield. Further studies are suggested in semi-arid areas (particularly in P deficient soils) to establish the economical levels of P application, suitable forms of phosphate and to identify easier and effective methods of P application.

Emongor V. E., Chweya J. A., Keya S. O., Munavu R. M. (1989). The effect of nitrogen and phosphorus on growth and flower yield of chamomile. *East Africa Agriculture and Forestry Journal* 1989 Vol. 55 (2) 63-67

Chamomile is cultivated for its flowers and essential oil which are used in pharmaceutical, beer and cosmetics industries. The flowers are used to make chamomile tea which helps in digestion and stops pain in the bladder region. The steam from water mixed with chamomile flowers is used to cure sore throat, diptheria, rheumatism, sciation, gout and lumbago. A field experiment was carried out at Kabete Campus field station at the University of Nairobi. The main objectives of the study were to investigate how nitrogen, phosphorus and their interactions would affect the growth, development and flower yield of chamomile, and whether chamomile can grow under Kenyan conditions at an altitude above 1800 m. The study showed that top-dressing chamomile plants with 50 kg N/ha two weeks after planting ensures good vegetative growth, development and high flower yield, and that

chamomile can grow in Kenya at an altitude of 1800 m a.s.l. Top-dressing chamomile plants with 50 kg N/ha two weeks after transplanting resulted in high vegetative growth and flower yield. Phosphorus and the interaction of nitrogen and phosphorus had no significant influence on chamomile growth, development and flower yield. Nitrogen had a significant increase on vegetative growth and flower yield of chamomile plants, and application of 50 kg N/ha gave the best results.

Floor J., Okongo A. O. (1989). Dry bean (*Phaseoulus vulgaris*) Responses to single and triple-superphospahtes in Kenya. *Proceedings of the 6th Annual General meeting of the Soil Science Society of East Africa*, July, 30th - August 1st 1984, Nyeri, Kenya. Pp 152-157

During the short rains 1980/81 and the Long Rains 1981, the Grain Legume Project carried out experiments on dry beans (*Phaseoulus vulgaris*) at five Agricultural Research Stations in Kenya. In these experiments the S-containing P-fertilizer Single-superphosphate was tested against the none-S-containing P-fertilizer Triple-superphosphate. The results show that only in two out of ten cases phosphorus significantly increased yield, and that in none of the cases a significant difference was observed between the two different P-fertilizers. This latter observation leads to the conclusion that, at least when no nitrogen fertilizers are added, sulphur is, under the present cultivation conditions, not a limiting nutrient in bean production in Kenya. Single superphosphate with a market price of about 75% higher per kg P_2O_5 than triple superphospahte cannot be recommended as a good substitute for the latter P-fertilizer for growing dry beans.

Kamindi M., Mose L. (1989). Evaluation of new formulations of glyphosate herbicide for use in reduced tillage. Kenya Agricultural Research Institute (National Agricultural Research Centre, Kitale) Annual Report, Pp 73-77, 1989

To determine the efficacy of new formulations of glyphosate, namely: Mon 8751 and Mon 14477. Sometimes weeds start growing before a farmer plants because he has to wait for a planter which are in short supply. To eliminate such weeds a farmer can either harrow the field or spray Gramoxone to kill the weeds then plant. Wince tractors are in short supply; he would end up planting very late if he had to harrow. Monsanto have developed new formulations of Glyphosato which are cheaper than Round up and can compete with Gramoxons which is a health hazard. The aim of this experiment was to assess the efficacy of these products and determine the rates at which they can be used.

Lusweti C. N., Chike J. E., Kamau J. N. and Cheruiyot D. T. (1989). Pasture research, fodder/forage agronomy: effect of fertilizer application on the yield and quality of sweet potato vines and tubers. Kenya Agricultural Research Institute, Kitale. Annual Report, Pp 84-85

The trial was established at the National Agricultural Research Centre Kitale at the end of March 1989. The major objective of the trial was to determine the effects of application of phosphorus and Nitrogen fertilizer on vine and tuber production by sweet potato cv. Husinyamu. There were 16 treatments replicated three times in 42 factorial using a completely randomized block design. Conventional tillage practice were used in preparing the seed bed. Cuttings for planting were cut 40 cm long and were spaced 90 cm inter-row and 30 cm intra-row. The phosphorus was placed next to the vine cuttings at planting time. Nitrogen was applied in two splits: at two and four months after planting. The Nitrogen was applied as a ring around the vines. The vines plus the tubers were harvested after 8 months from the date of planting. The parameters estimated were: Dry matter production and crude protein of the vines and tubers. Application of both nitrogen and phosphorus had no significant ($P<0.05$) on dry matter yield of sweet potato vines. Application of phosphorus alone significantly reduced dry matter yield of tubers.

Mwakha E. (1989). A comparison of moribund tea rehabilitation methods under different fertilizers. *East Africa Agriculture and Forestry Journal* . Vol. 54 (4) 207-214

It is imperative that the methods of rehabilitating moribund tea that are suitable under Kenyan conditions should be identified before recommendations can be made. A experiment was initiated to compare various moribund tea rehabilitation methods and their responses to different types of fertilizers. This paper provides the results obtained during five years of evaluation in African Highlands Produce Company at Dimbolil Estate. Yields obtained from trial on three methods of rehabilitating old seedling tea bushes showed that medium pruned (with or without infilling the gaps) seedling tea bushes responded poorly to the fertilizers and their yields had stagnated at around 1200 kg made tea per year. Rejuvenation pruning and interplanting with clone 31/8 cumulatively equalled the yield from medium pruning. Uprooting and immediate replanting with clone 31/8 produced only about half of the cumulative yield of medium pruned old tea. But both rehabilitation methods responded significantly to the fertilizer enriched manure during the fourth and fifth years. There was no yield advantage in applying enriched manure instead of inorganic fertilizer but the former was less soil acidifying than the latter. It was found that the crop loss due to the drastic rehabilitation methods to rejuvenation pruning or uprooting and replanting was not recovered within the first five years.

Odhiambo J. J.O (1989). The effects of nitrogen fertilization on maize (*Zea mays*. L. Katumani composite b. performance and nitrogen mineralization in Kabete nitisols. Msc. Thesis, University of Nairobi

The experiment on the effects of N fertilization on maize (*Zea mays*) L. Katumani composite B) performance was conducted at the faculty of Agriculture field station, Kabete for two seasons during the short rains of 1987/1988 and long rains of 1988. N rates of 0, 50, 100, 200 and 400 kg/ha was applied as Calcium Ammonium Nitrate (C.A.N). Available N at three depths (0-15, 15-30 and 30-60 cm) and total N in plant at different stages of growth were monitored throughout the two seasons. In addition, incubation studies to determine potential N release in soil were conducted in the laboratory for a period of 16 weeks. N fertilizer increased grain and dry matter yields in both seasons but with significance in grain yield only during the long raings. Percentage total N in grain was slightly low during the short rains (1.82-2.07) as compared to the long rains (1.58-2.12). N content in the plant declined from seedling to cobbing. Negative correlations were found between maize grain yield and leaf total N at different stages of plant growth during the short rains (r=0.07 to 0.05. Available N accumulated in surface soils during the short rains but declined progressively to very low levels during the long rains. Low correlations coefficients between N content in plant at different stages and available N in soil at different depths were recorded during the two seasons (r=-0.90 to 0.09). Ammonification processes were relatively higher at the top horizon compared to sub-surface horizons. Contribution of the 0-15 cm layer to the net mineral N in the 0-60 cm layer was 50%. The soil had a high nitrate supplying power, lying between 86-98% of the mineralized N. The results indicate a constituency in the amounts and profile distribution of the mineralized fraction.

Okalebo J. R., Keter J. K. A., Ssali H. (1989). Response of sorghum to fertilizer nitrogen and phosphorus in semi-arid areas of Machakos and Kitui districts Kenya. *East Africa Agriculture and Forestry Journal* . 54(3) 131-145

Cultivated sorghum (*Sorghum bicolor* L. (Moench)) is an important cereal for human and animal food. Its stalks are used as construction material and fuel in many countries. On the world production scene, sorghum ranks fifth after wheat, rice, maize and barley. More than 55% of the production is in the semi-arid tropics with Africa and Asia being the major producers. Field trials were carried out in 1979/80 at one site to study sorghum responses to direct and residual phosphate fertilizer application and in 1981 to investigate direct nitrogen (N) and phosphorus (P) fertilizer responses in three sites (Machakos and Kitui districts) of marginal rainfall. Yields of grain varied with site and season, but the lowest was 950 kg/ha, whereas the highest was 4200 kg/ha. Although N and P applications generally improved sorghum yields, a significant grain yield increase was obtained at Ithookwe sub-station, where 60 kg N/ha and 40 kg P/ha fertilizer combination gave a grain yield increase of 1700 kg/ha (79%) over the control treatment. This site was characterized by low levels of N and P in soils and high rainfall at the beginning of cropping season. Variability in major nutrient levels in soils within experimental plots were likely influenced N and P responses, particularly in two other sites with adequate high rainfall. Consecutive cropping of sorghum on the same piece of land resulted in yield reductions, possibly due to the decline in soil fertility. At harvest, sorghum accumulated up to 75 kg N/ha and 9.6 kg P/ha in grain and stock yielding 6 to 7 tons/ha in one growing season. N and P accumulation in these two sorghum components also varied with season and site. More work is suggested in the studies of N and P fertilizer responses, with attention to factors such as site selection, mineral N measurement and sorghum variety.

Ondieki B. O., Ngugi S. M and Mwania N.M. (1989) Fertilizer combination and soil pH Experiment. Kenya Agricultural Research Institute, Kitale. Annual Report, Pp 59-61, 1989

The experiment was in its third year, the objective still being to determine the effect of different fertilizer combinations and use of N- acidifying fertilizer on soil PH changes to occur as to affect crop (maize) production. This was to redress the problem of soil acidification reported to occur when certain fertilizers or fertilizer combinations are continuously used for a long time in some parts of Kitale mandated region. There was no significant interaction effect of phosphorus and nitrogen fertilizer combinations on maize grain yield. Di-ammonium phosphate (DAP) fertilizer had a significantly higher maize yield than Triple super phosphate, presumably due to the presence of nitrogen in DAP. Changes in pH were not significantly difference as a result of use of any fertilizer.

Kamindi M., Onyango R. and Mose L (1989) Evaluation of Herbicides for maize/bean. Kenya Agricultural Research Institute (National Agricultural Research Centre, Kitale), Annual report Pp. 71-72

Late and inadequate weed control results in significant yield reduction in maize/bean intercrops. The objective of this trial was to assess the effectiveness of different herbicides as compared to hand weeding. The effective herbicides would be recommended to farmers and will go a long way to casing the labour constraints which cause late and sometimes inadequate weeding in intercrops. All the herbicides were superior to the control (non-weeded). Panter at 6 litres/ha was phytotoxic to beans and this depressed the yield. All the herbicides evaluated except Panter could be used instead of hand weeding without affecting the quality of weed control and with non-reduction in yield of both crops. The best choice however would be the least expensive.

Achieng J., Mwania N. and Kiiya W. (1989) Evaluation of bean cultivars for suitability in intercropping with maize. Kenya Agricultural Research Institute (National Agricultural Research Centre, Kitale). Annual report. Pp 62-64

Maize-bean intercropping is a common practice by small-holder farmers. Those who interplant recommended maize varieties with a wide range of bean cultivars and have expressed differing views about the performance and other characteristics of these bean varieties when intercropped in different AEZs. the objective of this trial was to determine the growth, disease/pest resistance and yield of various improved bean varieties as compared to local (farmers') cultivars when sole-cropped or intercropped with maize in different AEZS. Intercropping depressed yields of all bean varieties, generally equally in both sites. There was no significant bean variety x location interaction. Bean variety GLP 24 had the lowest yield in both sites which was attributed to uneven maturity and tendency to rot easily. Although GLP92 performed quite well when intercropped with H613 at Sinoko it exhibited uneven flowering and maturity and tended to rot in the field. TMB 31 had a high lodging and rotting tendency compared to its improved version TMB 22. In terms of combined growth and yield performance and low incidence of rotting GLP2 and TMB 22 were rated best.

Karachi M.K. (1988). Effect of nitrogen, phosphorus, and potassium on growth and composition of natural pastures in Western Kenya. *East Africa Agriculture and Forestry Research Organization (E. A. A. F. R. O.)* Journal. Vol. LIII Pp 4

Fertilizer use on natural grasslands in Kenya is limited although these grasslands provide the bulk of the herbage for animal production. In their unimproved and unfertilized state, the grasslands' annual dry matter (DM) yields may be less than 1000kg/ha and the crude protein content less than 7% in the DM for much of the year. Thus severe restrictions are placed on livestock production particularly during the dry season. Limited studies have been conducted to examine the fertilizer requirement for improvement of forage quality and quantity from these grasslands. Earlier work with established leys demonstrated increases in DM production in response to application of nitrogen and phosphorus. The responses were attributed to increases in productivity of high fertility pasture species such as Rhodes grass (*Chloris gayana*) and Kikuyu grass (*Pennisetum clandestinum*). On Hyparrhenia-dominated grasslands. There was limited response to potash. Because of the importance of this grassland to livestock production and the lack of sufficient data on its response to improved fertility, studies to investigate the influence of N, P and K on DM yield, pasture quality, and botanical composition were initiated.

Karachi M. K. (1988). Effect of nitrogen, phosphorous, and potassium on growth and composition of natural pastures in Western Kenya. *East African Agricultural and Forestry Journal* pp.53

In the two field experiments, the fertilizer responses of natural pasture growing in a granitic soil were assessed. In experiment 1, the factors examined were nitrogen (N), phosphorous (P), potassium (K), and nutrient combination NP, NK, and NPK. In experiment 2, the effect of 4 rates of N varying from 0 to 84 kg/ha were studied. All fertilizers increased DM yield and modified the botanic composition. Yields were however depressed in the P*K treatment. The persistence of Eragrostis superba was poor in both experiments. Nitrogen fertilizer increased the N content of tops, whereas P and K had no effect on mineral contents of tops. It is concluded that the content in plant tissue maybe a poor indicator of soil P and K status. The recovery of applied fertilizer and the increase in residual soil nutrients suggest that response to residual nutrients may be expected.

Okalebo J. R. (1987) A study of the effect of phosphate fertilizers on maize and sorghum production in some east African soils. PhD. Thesis, University of Nairobi

Laboratory, pot and field experiments were carried out from 1975 to 1982 to study the responses of maize (*Zea mays* L.) and sorghum (*bicolor* L. Moench) to phosphate fertilizer applications in 19 sites in Kenya and Uganda. The locations varied widely in altitude, climate and soil properties. The surface soils (0 to 20cm depth) sampled from the high altitude and cooler areas, namely, Muguga and Kakamega (Nitisols), and Kitale (Ferralsols) gave higher levels of total nitrogen, organic carbon and clay, compared with soils from Machakos and Kitui areas predominantly Luvisols). These lattera areas are semi-arid and are of lower altitude and warmer climate. Total phosphorus in 19 surface soils ranged from 37 to 1213 ppm P; organic phosphorus was from 6 to 452 ppm P and accounted for about 69% of total P in all the 19 soils. Variations in P status seemed to be related to the soil parent materials in that soils derived from the undifferentiated metamorphic rocks contained higher levels of total and available P. Phosphate sorption by surface soils was highest in nitisols, which had a high clay content and lowest in luvisols. Pot tests, using rhodes grass (*Chloris gayana*) as a test crop,, showed widespread phosphorus deficiency. Thus, phosphate applied at 60kgP/ha significantly increased the dry matter yields and uptake of P by grass in almost all soils used for tests. Grass cropping in pots for 19 weeks resulted in a faster decline in yields in soils taken from semi arid locations, compared with soils from high altitude areas. Responses to P were obtained in soils where relative percentage yields

mainly of grass were below 80%. Cumulative yields of grass on control treatment from three consecutive harvests were negatively and not significantly correlated with procedures used to estimate available P in 15 soils used for pot tests. But in the 8 soils with higher organic matter content (taken from high altitude and cooler locations). Cumulative yields of grass were significantly related to Egner -Riehm (ammonium lactate+acetic acid; r= 0.90), Mehlich (0.1 NHCl+0.025 NH_2SO_4; r=0.84), Truog (0.002 NH2SO4; R=0.73 and Olsen (0.5M $NaHCO_3$; r=0.69) levels of available P. However, cumulative yields of grass from 7 soils with lower organic matter content were not significantly correlated with available P levels using Egner _Riehm (r+-0.51), Mehlich (r=-0.50), Truog (r=-0.42) and Olsen (r=-0.42) methods of P extraction. In all field trials, the growth of maize and sorghum was favoured by the side band application of 70 kg N/ha plus 80kg P/ha (placed 7cm to the side and 10cm below the seed, or in soil ridges at planting time. But patchy seedling emergence occurred when N and P were applied (in side bands) above these two rates. Combined N and P fertilizer applications, from 30 to 106 kg N/ha and from 13 to 130 kg P/ha, significantly increased the dry matter and phosphorus uptake of maize and sorghum tops during the vegetative stage of growth in nearly all locations. In addition, yields of maize grain and stover and sorghum grain and stalk, were increased by N and P applications; but the increases varied depending on the length of the growing season and hence the cultivars used. Thus, in the high altitude and high rainfall locations, 39 kg P/ha plus 60 kg N/ha gave significant maize grain yield increases (above control treatments) reaching 4162kg/ha (at Kitale Research Station 1975); whereas 40 kgP/ha plus 60 kg N/ha produced a grain yield increase of 1360 kg/ha (at Ithookwe Sub-location 1981) in the low altitude and marginal rainfall areas. With regard to sorghum, 40 kg P/ha plus 106 kg N/ha gave a significant grain yield increase of 2533 kg/ha in the high rainfall Severe Research Station in 1976; while 40 kg P/ha plus 60 kg N/ha gave a grain yield increase of 1692 kg/ha at Ithookwe Sub-location. Marginal analysis on maize grain yield data of 1977 showed that a farmer obtained cash profits from diammonium phosphate or triple superphosphate applications at 20 kgP/ha plus 100 kgN/ha. But net returns decrease with subsequent P increments. Hence higher P rates would be useful in soils where residual P effects are important (such as the nitisols)However, in view of wide variations in N and P fertilizer recommendations in East Africa, further studies are suggested to investigate the residual value of P and to establish economic levels in different ecological zones within the region. Maize and sorghum grain yields were significantly correlated with yields of tops obtained at the vegetative stage of growth, particularly in locations with large responses. Grain yields were also significantly associated with organic matter (total N and organic C) contents of soils, but not significantly correlated with available P extracted in soils using 8 procedures. Rainfall and its distribution and inherent soil fertility probably influenced the correlations. Thus, the correlation coefficient between grain yields of maize and Olsen P levels in soils were improved when data from locations with low rainfall and high soil P status were eliminated in correlation analysis.

Ssebuliba J. M. (1987). The effect of intercropping and nitrogen fertility levels on growth and yield of beans (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.) under semi-arid conditions in Kenya. Msc. Thesis, University of Nairobi, Kenya

Three bean cultivars (CVs) Mwezi Moja (NB 518), Small Rosecoco (NB 1122), and Canadian Wonder (NB 26) were planted in pure stands and in association with maize at varying N levels. In a split-plot design with 3 replications, nitrogen levels 0, 25, 75 and 225 kg N/ha formed the main plots. Maize, the 3 bean CVs in pure stands and in association with maize formed the subplots. Maize was seeded at (105*30am) and beans at (45cm*10 cm). Plants were sampled weekly during the growing season to determine the growth parameters, dry weight and leaf area (LA). Morphological components of growth measured were LAI, specific leaf weigh (SLW), leaf area to leaf weight ratio (LAWR), leaf weigh ratio (LWR), leaf area ratio (LAR), number of branches, number of nodules and plant length. At the time of anthesis for maize and flowering/pod set-ting for beans, the %N in bean leaf petioles and maize midribs was determined. At the end of the vegetative cycle the number of pods per plant, seeds per pod, cob size, seed size, yield/ha and harvest index (HI) were also measured. Land equivalent ratios (LER) were computed using dry weights of bean and maize grain yields. Bean plant weights were not affected by intercropping or nitrogen levels in early stages of growth, but maize plant weights taken at maturity were significantly reduced by intercropping. The majority of morphological components of both beans and maize were not affected by the competition from intercropping, and varying N levels. Nitrogen concentration (%N) in bean leaf petioles and maize mid ribs increased with increasing N rates, but were not influenced by intercropping. Maize yields were not significantly affected by bean CV or N levels, but they were significantly reduced by introduction of beans. Cob weight was the most important yield components influenced by intercropping. Bean yields improved as N rates increased with the peak tending to be reached at 75kg N/ha, but they were lowered by intercropping. Number of pods per plant was the most important yield component influenced by intercropping. Nitrogen levels influenced both number of pods per plant and seed size. The yield of the 3 bean CVS and maize were influenced by season. There were positive correlations between bean yield and stem dry weight, leaf dry weight, LA, LWR, LAR, LAI, Number of branches, plant height, TDW, Number of pods per plant, seeds per pod, seed size and HI. Positive correlations were found between maize yields and stalk dry weight, Leaf dry weight, LA, SLW, LAI, plant height and HI. Intercropping permitted a more efficient use of land. Highest LERs were produced when maize and beans were planted at 0 kg N/ha during the March rains.

Esilaba A. O.,Okalebo J. R., Karanja N. K., Gathua K. W., Mugane S.N., Ingavo A.K., Wachira F. M. (1983). Sulphur fertilization in medium potential regions of Kenya. Annual Report, 1983 pp 51

Sulphur is an essential component in both plant and animal nutrition; its deficiencies in soils are associated with crop yield and protein quality reductions (Zake, 1972). Some third world countries, such as India, Indonensia, Nigeria and Zambia have recognised and incorporated sulphur fertiliser practices within their agicultural programmes but in Kenya, there has been an emphasis on the use of Nitrogen and phosphate fertilisers. Sulphur deficiencies are likely to occur in our soils, particularly from the continuous applications of high analysis N and P fertilizers, such as the ammonium phosphates and triple superphosphates, which contain amounts of sulphur. In the period 1974-1980, the ODA/KARI Sulphur Project under Mr.A R.Bromfield, carried out research on the sulphur status of Kenya soils. They paid particular attention on the sources of sulphur (both atmospheric and fertilizers) and the effects of sulphur additions on grain legume production. But most of their studies were concentrated on thru high agricultural potential areas. It was therefore appropriate to pursue work on sulphur status under semi-arid conditions. An explanatory trial was therefore initiated by Mr. A. O Esilaba (prior to his departure for training in USA) in October, 1982 to March 1983 at Ithookwe sub-station, Kitui, to determine maize, beans and groundnut responses to sulphur fertilizer applications.

Mwania N. M. M. (1983). The influence of Nitrogen and Phosphate fertilizer levels on growth, development and yield of potatoes (*Solanum tubersum* L). Msc. Thesis, University of Nairobi

This thesis is subject of work conducted during 1980 short rains and 1981 long rains to investigate the influence of nitrogen and phosphate fertiliser rates and their interaction on growth, development and yield of potatoes under Kabete conditions with a view to evaluating the validity of current fertiliser recommendations. A completely randomised block 32×2 factorial experiment was laid in three replicates with three rates of nitrogen: 0, 75, 150 kg N/ha; three phosphate rates: 0, 100, 200 kg P_20_5/ha (0, 44, 88 kg P/ha), and two potato varieties: Annett (early maturity, 3-3.5 months) and B53(medium maturity, 3.5-4 months). Plants were grown under field conditions and sampled at intervals of two weeks from the time of emergence to maturity and various growth parameters and yield components assessed. Results showed that provided tubers were adequately sprouted and environmental conditions favourable, application of moderate and proportionate rates of nitrogen and phosphate fertilisers would promote crop emergence, growth and early tuber formation. Both nutrients enhanced tuber bulking rates during the early stage of growth (up to eight weeks after emergence) but phosphate tended to lower bulking rates towards maturity. Nitrogen was found to have a beneficial effect of enhancing both leaf area index and leaf area duration and increasing both tuber number per hill and size. Moderate phosphate application increased both tuber number per hill and size, but the highest phosphate rate caused premature senescence of plants and tended to reduce the number of tubers per hill. The number of stems per hill was mainly a varietal character and was determined by the initial degree of sprouting rather than the application of fertiliser. During both short and long rains, the recommended phosphate rate of 200 kg P_20_5/ha (88 kg P/ha) was found to be in excess of optimal requirement. During the long rains the recommended nitrogen rate of 75 kg N/ha was optimal, but during the short rains, heavier nitrogen application produced statistically higher yield in the early variety only, than did the recommended rate. Uptake of the greater proportion of the total nitrogen and phosphorous taken up was found to occur early in the growing season, up to four weeks after emergence. Uptake of nitrogen and its accumulation in tubers was enhanced by phosphate application, while that of phosphorous was decreased by nitrogen application. The levels of these nutrients taken up varied with the season. From these results it was concluded that both nitrogen and phosphate fertilisers need be applied at the time of planting as late applied fertiliser may not be beneficially utilized since uptake of these nutrients takes place early in the growing season. The recommended nitrogen rate of 75 kg N/ha was found optimal for Kabete but that of phosphate of 200 kg P_20_5/ha (88 kg P/ha) was found to be excessive. However, climate, nutritional and varietal influences appeared to superimposed on each other with respect to potato productivity, so that heavy fertiliser applications particularly phosphate, may be a waste under unfavourable conditions such as drought. Thus, although phosphate is known to promote root growth, thereby increasing water uptake by many plants under a drought environment, its negative effect of promoting plant senescence and producing few and small tubers, particularly when nitrogen level is low, tends to annul this benefit. Similar experiments with more closely-spaced fertiliser rates and a wider range of potato varieties are therefore, recommended to ascertain the consistency of the results of this experiment under different locations.

Okalebo J.R., Gathua K.W., Ingavo A.K. and Wachira F.M. (1983). Soil fertility and Plant nutrition (Pot tests in the study of Phosphate Responses). Technical Report 1983

Pot tests provide fast and cheap means of diagnosis related to plant nutrient responses and deficiencies in soils. Therefore, responses to phosphorus fertilizer additions were studied in pots in the greenhouse in 1983, using surface (0-20cm) soils obtained in sites where maize and sorghum phosphate fertilizer field trials were undertaken (EAAFRO/KARI) Record of Research, Annual Reports, and 1975-1982). These pot tests were also used to investigate the release patterns of phosphorus in the test oils, under greenhouse conditions, from the measurements of dry matter and subsequent P accumulation by Rhodes grass (*Chloris gayana*). This type of grass (Rhodes grass) was

selected because of its regularity in growth, its extensive rooting system, necessary to exploit nutrients from soil, and the small size of its seed, having only very negligible amounts of P additions to soils. In addition, Rhodes grass has a practical value associated with pasture improvement (Naveh and Anderson, 1966; Pasture Agronomist at Kitale N.A.R.S.' personal communication in 1981).

Kiriro F.H (1981). The effect of varieties spacing and fertilizers on the performance of ground nuts (*Arachis hypogaea* L) in Kakamega District western province Kenya. Msc. Thesis

University of Nairobi.

Work is reported in the growing of ground nuts at the western agricultural research station Kakamega district western province of Kenya. The work was done from October 1979 to October 1980 covering two seasons:- the short rains of 1979 and the long rains of 1980.The objective of the experiment was to check the effects of varieties spacing and fertilizers on the performance of groundnuts, (*Arachis hypogaea* L) The varieties used during the short rains 1979 were Red Valencia, Serere 116, Mani pintar, Makulu red, Texas peanut, Bukene and Homabay. There was no discernible treatment effects due to drought and birds damage towards the maturity of the crop. The varieties used for the long rains 1980 were Red Valencia, Serere 116, Mani pintar, Makulu red Texas peanut Bukene, Homabay and Altika and the best yielders were Mani pintar and Makulu red. Valencia types, Spanish types and Virginia types did not show any significant differences in yield. All the varieties yielded better than Altika. The inter row spacing used were 6 cm by 10 cm: 12 cm and 14 cm with cultivars Red Valencia, Serere 116 and Bukene. The inter row spacing was maintained at 45 cm. It was observed that the interow spacing of 6cm spacing was better than all the other inter row spacings of 10 cm was also better than that of 14 cm cultivator red Valencia cut yielded bukene and serere 116. There was no significant interaction effect. In the fertilizer experiments commercial products of gypsum (Ca SO_4 $2H_2O$ and triple super phosphate were used at rates of 0-200, 400, and 600 kg/ha. During the short rains of 1979 only Red Valencia was used. However there was drought and birds damage and there was no treatment effects observer. During the long rains of 1980 Red Valencia and homabay were used. Red Valencia out yielded Homabay significantly but there was no significant fertilizers effects. The interaction effects were also not significant.

Sigunga D. O. (1981). Fertilizer and varietal effects on growth and yield of potato (solanum tuberosum l.) under medium altitude tropical conditions. Msc. Thesis, University of Nairobi

Potato (*Solanum tuberosum* L,) production in Kenya still restricted to the highlands, and yet its consumption has spread to almost all over the country including medium and low altitude areas. An attempt was made to introduce potato growing in medium altitude areas. The experimental site, Bukura Institute of Agriculture is located at 0° 13′ N and 34° 37′ E and is 1463M above sea level. Two experiments were conducted during the short rains of 1979 and the long rains of 1980 to investigate the production potential as well as fertilizer requirement of the potatoes under Bukura conditions. Three potato varieties namely Annett, Roslin Eburu (B53) and Kenya Baraka representing early, medium-late and late maturing commercial cultivators in Kenya were used. Five levels of diamonium phosphate were applied at equally spaced intervals starting from 0 to 600 kg/ha. The 15 treatment combinations were randomly distributed in each of the three replicates. The plants were sampled fortnightly for analysis starting from three weeks after the beginning of emergence. In terms of tuber yields Anett significantly out yielded both B53 and Kenya Baraka during the short rains. The difference between B53 and Kenya Baraka was not significant. However, the performance of the crop during this season was poor mainly due to low rainfall. During the long rainy season Kenya Baraka was significantly the best yielder. Annet also significantly out yielded B53 in this season as well. The fertilizer level, 300 kg/ha, gave rise to significantly the highest tuber yield during the short rains, while the level, 450 kg/ha, resulted in significantly the highest yield during the long rains. The tuber dry matter percent of the total fresh tuber yield was not responsive to the fertilizer treatments in experiment 2, but showed slights light decrease with increasing fertilizer levels in experiment 1. The performance of crop in terms of leaf area developed, total and ware tuber yields was far better in experiment 2 than in experiment 1. The interaction between variety and fertilizer in both experiments was not significant. This was thought to be so because the fertilizer was applied once at the time of planting thus providing no advantage for the late maturing variety, Kenya Baraka, to significantly benefit over the early maturing variety, Annett. The results of these experiments showed that potato production can be extended to medium altitude tropical areas provided water and fertilizer supplies are adequate.

Bromfield A. R., Hancock I. R. and Debenham D.F. (1980). The deposition of sulphur in rainwater in Central Kenya. Technical Report volume 3375

The deposition of S in rainwater was measured at ten locations in Central Kenya, monthly for 1 year (1977-80). Amounts deposited ranged from 1.58 to 3.81 (mean 2.47) kg S/ha. Concentrations ranged from 0.10 to 0.17 (mean 0.12) mg S/1 rainwater. The washout factor (w) was 200 and the vertical deposition velocity (Vg) for dry deposition was 0.31cm/sec. Two locations were affected by local anthropogenic emissions. The agricultural significance of these results is briefly discussed

Bromfield A.R., Hancock I. R. and Debenham D. F. (1980). The effects of elemental-S and gypsum on yield, uptake and apparent and true recovery of sulphur by beans (*Phaseolus vulgaris*) and maize *Zea mays*_grown in Western Kenya. Ministry of Agriculture; Agricultural Research Division; Agriculture Research Department, Muguga. Technical Report volume 3375

Maize and beans grown at eight sites in Western Kenya were given 20 kg/ha radioactive elemental-S and gypsum as S sources. Bean yields were not affected by the sources except at one site where gypsum depressed yield. Maize grain yield was increased by elemental -S at one site and stover increased by both sources at a second. At a third site and stover increased by both sources at a second. At a third site both sources reduced stover yield. At maize thinning every plant sampled was radio-active and true recovery from gypsum was superior to that from elemental-S. At final harvest five of the eight maize crops and all the bean crops for both harvests contained more S from gypsum than from elemental -S. True recovery of S-ranged from 0.2 to 2.8 for maize and 0.08 to 2.1 kg S/ha for beans. Apparent recoveries ranged from 2.2 to 8.1 for maize and 0.08 to 2.2 kg S/ha for beans. After allowance for atmospheric-S but not leaching losses the S deficit for maize given no fertilizer-S was 9-12kg S/ha annually at the best sites.

Bromfield A. R., Hancock I. R. and Debenham D. F. (1980) Effects of ground rock phosphate and elemental Sulphur on yield and P uptake of maize in Western Kenya.

Ministry of Agriculture; Agriculture Research Department, Muguga. Technical Report volume 3375

The effects on maize yields of ground rock phosphate, alone or mixed with sulphur in either of two proportions, and of single-superphosphate, was measured at five consecutive harvests. At the first harvest single-superphosphate increased yield by 1.54 t/ha and the best of the mixtures by 0.56 t/ha. Ground rock phosphate alone had no effect on yield. At the third harvest there were no yield differences between sources, because yields produced by rock phosphate and the mixtures improved. The cumulative increase in yield produced by single-superphosphate was 3.58 t/ha and by rock phosphate 2.69 t/ha, but because the fertiliser cost ratio was 3:1, additional grain produced by rock phosphate cost half as much. The apparent P recovery ranged from 5.40 to 8.28 kg/ha and was mostly from single-superphosphate and least for the mixture containing most elemental -S.

Bromfield A. R., Hancock I. R., Debenhum D. F., Mugane P. G., Kahumbe R. J. and Wachira F.M. 1980 Sulphur Project. Kenya Agricultural Research Institute. Record of research Annual report 1977-1980.

Trials to test the efficiency of different P sources on groundnuts laid down in 1977 were continued in 1978 to measure the residual effects. Of these trials three gave residual responses, one gave a total dry matter response to all P sources, one to the two rock-S treatments only one a haulm response to all P sources except the Rock-S mixture having one-half the sulphur content of single-superphosphate. Where residual responses were obtained single-superphosphate was not superior to Rock-S mixtures but both sources were superior to ground rock phosphate alone. This indicates an increased solubilisation of ground rock phosphate by addition of element-S. A series of five trials with maize and beans (*Phaseolus vulgaris*) respectively were planted South of Mount Kenya between Embu and Nyeri. He design and treatments were similar to the groundnut trials. Responses were obtained at two sites- Kagumo and Kerugoya. At Wambugu and Embu two NPS factorial trials indicated that for maize P was the primary limiting nutrient closely followed by N. No response to S was obtained. The monthly sampling of rainwater at the rainwater at the eleven sites in Central Kenya was completed in February at the end of one year's measurements. The amount of S deposited adjusted to the 26 year rainfall average, ranged from 1 t0 2.3 mean, 1.5 kg/ha annually. The results are being prepared for publication. The monitoring of sulphur dioxide in air continued at Muguga. No clear seasonal pattern has emerged but amounts are usually less than 1*10^-6 g S/m^3. One year's result from the four sites viz. Muguga, Kericho, Kimakia and Thika show that from 0.7 to 1.2 kg S are deposited annually by this mechanism. Routine analysis of plant samples for N and S and soil samples for C, N and S from the field experiment sites continued. Absorbed plus soluble sulphate and isotherms were completed on all soils sampled. A series of pot trials to study the effectiveness of various rock phosphate elemental sulphur mixtures was started. During the 1979 season the study of residual-P from a phosphate sources trial planted at Siaya was completed. The trial was continued for five harvests, i.e. two in 1977 and two in 1978 and one in 1979. Only basal N was applied to subsequent crops. For all five harvest the P treatments significantly (P=0.01) out yielded the control and there were no differences between ground rock mixtures. Single-superphosphate gave a larger yield in the first harvest only, the same in the next two harvests but significantly less in the fourth. The last harvest was affected by drought but again all P treatments out yielded the control. The cumulative yields for the five harvests were better than the control for all treatments.

Bromfield, A. R., Hancock, I. R., Debenhum, D. F., Mugane, P. G., Kahumbe J. E., Wachira, F. M. and Hinga J. (1980). Soil and Crop Sulphur Research Project. Kenya Agricultural Research Institute Record of research. Annual report 1977-1980

The field programme was continued in Western Kenya where a series of field trials using maize and ground nuts as indicator crops were laid down. The aim of these trials was (a) to test low-cost sulphur/phosphorous fertilizer assemblages and (b) to assess at what point, if any, sulphur becomes limiting while trying to maximise yields under high levels of Nitrogen and phosphorous. Groundnuts: A source of phosphate trial which compared a number of rock phosphate/sulphur mixtures to single superphosphate, straight rock phosphate and a control, were laid down at ten sites stretching from Kakamega to Siaya. All phosphorus treatments had 24.6 kg P/ha. The trial was designed to run for two years so that the residual effects of the fertilizers could be ascertained. No real responses to phosphate were apparent during this first year. However, on a large number of sites excellent yields were achieved, with kernel yields of 2700 kg/ha on a dry weight basis. The total nitrogen and sulphur removal for a crop like this was in the region of 190 kg and 10 kg/ha, respectively. Maize: A source of phosphate trial comparing again similar mixtures of rock phosphate and sulphur to rock phosphate alone and single superphosphate were laid down at seven sites stretching from Siaya through Kakamega to Kitale. All treatments had 50 kg P/ha. Again the trials were to run over a period of two years and initial responses were achieved during 1977 at a large number of sites; this being ore apparent on the poorer sandier soils near Lake Victoria. Also at the same sited, and including Muguga, a series of N P S factorial trials were planted using maize. The idea was to produce a blue-print from which crop responses and nutrient uptake can be related to other factors such as soil status mineralization rates, leaching losses and environmental inputs. In general, however, the number of responses to sulphur fertilization were low, owing (a) to the ability of majority of the soils in Western Kenya to sorbs applied sulphur into the profile/and (b) to the high sulphur status of these fertile soils which are derived from volcanic ash. However, intensive cropping systems and applications of high analysis compound fertilizers with little or no sulphur could change this picture. In contrast six sites responded to the application of phosphorus and four sites to application of nitrogen. A good crop of maize yielding 270 quintals total dry matter/ha can remove 150 kg N, 19 kg p and 12 kg S

Dorrah, L. L., Mukuru, S. Z., Wolfram, S. H., Muthoka, D. K., Ochieng J.A.W. (1980). Maize Genetics: General Technology. Kenya Agricultural Research Institute Record of research Annual report 1977-1980

There were three selection trials in the maize breeding methods study which were grown at the National Agricultural Research Station (NARS, 1860m), Kitale, Sabwani ADC Farm (1860 m), Endebess, Western Agricultural Research Station (WARS, 1580m), Kakamega and Elgon Rock Farm (2100m), Mount Elgon. Western Agricultural Research Station (WARS) was discarded due to army worm damage. Fertilizer were applied at a rate of 80 kg/ha P_2O_5 as triple superphosphate and 160 kg/ha of N topdressing as Urea when plants were 30cm high. Plots were overplanted and thinned to the desired stand before topdressing. Selection trial plots consisted of two rows of nine hills each, with two plants in the end hills and one in between after thinning. Evaluation trials had three rows per plot except the trial involving KCA (E4, E5, M10 and M17) and various spacing. Here a five row plot was used with data being taken on the centre rows. A plot length of 3.6m was used with varying numbers of hills according to the spacing within the row and the end plants in each row were discarded. A row width of 75cm was used in all trials and between plant distance of 30cm was used, except in the spacing trial where distance were 24, 30 and 40 cm. Stalk borer control was obtained by placing a pinch of 5% DDT dust mixed with sand into the leaf whorl at 30cm. Atrazine herbicide was applied post planting at a rate of 2.5 kg 1.1/ha. At the Kitale and Endebess sites, 6 litres/ha of Eradicane 6-E was incorporated pre-planting to control water grass (*Cyperus* sp) and Couch grass (*Digitaria solarium*). Control of grasses and annual weeds was very satisfactory. Data for the selection trials was taken on ears weights with a sampling shelling percent and moisture percent being calculated. Ear weights were converted to shelled grain adjusted to 12.5% moisture using a constant factor for each trial at each site.

Kariuki P.N., Mangale N., Rugui P.M.W., Gathua K.W., Mugane S.N., Kung'u N.K. and Gacao J.K. (1980). Nitrogen Studies under dryland Farming. Record of Research Annual Report 1977-1980.

Studies related to the nitrogen status within semi-arid and arid areas were started towards the end of 1977. A literature survey was made on the work related to this macronutrient in relation to dryland agriculture. The second stage consisted of pot trials in the greenhouse and field to study the fate of the applied N as fertilizer (nitrogen flush). The nitrogen-flush is well-known phenomenon (Birch-effect), but has not been conducted with applied nitrogen phosphate fertilizers (plant and soil, volume 10, 1958/1959. A third aspect of the study incorporated N and P fertilizers additions to isolate the effects of these two major nutrients and to establish economic levels of their additions. Residual effects of the nutrients were also studied, the key measurements being the grain yields. Data on greenhouse pot trials will not be given in this report. The observations made are therefore subject to the completion of statistical studies, laboratory analysis of samples completed and further experimentation. Thus the outline of the N-flush and field trials is presented. The results showed that too much nitrogen decreased grain yield while phosphorus increased yields. Greatest yields were obtained where low levels of Nitrogen and higher levels of phosphorus were applied showing that little nitrogen is required in the these areas for good yields.

Kariuki P.N. (1980) Soil Fertility studies under Marginal Rainfall Forming Nitrogen Studies. Record of research annual report 1977-1980

In the past, little attention has been given to problems related to forming under dryland or marginal rainfall areas. However, from the high population pressures now prevalent in the high potential agricultural areas, it will be necessary to identify and rectify problems associated to dryland farming. In the soil fertility programme nitrogen is one of the mononutrients that has been isolated for studies under marginal rainfall farming. Measurements to be made will include N uptake, fixation, and losses through leaching and immobilization. Specific crops such as maize, sorghum, millets and beans will be used in the studies. Nitrogen fixation will be monitored using the newly acquired gas chromatography technique. Thus nitrogenose reduces acetylene to ethylene.

Okalebo J.R., Welfrom J.H., Ochieng' J.W., Nkonge C.N. and Barasa F. (1980) Nitrogen and phosphate Fertilizer on protein and amino acid contents of maize grain. Record of research annual report 1977-1980

From 1974 to 1977, mono ammonium phosphate diammonium phosphate (DAP) and triple superphosphate (TSP) with urea or calcium ammonium nitrate (CAN) were compared in the field within the areas growing maize extensively. Measurements were made mainly on yields, major nutrient concentrations and uptake and the recoveries of the applied phosphorus from specific maize components. The objectives observations and data are given in the EEAFRO Records of Research 1974 to 1976. The two amino acids lysine and tryptophan, are often detected in small quantities in maize grain. Therefore the nutritional value of protein in maize have been successfully elevated in breeding studies, such as the introduction of Orwue-2 maize. The application of fertilizers, particularly the nitrogen carriers, it also known to increase the protein content of maize and cereals in general (Du-ets, 1961; Kyim et al 1976. Maize grain samples from field trials were therefore analysed at Kitale Quality Laboratory to study the effects of nitrogen and phosphorus fertilizer applications on the protein, lysine and tryptophan contents.

Maize Response to different forms of phosphate fertilizers

Okalebo J.R., Patel P.K., Opolot B.A., Rugui P.M., Mwaura T.D.N., Alose N.O., Michobo W.G. and Ingovo A.K. (1980). Maize response to different forms of phosphate fertilizers. Record of research annual report 1977-1980

In September, 1976 the East African Specialist Committee for soil fertility and Plant Nutrition recommended a cheaper source of phosphorus to be included in the evaluation of phosphate fertilizers for maize production. However, the closure of Kenya/Tanzania border early in 1977 made it impossible to acquire the low cost 'Minjingu' rock phosphate (containing about 30% P_2O_5, soft ore) mined in Tanzania. Therefore, only diammonium phosphate (DAP) and triple superphosphate (TSP) were compared in 1977 field trials. The main objectives were again to assess if phosphorus applications were necessary in the soils chosen and to find the economical quantities of fertilizer phosphors applications, to confirm similarities in effectiveness of the P carriers observed in 1974 and 1975; and to study the effects of the fertilizers on the uptake of macronutrients. Three sites outside agricultural research stations were included because they had not received fertilizer additions. The sites in 1977 were: Kakamega Research Station and Chapman Keree's Farm at Malava. Soils in these two sites are classified as Eutric nitisols, according to the FAO/UNESCO system, 1974. Likhovero Primary School site near Kakamega has its soil classified as Pellic vertisol, whereas soils of Serere Research Station and Kidetek Catholic Mission sites (Soroti, Uganda) are classified as Orthic Ferralsols. Experimental methods have been outlined in the EEAFRO Records of Research 1974-1976. But the rates of phosphorus application were 20, 40 and 60kg/ha for each phosphate carrier and nitrogen to a final level of 100kg/ha was added as calcium ammonium nitrate (CAN). H512 maize was planted in all plots.

Okalebo J.R., Mwaura T.D.N., Kironji C.N., Michobo W.G., Kaiyare J.M., Koimo D.K. and Ingavo A.K (1980). Phosphate fertilizers under marginal rainfall farming. Record of research annual report 1977-1980

High population pressure will encourage substantial migration into the medium and low agricultural potential areas of Kenya receiving total annual rainfall in the range between 500 and 800 mm a year. Low crop yields and unstable production from year to year are prevalent in the marginal rainfall areas. The immediate problem will therefore be the stabilization of food production in the newly settled areas. Main factors associated with semi-arid farming in general are re resource (mainly water) proper utilization and conservation, cropping pattern development and adoption, and practices such as tillage, irrigation, fertilizer uses and farm mechanization. In relation to fertilizers, there is other scanty information based on a few field trials that can be useful to the farmer. For example, Marimi (1975) carried out N and P experiments in eight sites in Machakos, Kitui and Makueni areas. He observed that although responses to those nutrients were not found, maize yields wee superior to those of the peasant farmers. In some areas where rainfall was adequately distributed, he suggested that the maize type used in the trials was probably not responsive to the levels of fertilizers added. On the other hand, Siderius and Muchena (1977) at NAL, Nairobi, report a deficiency of N and P at Katumani Kampi ya Mawe, Makueni and Kitui localities. In the second half of 1978, a project was initiated within the Chemistry Section, to look into the role

of phosphorus fertilizers under semi-arid agriculture. The soils of Kitui and Machakos districts mainly consists of Precambrian rocks of the basement system. Predominant rocks are the biotite gneisses found in Makueni Kambi ya Mawe; gneisses rich in ferromagnesian menrals, prevalent in Kitui and the quartzofeldspatic gneisses at Mahakos-Katumani Research Station. The soils are well-drained, deep in most areas and generally light in texture (sandy clay to sandy clay loam). The soils have been classified under the FAO/UNESCO 1974 system as Acrisaols, Luvisols and Nitosols, depending on the area. The soils in the area have low organic matter contents. Organic carbon content ranges between 0.4 and 2.0% with a mean of 1%. The total nitrogen content has a range of between 0.04 and 0.23%, with a mean of 0.10%. Extractable phosphorus by Bray No. 2 method has a range between 5 and 747 ppm P, with a mean of 81 ppm. The soils were grouped into 3 classes using the analytical data of extractable P by Bray No. 2. method. Thus the group 1 soils test between 0 and 15 ppm P; groups 2 soils have a range from 16 to 40 ppm P and group 3 test above 40 ppm, extractable phosphorus. Most soils indicated adequate levels of the cations K, Ca and Mg. But group 1 soils may require K additions in the form of compound fertilizers or organic manure. There was a close correlation between the 2 methods used for P extraction: Bray No. 2 and the AL methods (r=0.919). The relationship between the 2 proceedures is fitted by the equation $P_{AL}=0.021P_{Bray\ 2}+1.411$. However, Bray No. 2 extraction takes only 5 minutes whereas the AL method takes 1½ hours.

Moshi A.O., Osborne J.F, Flguctredo C.T., Gathua K.W., Mangara J.K. and Mugane S.N. (1980) The zinc status of East African soils with reference to Maize nutrition. Record of research annual report 1977-1980

Two field experiments were planted and harvested in the Kitale areas during 1977. At the National Agricultural Research Station, Kitale, two replicates each with hybrids H512 and H614 were planted and at the S.F.T Sitetunga Farm, Cherengani two replicates with hybrid H614C. The fertilizer treatments were laid out in randomized blocks using a 23 factorial design. The three levels phosphorus (as triple superphosphate) were 0.28 and 56kg P ha of zinc (as zinc sulphate) 0, 4.5 and 9 kg Zn). Overall dressings of nitrogen (CAN) were applied at planting and at knee height, the rate being 32kg N ha for each application. Soil analytical data pre-planting are shown in Fresh and dry yields were obtained for grain, husks and stover for single and three rows per plot. At 35 days from planting, significant effects of phosphorus were recorded in both trials for fresh and dry plant weight concentrations of phosphorus calcium and rations of N/P and K/P in the tissues, with an additional effect on iron and the concentrations of Cherengani. The only effect of zinc in both was to increase concentrations of zinc, and at Cherengani to reduce the concentration of iron. At 66 days from planting the only significant effects at Kitale were recorded for P on content of Zn and for Zn on content Zn and Mg. At Cherengani plant fresh and dry weights showed response to P fertilizer and there were significant effects of P on P, Ca, Zn and Mn contents and of Zn on P and Ca contents in the tissue. Almost no significant effects were recorded for the fertilizer treatment from the leaf index samples. There were no significant effects of P and Zn on Zinc content at Kitale and of P on K and Mn contents at Cherangani. Harvest data recorded no effects of P and Zn in the Kitale trial. There were some differences for parameters between the two hybrids but only husk yield and shelling out percentage were significant. Cob and grain yields in the Cherangani trial showed significant positive responses to application of phosphorus but negative responses to zinc at 9 kg/ha at the first level of P and marked negative responses to zinc in the absence of P.

Ssali H., Keya S. O. (1980). Nitrogen level and cultivar effects on nodulation, dinitrogen fixation and yield of grain legumes: Cowpea cultivars. *East African Kenya Agricultural and Forestry Journal* Vol. 45 (4) pp 247-254

The effects of a low (20 kg N/ha) and a high (100 kg N/ha) doses of N fertilizer on the nodulation, growth and di-nitrogen fixation as measured by the 15N technique of three cowpea (*Vigna unguiculata* (L.) (Walp.) cultivars were investigated in a field study. A high dose of N reduced nodulation on all three cultivars but the extent of the reduction varied with cowpea cultivar. Dry matter yield and tissue N were higher at 100 kg N/ha for the three cultivars. A high dose of N fertilizer severely reduced di-nitrogen fixation by the three cultivars: 50.5 to 73.7 kg N/ha fixed at a low N fertilizer dose, 0.0 to 18.8 kg N/ha fixed at a high dose of fertilizer N. A high dose of N fertilizer increased uptake of non-fertilizer soil nitrogen by the three cowpea cultivars.

Ssali H., Keya S. O. (1980). Phosphorus and cultivar effects on nodulation, growth, nitrogen fixation and yield of cowpea (*Vigna Unguiculata*). East African Agricultural and Forestry Journal Vol.45 (3) pp 188-193

The effect of phosphorus on growth and di-nitrogen fixation (as determined by the 15N technique) of two cowpea (*Vigna unguiculata* (L) Walp.) cultivars was evaluated in a field experiment conducted at Katumani, Kenya. Although applied phosphorus significantly increased dry matter yield and phosphorus uptake by barley which was used as a non-dinitrogen fixing control crop, applied phosphorus had no significant effect on nodulation, dry matter and seed yield, phosphorus uptake and di-nitrogen fixation by the two cowpea cultivars investigated. For both cultivars, application of phosphorus reduced nitrogen fixation. Results indicate that cowpea might be more tolerant to phosphorus stress compared to some other grain legumes.

Mugambi S. M. (1979) Manure and fertiliser requirement of potatoes on acid soils. East African Agricultural and Forestry Journal 1979 Vol. 44 (4) pp 278-284

34 confounded factorial trial was laid down at Gituamba Substation, altitude 2130 m, in the Long Rains 1979 in order to determine manure and fertilizer requirements of potatoes on acid soils. Nitrogen at 50, 100 and 150 kg/ha N as calcium ammonium nitrate, phosphate at 100, 200 and 300 kg/ha P_2O_5 as single superphosphate, potash at 0, 100 and 200 kg/ha K_2O as sulphate of potash and farmyard manure at 0, 5 and 10 t/ha dry matter were applied at planting in the presence of a blanket dressing of 1 t/ha lime in the form of Magmax. In the first season the total yield of potatoes was equivalent to 17.27 t/ha and only manure had significant effect on yield, mean plot yields at 0, 5, and 10 t/ha being equivalent to 13, 20 and 21 t/ha. In the Short Rains, 1979 a residual maize crop which yielded the equivalent of 3.6 t/ha showed significant effects of manure, potash and phosphate in descending order. Potatoes replanted in the Long Rains 1980 with reapplication of all treatments gave a total yield equivalent to 16.22 t/ha. Manure and potash had significant main effects on yield and there was a significant positive KF interaction. The treatments increased available nutrients in the soil and uptake of nutrients by the plants. The results showed that farmyard manure is the best treatment for potatoes grown on acid soils but may be supplemented by mineral fertilizers where insufficient amounts are available.

Okalebo J.R., Wolfram J.H., Ochieng J.A.W. and Nkonge C. (1979). The effects of nitrogen and phosphorus fertilizers on protein, lysine and tryptophan contents of maize. *The soil Science Society of East Africa; The Third Annual General Meeting held at the Kenya Agricultural Research Institute, Muguga* Vol. 3 PP 1-10

The effects of nitrogen and phosphorus fertilizers on protein and tryptophan contents of maize grain were studied in the field in 1975 to 1977 at Kitale, Kakamega and Serere sites. The grain protein content ranged between 5.73 and 9.7 whereas tryptophan content appeared to vary with maize hybrid. The protein concentration of seed was raised at Kitale and Serere, but reduced in Kakamega by fertilizer applications. All fertilizers were equally effective in increasing or decreasing the protein and tryptophan contents of grain. Nitrogen appeared to be the main nutrient contributing to protein increases and tryptophan reductions. Fertilizers continue to be evaluated, incorporating grain lysine contents, climatic and maize varietal factors; Part of the work in Kenya, done by the Agricultural University of Wageningen, the Netherlands, dealt with the role of volcanic ash in the soils of South-Western Kenya, particularly the Kisii -area. The paper discusses the influence of ash on soil characteristics and fertility, the biogenetic and colluvial processes responsible for incorporation of the ashes in the soils and source and age of the ashes.

Okalebo .J.R (1979) Maize Response to Three High Analysis Phosphate fertilizers in Some Soils of East Africa. East Africa Agriculture and Forestry Research Organization Journal 1979 43-No.1

Fertilizers were not used widely in East Africa before 1945 probably because most soils were rich in plant nutrients following forest clearance (Cooke, 1967) and the crop species grown removed only low quantities of nutrients. Fertilizer requirements have increased recently as a result of increased food demands, particularly in the highly populated maize growing areas, where continuous cropping are prevalent. Phosphorus and nitrogen are frequently deficient in East African soils (Robinson, 1953; Mills, 1954; Le Mare, 1959). Phosphate fertilizer experiments carried out in 1947-1951 in East Africa showed that P responses are frequent on the more acid, highly leached red soils and on the basement complex soils such as those in north-east's of Nyanza Province in Kenya (Doughty, 1953). In addition, triple superphospahte significantly out yielded Uganda's Tororo rock phosphate and soda phosphate in cereal grain production, but all three materials had pronounced accumulative effects. This paper summarizes results of a field study in which triple superphosphate with urea or calcium ammonium nitrate, mono and diammonium phosphates were compared in seven high agricultural soils of East Africa. The chemical, physical and their economic aspects associated with their use have been outlined by Terman (1971). Poor germination and seedling damages have been reported with diammonium phosphate and urea (Anderson, 1964/66; "Mehlich Concept", 1964; Allan, 1976). It was therefore important to observe the effects of P carriers on maize germination and emergence, yields, uptake or removal of phosphorus, and to obtain guidelines on the economic uses of three phosphate sources.

Mulamula H. H. A, Oggema, M. W. (1978) The comparative effect of water soluble phosphorus and citrate soluble phosphorus on yield and plant characters of wheat in Kenya. East African Agricultural and Forestry Journal 1978 Vol.43 (3) pp 179-184

The effect of two forms of phosphorus (MCP and DCP) and varying inverse proportions of the two on grain yield and plant characters of wheat cultured under field and greenhouse conditions was determined. MCP was superior to DCP in most parameters studied. But there were no significant differences when a mixture of the two forms was applied. However, DCP tended to encourage the accumulation of nitrogenous products, possibly protein, in the vegetative parts of wheat.

Muriuki S.K. and Barber R.G. (1978) A greenhouse study of the effect of wet-dry cycles on the phosphorus uptake and dry matter yield of three crops. *East African Agricultural and Forestry Journal*. Vol. 44 (2) pp. 119-121

It has been shown that moistening soil following a dry period leads to a release and subsequent increase in the availability of several nutrients especially nitrogen in amounts which are adequate to exert considerable influence on soil fertility (Birch, 1960). Lebedjantzev (1924) showed that millet yields in a soil that had been air-dried and then remoistened were on an average 45% greater than those in a soil that had been air-dried but was otherwise identical, possibly due to the increase in the solubility of nitrogen constituents of the soil. Drying of soil has been shown to lead to a release of organic phosphorus through mineralization; the amount released being directly proportional to the intensity of the drying (Cunningham, 1963). This release of nutrients, especially phosphorus, would be expected to be important in East African soils, where organic phosphorus can account for up to 86% of total phosphorus (Friend and Birch, 1960). Tais investigation was designed to assess the effect of wetting and drying cycles on phosphorus uptake and dry matter yield by three test crops in a greenhouse.

Allan A.Y. (1976). The effect of sulphur on maize yields in Western Kenya. Maize research station National Agricultural Research Station, Kitale, Annual report

Sulphur (S) is one of the essential secondary nutrients required by maize. Olson and Lucas (1966) indicate that it is a vital constituent of the amino acids methionine and cystine, as well as one of the growth regulators thiamine and biotin, which control carbohydrate metabolism. S also apparently affects chloropyl synthesis and root development. Bixby and Beaton (1970) point out that high-yielding maize crops may contain as much as 70 kg/ha of this element. In May 1968, several large-scale maize growers near Kitale in the Trans Nzoia District of W. Kenya reported the occurrence of widespread leaf-yellowing on young maize. Investigations suggested that this was caused by S deficiency, and in fact when S-containing nitrogenous fertilizers were applied, the leaves regained their normal, healthy green colour, whereas the application of nitrogenous fertilizers without S did not have the same beneficial effect. In early July 1968, samples for analysis were taken from a badly affected field on Mr. W.A. Davidson's farm, about 3km south of Kitale. The crop was nine weeks old, and 1-2 m tall Whole plants were taken from both normal and apparently S-deficient areas. The soil Chemistry Section, E.A.A.F.R.O., Nairobi which performed the chemical analyses, prepared the samples in the following standard fashion. The five youngest leaves, excluding the spindle, were taken from each plant; the middle 15cm portion of each leaf was cut out, washed and dried, after removing the midrib, the laminae were ground up. Two analyses for S and N were carried out, the first on the total dry material, and the second on the residue which was left after 41/2 hours Soxhlet extraction with 70 percent ethanol. The results of these analyses are shown in Table 1, with the first analysis annotated A, and the second B.

Joacha E. (1974). Nutrition in Smallholder Systems. Pyrethrum Research Station, Molo, Kenya

***Conference proceedings of the 13th meeting, E.A.S.C on soil fertility and crop nutrition*. Nairobi-9th-13th September, 1974.**

Agronomic research into nutritional requirements of pyrethrum should recognise the nutrient status of the soil on which the crop is grown, the perenniality of the crop, the quantitative aspects of nutrient removal from the soil and other cultural practice which maximise pyrethrum flower yields. Recommendations based on past research findings stipulate the application of 150-200kg per hectare double superphosphate at planting time and the amount is considered adequate to last the three years duration of a pyrethrum crop. Field experimental studies carried out between 1949 and 1970 failed to show pyrethrum giving positive response to nitrogen, potassium and sulphur, (Anon. 1949-1970).

Keya S.O (1974) Summary of research on soil fertility and crop nutrition at the University of Nairobi, Kenya. Conference Proceedings of the 13th Meeting of the East African Specialist Committee For Soil Fertility and Crop Nutrition -9th-13th September, 1974-Nairobi, Kenya. University Of Nairobi 1974

In the soil profiles studied, total occluded (iron oxide and aluminium oxide coated) phosphate was found to contribute predominantly to the downward trend of increase in total phosphorus. The distribution of total phosphorus in coffee plots was found to be related to fertilizer, mulch, and cattle manure applications and also to sampling depths. The application of cattle manure and phosphate considerably increased the total phosphorus content of the soil; mulch and phosphate had a similar effect. The apparent relative increase of total P was found to be greater for 0-15 than 15-30cm. Sampling layers. In the surface layers of the soil profiles and the control plots, the various phosphate fractions increased in the order Ca-PO_4, AL-PO_4, Fe-PO_4,and occluded-PO_4 This distribution tends to measure the degree of chemical weathering of the soil the chemical weathering sequence being in that order. Application of phosphate supervisor and mulch or cattle manure significantly increased the accumulation of calcium phosphate, aluminium phosphate and iron phosphate but did not seem to have any

noticeable effect on the relatively insoluble (occluded) form of phosphate indicating that this form is relatively unimportant in problems of phosphate absorption. The percentage of organic phosphorus in the profile decreased progressively with depth; the decline was attributed to decreasing amounts of organic matter which followed the same trend. Significant correlations were found between available phosphorus determined by the $NaHCO_3$ method of Olsen and inorganic phosphorus fractions. The correlations coefficient between iron phosphate and available phosphorus suggested that iron phosphate was the main contributor of available phosphorus in this soil. The water soluble, KH_2PO_4, applied to some soil samples was mostly fixed as aluminium phosphate. The amounts fixed in this form and also as iron phosphate. The amounts fixed in this form and also as iron phosphate increased from three days to thirty days. The amounts fixed as iron phosphate were about two-thirds of the amounts fixed as aluminium phosphate. Comparatively small amounts of phosphate were fixed as calcium phosphate. The activity of the surface phosphate fractions were found to decrease in the order: iron phosphate, aluminium phosphate the amounts of surface phosphorus of the fractions respectively. The specific activity of aluminium and iron phosphate was surface activity of aluminium and iron phosphate and iron phosphate was higher than that of calcium phosphate. The means of the specific surface activity of aluminium phosphate, iron phosphate an calcium phosphate decreased in that order. In the soils studied,, regardless of pH, aluminium and iron phosphate may be more important sources of available phosphorus than calcium phosphate, owing to the high specific surface activity of the first two, and the much larger amounts of surface phosphorus of the second. Calcium phosphate may not be the main source of available phosphorus, owing to its low specific activity and its low total amount. The percent uptake of 32P by the barley seedlings from each of the soil-P fractions showed that the uptake decreased in the order: iron phosphate, aluminium phosphate and calcium phosphate. The practical significance of these results is that iron phosphate and aluminium phosphate appear to contribute more to plant growth than calcium phosphate in the present study. The work has been completed and written up a M.Sc. thesis and is now under consideration for the award of the degree.

Laylock D. and Allan A.Y. (1974). Maize Agronomy Research For Small-scale Farmers.

Maize Agronomy Research Project, National Agricultural Research Station, Kitale, Kenya.

***Conference Proceedings of The 13th East African Specialist Committee For Soil Fertility And Crop Nutrition*. Nairobi-9th-13th September, 1974.**

Most of Kenya's maize is grown by small scale subsistence farmers. Factors limiting maize production such as husbandry methods and fertilizer use are examined with a view to reducing physical effort and increasing the efficiency for cash inputs. Profitability and cost-benefits of inputs such as fertilizer, weed control and pest control are very dependent on correct timing of operations.

Tveitnes S, Nyaas-Aakerbakken O. (1973) Fertilizer experiments on small cotton farms in Kenya 1968-1971 *East African Agricultural and Forestry Journal* . Vol. 38

During recent years there been an increase in the cotton acreage in Kenya. This is due partly to an extension of the cotton growing area, and partly to improved husbandry techniques. To date fertilizers are not commonly used by cotton farmers in Kenya, but reports available from East African Cotton Research Stations indicate that the yield of cotton may be increased in various areas by applying nitrogen and phosphorus fertilizers, (Stephens 1968), (Peat *et al*., 1948-49 in 1968-69), (Striven 1971). At Kibos Cotton Research Station in Nyanza Province, Kenya, a response to nitrogen fertilizers was shown in several trials during a 4-year period (Popay 1969-70). In 1967/68 an experimental programme covering all the main cotton growing areas in Kenya, i.e. Western, Nyanza, Eastern, Central and Coast Provinces, was started. The object was to investigate the response of cotton to artificial fertilizers and the role that these might have in increasing production. The programme continued during the four years 1968 to 1971. Over 400 experiments were sown during this period, most of which were accepted for the final analysis. Supervision of this large number of trials involved the service of 21 junior field staff and two agronomists from the Norwegian Agency for International Development (NORAD) in collaboration with officers of the Ministry of Agriculture, Each trial was visited by an agronomist on average every three to four weeks, which must have influenced the acceptability of a large proportion of all trials planted.

Wapakala, W. W. (1973). The effect of nitrogen, phosphorus and copper on grain yield of wheat on a copper deficient soil. *East Africa Agriculture and Forestry Journal* 1973 Vol. 69 (4) 291-295

Sorghum (*Sorghum bicolor*) is the second most important cereal crop in semi-arid eastern Kenya after maize. Its production is constrained by low soil water status and nutrient deficiencies, particularly, nitrogen and phosphorus. A study was conducted at Masinga. Machakos district to determine the response of sorghum to two water harvesting techniques at low and optimum fertility levels. The effects of water harvesting and fertiliser on yield and water use efficiency of sorghum were investigated in this study. Tied ridges with fertilizer and Zai pits with and without fertilizer significantly increased total dry matter and grain yields, while fertilizer, tied ridges

without fertilizer and the interactions between fertilizer and water harvesting techniques had no such effects. Both water harvesting techniques and fertilizer increased water use efficiency. Water harvesting was economic during the two seasons of study while a combination of tied ridges and fertilizer was economic in one of the two seasons.

Allan A. Y. (1971). The influence of agronomic factors on maize yields in western Kenya with special reference to time of planting. Part I. PhD. Thesis, University of East Africa (University of Nairobi)

Maize is Kenya's staple food and most important crop. About one million hectares are grown, and estimated average yields are 12.5 quintals per hectare. Over 90% is planted by small farmers for subsistence and only their surplus is sold. Under 20% of Kenya receives adequate rainfall for maize,; this area is mostly at higher altitudes in Central and Western Kenya. Although the Portuguese probably brought maize to the Coast in the 16th Century, it did not spread inland until much later, in some areas it arrived within living memory. Maize research in Western Kenya is centred at Kitale, 1° N, 35° E, altitude 1890 meters above the sea level. The mean temperature is 18.5° C with moderate diurnal but negligible seasonal variations. Annual rainfall averages 1,140 mm, occurring from late March to November. Before 1964 maize agronomy research was rather uncoordinated, studying mainly fertilizers, varieties and spacings. Objective information was lacking on the relative importance of agronomic factors, and on their interactions. Without this knowledge there was little understanding of shy yields were low, or how to improve them. Part I of this thesis was designed to obtain this information. A large factorial trial was laid down at 3 sites around Kitale in 1966, and again in 1967. Six agronomic factors, in a 26 confounded design, were included each at either a high level representing current good practices, or a low level representing a defined level of bad practices. The treatments, with the high level first, were:-1. Planting early in the rains, or 4 weeks later. 2. Plant populations/hectare of 39,450, or 19,725. 3. Kitale hybrid, or a local open-pollinated type. 4. Clean weeding, or one late weeding at 45 cms. 5. 56 kg. P_2O_5/ha as single superphosphate at planting, or none. 6. 70.7 Kg N/ha as A.S.N. top-dressed at 45 cm or none. The mean yield was 51.5 q/ha. Overall, high levels out yielded low by the following margins, (q/ha.):- Early planting, 10.3; high population, 6.6; hybrid, 8.6 clean weeding, 5.3, phosphate, 0.9 nitrogen, 3.2. Several important interactions considerably modified the main effects, especially the response to fertilizers. From these results, it was deduced that: 1) farmer's yields are low because of poor husbandry, especially late planting; 2) output could be increased fourfold by adopting better practices and hybrid seed; 3) at current low yield levels, lack of fertilizer is not a major limitation; 4) fertilizer applied to poor maize is unprofitable, but cultural improvements make fertilizer profitable. Next to cost/benefit ratios were calculated, to assess the profitability of various treatments. These results were then discussed in relation to:-1) The National policy on maize production; 2) extension work; 3) Maize Research; 4) Commercial and administrative bodies. It was concluded that the time of planting effect needed more study; this was undertaken as Part II of the thesis.

Allan A. Y. (1971). The influence of agronomic factors on maize yields in Western Kenya with special reference to time of planting. Part II. PhD. Thesis, University of East Africa (University of Nairobi)

Previous research showed that late planted maize yields less in many tropical countries. Amongst several hypotheses, three seemed to need further study and were investigated in turn. 1) To determine if late planted maize yielded less because it was more severely attacked by fungal leaf diseases, which apparently increase during the rains, factorial trials with sequential plantings and weekly fungicide sprayings were done. Fungicides increased the yields of early but not of late planted maize, hence the yield decline was not due to differences in the severity of fungal leaf diseases. 2.) Birch (1960) suggested that early plantings benefited from the transient flush of extra nitrogen mineralized when the rains started, whereas late plantings missed this, and hence yielded less. To test this, the results of 27 factorial trials incorporating sequential plantings, with or without nitrogen top-dressing, were analysed. Nitrogen responses were greatest with the earliest plantings and progressively diminished with later plantings. The nitrogen uptake pattern showed that young maize needed very little nitrogen, hence the large amounts mineralized at the start of the rains could not possibly be utilized before the flush was over. Thus, the ''Birch effect'' could not account for the time of planting syndrome. 3. Moisture effects at different stages of growth were next studies (a) Trials with sequential plantings of early and late maturing genotypes showed that most of the yield decline occurred during the first 4 out of 8 plantings; this happened before there were any moisture deficit stresses at the grain filling stages. This suggested that soil aeration during early growth was important. b) A watering trial with measured amounts of water applied from planting to 5 weeks, showed that excessive moisture reduced early growth, grain yields and numbers of Kernels initiated. Excessive moisture causes poor root aeration, which reduces root growth, nutrient uptake, shoot development and hence grain initiation. (c) to verify this, a regression analysis was run on the yields of the same 27 trials, to find the effects of rainfall during 4 specified periods of growth. The results were: (1) Pre-planting rainfall from 1st January to planting had the greatest effect causing linear yield reductions and also progressively reduced the effect of nitrogen. (2) From planting to 5 weeks, 250mm. of rain was optimal, and more or less than that reduced yields. (3) From 5 to 15 weeks, and 15 to 23 weeks, increases in rainfall caused small linear yield increases. (4) There was little interaction between rainfalls in the 4 different periods. Previous times of planting experiments were then re-examined and poor soil aeration, water logging and intermittent flooding during early growth were undoubtedly important factors,

although overlooked. d) A growth study showed that although both early and late plantings eventually reached the same total weights, the assimilates were partitioned differently as the early planting put far more into the grain. It was concluded that in areas with long rainy seasons, the main cause of the decline in yields of late planted maize is the early growth check caused by planting in wet, poorly aerated soil. In areas with shorter rains, late planted maize may suffer this early check, and then may also suffer from moisture deficits at grain filling.

Pinkerton A. (1971) Effects of acidity and cation content of nutrient surplus on yield of pyrethrum (*Chrysanthemum cinerariaefulium*). East African Agriculture and Forestry Research Organization Journal volume 37. PP 2

Pyrethrum (*Chrysanthemum cinerariaefolium* Trev) is grown in Kenya on a wide variety of soils, many of which are highly leached, of low base status, and strongly acid in reaction. Poor growth of pyrethrum is often observed, the plants being stunted, with yellow leaves and few flowers, and there are a large number of ''misses'' in the crop, particularly in the year following planting. As the plants wilt and die the succession of symptoms is similar in many respects to that observed with calcium deficiency. Associated soils often contain less than 1m- equivalent per cent potassium, but more than 1m-equiv per cent potassium, but more than 1 m-equiv. per cent magnesium, the pH being little over five. Toxicity due to high availability of manganese or aluminium does not appear to be a problem, and responses to liming have been irregular. Yield increases have been recorded consistently only with superphosphate, though responses to applications of calcium and magnesium have been recorded with other crops. A critical evaluation of nutrition in relation to root medium reaction has not been reported from pyrethrum although species of decorative chrysanthemum have been investigated. The present study was undertaken, therefore, to assess the effects on flower production of variations in pH and cation supply.

Pinkerton, A. (1970) Effect of Acidity and Cation Content of Nutrient Supply on Yield of Pyrethrum (*Chrysanthemum cinerariaefolium*). Cation Content of nutrient supply on Pyrethrum. National Agricultural Laboratory 1970 XXXVII- No.2

Pyrethrum (*Chrysanthemum cinerariaefolium* Trev.) is grown in Kenya on a wide variety of soils, many of which are highly leached, of low base status, and strongly acid in reaction. Poor growth of pyrethrum is often observed, the plants being stunted, with yellow leaves and few flowers, and there are large numbers of "misses" in the crop, particularly in the year following planting. As the plants wilt and die the succession of symptoms is similar in many respects to that observed with calcium deficiency (Pinkerton, 1970). Associated soils often contain less than 1m-equiv, per cent calcium less than 1 m-equiv. per cent magnesium, the pH being little over five (Mehlich et al., 1962). Toxicity due to high availability of manganese or aluminium does not appear to be a problem (Pinkerton, unpublished data), and responses to liming have been irregular (Weiss, 1966). Yield increase have been recorded consistently only with superphosphate (Kroll, 1962), though responses to applications of calcium and magnesium have been recorded with other crops. A critical evaluation of nutrition in relation to root medium reaction has not been reported from pyrethrum although species of decorative chrysanthemum have been investigated. The present study was undertaken, therefore, to assess the effects on flower production of variations in pH and cation supply.

Seitzer J. F., Butt M. J., Mulamula H. A. (1970) Fertilizer response to wheat in Kenya. *East African Agricultural and Forestry Journal* 1970. Pp. 131-138

A fertilizer research programme on wheat was started in 1967 to investigate some of the factors limiting grain yields in Kenya, and to obtain estimates of response to nitrogen, phosphate, potash, lime and seed rate. In 1967 and 1968, 30 and 32 trials respectively were conducted throughout the wheat-growing areas. The average yield obtained in the two years was 3,028 and 3,084 kg/ha respectively, with 1,207 kg/ha as the lowest yield, and 6,597 kg/ha as the highest. The latter figure serves as an indicator of the yield potential under good husbandry methods and proper fertilization. Phosphate remains the most important single nutrient. Fifty per cent of the trials gave significant response to applied P. Response to P was found to be higher when wheat was planted after grassland, etc., than under continuous cropping systems. Response to nitrogen was found in 40 per cent of the trials, and was considerable under continuous cropping but less effective if wheat is planted after grass. There was response to potash application on a few forest soils but only in the presence of high dressings of N and P. Agricultural lime and different seed rates had no significant effect. The use of soil analysis data for the purpose of predicting fertilizer response is discussed.

Shuttie J.M. (1970). The effects of single SuperPhosphate on the yield and chemical composition of a grazed grass/ Legume pasture at Kitale, Kenya. East African Agriculture and Forestry Research Organization Journal. Volume 35 pp 4

The use of temporary leys as part of a mixed farming rotation has been common in Kenya for many years, but the inclusion of legumes in seed mixture is a relatively new practice. The value of legumes in raising both the yield

and feeding value of the pasture has long been evident in those areas where the indigenous Kenya Wild White Clover (*Trifoliam semipilosum* Fres.var glabrescens (Gillet) occurs, and enhanced soil fertility on increasing the proportion of clover in the sward was noted by Hall and Allen (1938). Legume based leys first became popular in Kenya at high altitudes above 2,300 metres where the suitability of subterranean clover as a pasture legume was demonstrated by Morrisson (1966) and the contribution to yield by subterranean clover and Louisiana White Clover described. Lately legumes suited to the medium altitudes have been found and are increasingly used in these areas. The grasses and legumes used in sown pastures in the medium altitude areas are described by Bogdan (1965). The fertilizer needs of grass in pure stand in the Kitale area have been studied. Dougall (1954), but the fertilizer needs of grazed swards containing both grasses and legumes had not been studies in detail prior to 1964. At Kitale, All crops usually show marked responses to phosphate fertilizers, especially at the establishment stage. There have been frequent indications that sulphur is locally scarce. Phosphatic fertilizer is generally necessary for the establishment of pasture legumes at Kitale, and there is a food deal of evidence to suggest that top dressing with a phosphatic fertilizer is beneficial to the vigour and longevity of legumes both in pasture and in pure stand for seed production. The legume component of pastures frequently becomes scarce and unproductive after the second season at Kitale; this was thought to be due to phosphate deficiency. A trial to study this was planted at the National Agricultural Research Station in April 1964**.**

Allan A.Y. (1969). A review of maize agronomy research in Western Kenya. Conference Proceedings of the East African Specialist Committee on Soil Fertility and Crop Nutrition March 25th-27th,1969-Makerere University, Kampala, Uganda.

Investigations into various aspects of maize- growing were started in Kenya in the late nineteen-twenties, but these were done on a part-time basis by many different research workers on different stations, and this uncoordinated approach naturally limited progress. It was not until 1955 that a research worker was assigned to work exclusively on maize. In that year Mr. M.N. Harrison was posted to Kitale as Kenya`s first full-time maize breeder. He developed and expanded the breeding programme, and by 1963 had reached the stage where the first hybrids were ready for commercial release to farmers. As it had been foreseen that the higher genetic potential of the hybrids would not be fully realised unless improved cultural methods were used along with the hybrids, an approach programme at Kitale, and this commenced in June 1963.

Dagg M., Tapley R.G. (1969) Water balance of cashew nut trees in relation to spacing. Conference Proceedings of the East African Specialist Committee on Soil Fertility and Crop Nutrition March 25th-27th, 1969 Makerere University, Kampala, Uganda.

In the Nachingwea area plantations of cashew nut trees at close spacing failed whereas isolated trees thrived. An analysis of probable water balance, taking into account the rooting habit of the tree, showed that trees planted so close that their canopies began to meet as they grew older were liable to suffer severe water stress at the time of fruiting, whereas the widespread nature of the roots enabled isolated trees to exploit water stored in the soil outside their canopies, so avoiding serious water stress. The conclusion to be drawn is that cashew trees must be allowed to use their ecological gambit for successful competition. The actual spacings that would be satisfactory depend on the environmental conditions and can be calculated from a knowledge of monthly rainfall and monthly E_o data, and the local soils data- particularly the depth of soil.

Garberg P.K. (1969). Uptake of N, P, K, Ca and Mg at different growth stages. Conference Proceedings of the East African Specialist Committee on Soil Fertility and Crop Nutrition March 25th-27th, 1969-Makerere University, Kampala, Uganda.

The content of the different macro nutrient elements in percentage of dry matter was much higher in maize plants at an early stage than in more mature plants. The decrease in percentage composition of dry matter is generally much faster up to tasselling stage than from tasselling to maturity. The figures at tasselling (% dry matter) indicate medium content of N at Muguga and very low content at Katumani. The corresponding figures for P indicate medium to high content at both sites. The soil inorganic P values at both sites, however, indicate a low to very low content of available, inorganic P. The fact that the leaf analysis show a satisfactory level of P, indicates that the plants probably derived P from sources other than available inorganic P e.g. from organic P fallowing mineralisation. The dry matter yield increased very rapidly up to and beyond tasselling stage, followed by a slower increase during the last part of the Season, to maturity. Over a period of six to eight weeks before tasselling the growth of maize was very fast. During this time the plants produced about three quarters of the dry matter and absorbed 60-80% of the total amounts of macro-nutrients. It therefore seems to be very important that the plants over this period of growth do not suffer from lack of water and readily available nutrients. The advantages to be gained by planting at the onset of or just before the rains, which have been observed in several field trials, were experienced under trial conditions.

Gitau J.K. (1969). Relative efficiency of some N:P compound fertilizers, and the optimum N:P ratio for different crops on different soils in Kenya. *Conference Proceedings of the East African Specialist Committee on Soil Fertility and Crop Nutrition*. March 25th-27th, 1969 Makerere University, Kampala, Uganda.

There has been in recent years an enormous number of N:P and N:P:K compound fertilizer released to Kenya market by fertilizer companies, but yet we have very little knowledge of their relative values on our soils. Indeed many farmers are at a loss as which ones are best for their crops on the particular soil types. While it is recognized that phosphorus followed by nitrogen are the main plant nutrients that are lacking for the majority of our agricultural soils today, yet the correct ratios of N:P for optimus production of different crops on different crops on different soil types, are not known. Some crops such as wheat, barley, oats, potatoes etc. received their N & P in seed bed, generally as compound fertilizers. Because of extra labour and material costs involved in topdressing crops like beans, maize etc. many farmers are turning into use of compound fertilizers especially the N:P ones. Potash is not as yet important in the same way as N & P. The present investigation is aimed at finding out the relative efficiency of different N:P compound fertilizers as well as finding the best N:P ratio for different crops. The initial trials will be purely exploratory and will initially be confined to red soils on Kenya Highlands. As there are no definite research findings to report as yet, the present paper is aimed at introducing the subject for discussions and suggestions. As a start in this project a simple trial was conducted on the red loam soils of the National Agricultural Laboratories in 1968. The intention of the trial was to compare the effectiveness of some common N:P compounds on the Kenya market. Indicator plant was Muratha maize. The above compound fertilizers were applied to give some quantities of P_2O_5 i.e. 80 lbs P_2O_5 in all cases. The site chosen for the trial was National Agricultural Laboratories which is characterized by Kikuyu red loam soil. This soil has a pH of about 5.8 and is extremely poor in soil phosphorus as well as being poor in nitrogen. Response to phosphorus on this soil is extremely good, but without phosphorus nitrogen application has not been found to be beneficial. 80 lbs P_2O_5 per acre (= 400 lbs/acre, single supers = 200 lbs/acre Triple supers) has been found to be the rate that gives economical results for maize in this type of soil.

Semb G., Garberg P. K. (1969). Some effects of planting date and Nitrogen fertilizer in Maize *East African Forestry and Agriculture Research Organisation* Vol.34 (3) pp.371-380

Experience and the results from field experiments in East Africa have shown that planting maize early in the rains or even before the rains start, usually results in higher yields than planting later in the rainy season. Inadequate supplies of nutrients particularly nitrogen and limited water supply in critical periods have been mentioned as the most likely reasons for lower yield of late-planted maize. At the onset of the rains a flush of mineral nitrogen appears in the soil, and the content of available nitrogen is supposed to be better early into he rainy season than it is later on. With early planting the crop may be able to benefit from better supply of Nitrogen and some workers have explained higher yields with early planting partly in this way. Application of fertilizer has been shown to increase maize yields but did not eliminate reduced yields with late planted crops; maize response per unit of nitrogen fertilizer was better with early planting. The maize response to water has been studied in many investigations Salter and Goode in their summary of investigations concluded that the moisture conditions during the period of silking and early grain formation are particularly critical in determining the grain yield in maize. Several examples are given where drought during these periods has reduced the yield considerably. Research in East Africa has also shown that there are three periods when water is most essential namely germination, fertilization and grain filling. After germination the maize can survive with very little water for some time because the first five leaves have a high development of wax-micro particles which significantly reduce cuticular water loss. Lack of water at the fertilization stage usually results in a drop in yield. This may be due to high leaf development at this stage and also because the reproductive organs of most plants are composed of thin-walled cells which are easily desiccated and irreparably damaged if they dry out. By early planting the maize develops a better root system and will thus be able to utilize the water content of the soil more effectively. In experiments at Illonga, Tanzania, Turner found that the late-planted maize received much less rainfall from tasselling stage to harvest than maize planted early in the rainy season. He therefore explained the low yield from late-planted maize essentially as lack of water during the period of grain formation.

Allan, A.Y., Masianga B.S. (1968). Maize Agronomy Research: Late Maturity Maize. National Agricultural Research Station (Section III, Maize agronomy research). Annual report

In contrast, during the very favourable season (March 1968 rains), E 511 out yield the Katumani synthetic. Although the later maturing Local White variety would out yield the early unimproved variety, Taboran, under favourable conditions, improvement has been so great in the Katumani synthetic varieties that they will now equal the yield of the Local White variety even in seasons with adequate rainfall for later maturing varieties. The increase of Katumani maize in Machakos, Kitui and drier areas of Meru and Embu districts increased greatly in 1967. With the help of a 'Freedom from hunger' grant 5440 hectares (13440 acres) were planted with new seed from the Kenya Seed company and the Katumani Research Station. An additional acreage of 30,150 hectares (74,466 acres) were planted with seed from farm -to-farm sales for a total of 35,590 hectares 89,906 acres) compared to 2860 hectares (7065 acres) in 1966.

Weiss, E. A. (1967). Fertilizer trials on maize and wheat. *East African Agricultural and Forestry Journal* pp 326-340

A detailed and comprehensive series of fertilizer trials on maize and wheat were carried out from 1960 to 1965 on estates of the E. A. Tanning Extract Company in the Soy, Nandi Turbo and Kipkabus Districts, West Kenya, to determine the most profitable application of phosphate and nitrogen -and the effects of various forms of both -in the seed-bed and as top-dressings. It was ascertained that there is a basic difference in crop response from similar levels of fertilizers on the two main soil types which occur in this area. Crops grown on soils derived from granite and gneiss require less phosphate in the seedbed and more nitrogen top-dressing for optimum yields than those grown on soils derived from phonolites. The residual effect of annual applications of phosphate on both soil types was found to be high. Various types of phosphatic and nitrogenous fertilizers were compared and the effect of varying ratios of N-P in the seedbed investigated. It would appear that this ratio is more critical for wheat than maize and too close a ratio may depress yields. The effect of wattle on following crops is discussed in some detail. Applications of nitrogenous fertilizers to crops in the year following wattle generally depressed yields, both as a seedbed application and as a top-dressing. The "brushwood line" effect is described, with the probable reasons for improved plant growth on these areas. Nitrogen top-dressing of maize is essential for maximum yields on all soil types but the optimum amount varies. It would appear that even distribution of the fertilizer is more important than the method of application. Mechanical spreading was effective and speedy. Top-dressing of wheat was uneconomic except in certain restricted circumstances. Seedbed applications of magnesium sulphate to acid volcanic soils in the Nandi Border area increased yields, the increase being greater in the presence of seedbed nitrogen. Liming also increased yields on these soils, but the amounts required made its use unprofitable and on other soil types may have little effect on crop yields. Potash generally depressed yields and no other fertilizer had any significant effect. Foliar nutrient sprays had little effect on below-average crops of both wheat and maize.

Boswinkle E. (1960). The effects of the use of urea compared with sulphate of Ammonia; Soil fertility Investigation in Kenya Colony. *Special committee on Soil Fertility; Report on meeting held at Kawanda, Uganda*. April 11-13th pp 1-3

Under the suspices of the Swynnerton plan, it was agreed to undertake a long term programme of soil fertility investigations in the native areas of Kenya Colony. At first, a network of 24 confounded exploratories was laid down in various provinces, and distributed in such a way that two replicates of 16 plots each were considered to be a bare minimum for each site, soil, ecological zone and crop, sulphate of ammonia (21%N), double superphosphate 39-41) water soluble P_2O_5) and muriate of potash (60%K_2O) were applied at 1 cwt/acre each and FYM at 71/2 tons/acre to grains, and double the above rates when root crops were the test crop. In bracken zones, FYM was replaced by agricultural limestone at rates as determined by laboratory investigation of the lime requirements of the soil. Experimentation has indicated that soils of the bracken zones mainly from acid tuffs may be sub-divided into two distinct groups. The first group comprises very acid soils where crop growth is impossible without the application of limestone due to severe toxicity effects of aluminium (exchangeable aluminium 6-8 m.e %), and the second group where equal responses can be obtained with either limestone or double super phosphate. The trials were undertaken by staff of the Field Services of the Department of Agriculture, and in average, each officer was responsible for four replicates of the 24 factorial. Selection of sites was not based on randomisation and a systematic bias could not be excluded since often selection depended on accessibility from the Divisional Headquarters, standard of farming of the owner of the site, etc. Whereas in the first two years, no fixed rotation was adhered to, it was the aim to achieve in the shortest possible time a standard rotation of crops which would be the most efficient from fertilizer application point of view. Results obtained so far in Central Province is centred around the extinct volcano Mt. Kenya, and four distinct ecological zones can be distinguished of which the two centre zones, star grass- and 4,000 to 6000' with an average annual rainfall of 35'', with two clear rainy seasons in any one year, and soils are uniformly of volcanic origin (lava and tuffs).In the first two years of the scheme, 1956 and 1957, evidence was obtained that these areas were universally deficient in phosphate and FYM, and sometimes N, though the latter in a very erratic way. Moreover, fertilizers could be applied most efficiently to root crops more so than grains especially if grains would follow the root crops and thus benefit from any residual effects of the fertilizer applied to the root crops. It was decided to adhere to the following standard rotation in these areas: Potatoes (with fertiliser application) in the long rains after break of grass, followed by beans and no reapplication of fertilizers in the short rains, after which maize was planted as the third crop in the long rains when only N and K were reapplied. This concludes the first fertilizer cycle and a second fertilizer cycle is undertaken again with potatoes as the opening crop and a full reapplication of fertilizers in the short rains. This rotation was also strictly followed up in the next stage of the investigations, the 33 rates trials where N, P and F.Y.M were applied to potatoes, N and P each at 0-11/2 -3cwt/acre and FYM at 0-11-22 tons/acre, and residual effects of P and M were again followed up in beans and maize. Since K had shown itself ineffective in the exploratories it was subsequently omitted from the rates investigations. In all cases, the aim was to establish relationships between yield responses in the field on the one hand and soil analysis date, as indicated by Mehlich's extraction method (0.1 N-HCl-0.25 N-H_2SO_4 mixtures) on the other hand, and with this in mind, all trials were sampled each season.

Evans H.R. (1957). The influence of fertilizers on pineapple replants areas. *East Africa Agriculture and Forestry Research Organization (E. A. A. F. R. O.) Journal*. Vol. 22 1957 No.3

Experience in Kenya has shown that, when pineapples are replanted immediately following a previous cycle under this crop and without the addition of fertilizers, the replant crop often fails. The experience is in common with that of most other pineapple producing countries of the world. Though crop rotation appears to offer a solution, knowledge of the form that this should take is lacking. While steps have been taken to acquire this knowledge, the rapid expansion of the pineapple industry necessitated an interim answer to ensure the productivity of replant crops. As there have been no really serious nutritional problems with pineapples grown on virgin soils in Kenya, the trial discussed in this paper which was initiated by Mr. T.H. Jackson, Senior Horticultural Officer, was concerned solely with the problem of the response of pineapples to various fertilizer treatments where one cycle of pineapples was immediately followed by another on the same land. Since good results have been achieved with sulphate of ammonia in Hawaii and Australia, it was decided to lay down a field trial to investigate the influence of nitrogen in this form on smooth Cayenne pineapples. Pineapples on replant soils often develop yellowish foliage which has been thought to be associated with an iron and/or magnesium deficiency, and it was accordingly decided to include treatments with these two plant nutrients at the same time. In Hawaii, it has been found that soil fumigation stimulates pineapple growth whether nematodes are present or not. Consequently, a soil fumigant, ethylene dibromide, was also included. Pineapple growing in the European farming areas has recently been taken up by coffee planters amongst others. Since coffee requires the best of the red soils, with Napier Grass (*Pennisetum Purpureum*) grown to produce mulch for the coffee often taking second place, the type of land left for the pineapple 'crop is frequently poorly drained, shallow, red to light brown clay-loam soil, often containing much ''murram'' in the profile. It was therefore to be expected that some form of fertilization would prove beneficial for the economic production of pineapples where continuous cropping is practised.

Evans, H.R (1956). The Influence of Fertilizers on Pineapple Replant Areas. *East Africa Agriculture and Forestry Research Organization Journal* volume XXII-No. 3 1956

Experience in Kenya has shown that, when pineapples are replanted immediately following a previous cycle under this crop and without the addition of fertilizers, the replant crop often fails. This experience is in common with that of most other pineapple-producing countries of the world. Though crop rotation appears to offer a solution, knowledge of the form that this should take is lacking. While steps have been taken to acquire this knowledge, the rapid expansion of the pineapple industry, necessitates an interim answer to the productivity of replant crops. As there have been no really serious nutritional problems with pineapples grown on virgin soils in Kenya, the trial discussed in this paper, which was initiated by Mr.T.H Jackson, Senior Horticultural Officer, was concerned solely with the problem of response of pineapples to various fertilizer treatments where one cycle of pineapples was immediately followed by one another on the same land. Since 900 results have been achieved with sulphate of ammonia in Hawaii and Australia, it was decided to lay down a field trial to investigate the influence of nitrogen in this form on smooth Cayenne pineapples. Pineapples on replant soils often develop yellowish foliage which has been thought to be associated with an iron and/or magnesium deficiency; and it was accordingly decided to include treatments with these two plant nutrients at the same time. In Hawaii, it has been found that soil fumigation stimulates pineapple growth whether nematodes are present or not. Consequently, a soil fumigant, ethylene dibromide, was also included. Pineapple growing in the European farming areas has recently been taken up by coffee planters amongst others. Since coffee requires the best of the red soils, with Napier grass (*pennisetum Purpureum*) grown to produce mulch for the coffee often taking second place, the type of land left for the pineapple crop is frequently poorly drained, shallow, red to light brown clay-loam soil, often containing much "Murram" in the profile. It was therefore to be expected that some form of fertilization would prove beneficial for the economic production of pineapples where continuous cropping is practised.

Dougall H. W. (1954) Fertilizer experiments on grassland in Kenya highlands. *East Africa Agriculture and Forestry Journal* Vol.19 (3) pp.171-177

In 1926 attention was directed by the Committee of Civil Research(1) to the grasslands of Kenya, when this colony was selected by it as the most suitable for pursuing an inquiry into the mineral content of natural pastures. Boyd-Orr, who directed this investigation, selected four districts (Naivasha, Athi Plains, Nakuru, and Molo), in which he studied the chemical composition of natural herbage as affected by soil and climate. Results of preliminary work indicated clearly that, in three of the four districts, pastures were deficient in all mineral nutrients and also in protein. Phosphorus was the element most deficient and he considered it to be the factor limiting the assimilation of other minerals by the plant. Boyd-Orr inclined to the view that if Phosphorus were supplied by fertilizers, the amount not only of phosphorus but also of calcium would be increased in the pastures. However, when the most deficient area was treated with fertilizers, the first direct effect to be measured was productivity and yields of herbage were increased from 25% when common salt was used, to well over 300% where nitrogen and phosphate were used together. It is unfortunate that the composition of the herbage harvested was not reported, but we may infer that its mineral status was enhanced, for it is recorded that when stock were allowed

access to the plots at the end of the test. They "showed a marked preference for those which had been fertilized, while controls were left practically untouched". It was observed that where phosphates had been applied the herbage maintained its green appearance for a longer period during the subsequent dry weather. This pioneer work of Boyd-Orr and his colleagues was not advanced to any marked extent in the years which followed, but nevertheless, it does seem that a proper appraisal of grass was being sought. It was beginning to be regarded in all its forms as: (1) the "raw-material" factor limiting the formation of milk, meat, mutton, wool e.t.c and (2) in the form of a ley, as an integral and probably pivotal crop in a suitable system of alternate husbandry. The need for field experimentation to test these views became more urgent in recent years and in 1950, under the Government-sponsored "Highland Fertilizer Scheme", a restricted number of field experiments were carried out with the object of examining the effect of certain out the object of examining the effect of certain fertilizers on the productivity of natural pastures and established grass, and on the establishment of suitable ley swards. These experiments demonstrated beneficial effects of phosphate on ley establishment, and marked herbage-yield responses to nitrogen on established leys and certain natural pastures. Lime and Potash at the levels applied appeared to have appreciable effect on the productivity of the few permanent pastures investigated. In 1951 the Department of Agriculture extended the scope of this work and studied the role of a phosphatic fertilizer (P) and a nitrogenous fertilizer, sulphate of ammonia (N) on ley establishment and on the productivity of established grass and natural pastures, including rough grazing. These studies were undertaken on different kinds of soil, with different herbage species, and in areas of varying altitude and climate, with the object of (1) obtaining an assessment of optimum dressings of these fertilizers, and (2) determining responses to P and N as measured by productivity and nutrient value of the herbage. In ley-establishment trials, factorial combinations of P (18% CitricsolubleP205) and N (20%) were used. There were 16 treatments and two replications. Fertilizer dressings applied at the time of seedling down were: 0, 30, 60, and 120 1b N per acre and 0, 36, 72, 144 1b. P_20_5 per acre; and each of the following grasses-Rhodes, Molasses, Cocksfoot and Kentucky fescue-were sown in combination with a legume-Lucerne or Seradella. In the permanent grassland trials, factorial combinations of the same fertilizers were arranged in the form of a quasi-Latin square, with 18 treatments and two replications. Fertilizer dressings were: 0, 15, 30, 60, 90, 120 1b.N per acre and 0, 36.72 1b P_20_5 per acre, broadcast at the beginning of the growing season. Nitrogen was re-applied at the same levels after time the herbage was cut. Herbage was cut when it had reached a stage growth considered suitable for stock grazing. Yields of fresh materials were recorded and samples were taken for dry matter determinations and chemical analysis. Soil samples to a depth of six inches were obtained from plot of each plot of each experiment prior to the initial application of the fertilizers and again after each herbage cut; with permanent grassland, however, the soil samples were taken before re-applying nitrogen. Final samples were obtained in December, 1951. Herbage samples obtained from the first cut in each kind of trial were analysed for crude protein, phosphoric oxide (P_20_5) and lime (CaO).

Bellis E. (1953) Studies in the fertilizing of annual crops in Kenya. East African Agricultural and Forestry Journal

Fertilizer studies on annual crops in Kenya were first initiated mainly to meet a demand for prolongation and expansion of cereal monoculture on European-occupied farms in the Kenya Highlands. The early trials (as have most succeeding trials) followed a variety of patterns, but in main they comprised a wide scatter of 4x4 and 5x5 Latin squares on wheat and maize. Numerous forms of phosphate (the superphosphates, Seychelles phosphate, basic slag, Ephos, bone meal), common forms of potash, sulphate of ammonia, ground limestone boma manure and green manure were the fertilizers and amendments used. Inadequate replication, widely varying environments and low efficiency of the phosphate application technique led to erratic results. Nevertheless, these early trials clearly established the dominant importance of phosphatic fertilizers and organic manures and the relative unimportance of the potassic and nitrogenous fertilizers on maize and wheat. They also established that the superphosphates and Seychelles phosphate were superior to the other forms of phosphate and that an application of about 25 lb. total P_2O_5 per acre or of about eight tons boma manure per acre may be expected to bring about useful increases in the yield of maize and wheat. In areas which are sufficiently well watered for green manuring to be practicable, fertilizing the green manure with less soluble forms of phosphate had as beneficial an effect on a succeeding crop of maize as did the same application of phosphate as superphosphate applied directly to maize. Later trials involving placement of superphosphate have demonstrated that for maximum economy of its use for wheat, this fertilizer at least should be sown with the seed in the drill. A few trials with NPK fertilizer mixtures and boma manure on potatoes were also undertaken, but these served merely to hold out promise for the use of a fertilizer mixture, particularly if the fertilizer mixture is rich in phosphate, and of boma manure as a means of increasing potato yields on some soils. The value of phosphates having been established, the intervention of war in 1939, and with it a pressing demand for increased cereal acreage in the face of contracting stocks of recognized phosphatic fertilizers, demanded full exploration of the possibility of developing local sources of phosphates. The materials which came under particular examination were bone meal, cotton-seed ash, and Uganda rock phosphate, though having a low early availability, promised if applied sufficiently heavily and in a sufficiently fine state of subdivision also to be effective. The citric solubility of soda phosphate was found to be a direct measure of its early availability relative to superphosphate. In the field trials, the high early availability of soda phosphate and the low early availability of Uganda rock phosphate were confirmed whilst cotton seed, introduced direct from pot culture into general farming, was an immediate and long-standing favourite: bone meal supplies proved inadequate for its

thorough testing in the field. The possibilities of soda phosphate production in East Africa are great, so in view of the value which it demonstrated for itself the areas in which it was subjected to trial were expanded as quickly as the availability of supplies permitted. African areas in central and Nyanza provinces received particular attention. While the trials concerned suffered from the inadequacy of the supervision which was possible at many of the centres, the observations which were made gave promise of soda phosphate, provided it could be produced cheaply, finding a wide application in Kenya. More detailed examination of the value of soda phosphate (and of other fertilizers) was undertaken under the African and the Highlands Fertilizer Schemes. Recent fertilizer investigations connected with annual crops have continued and extended the studies undertaken under these two schemes. In African areas, the exploratory rates of application, and placement trials initiated under the African Fertilizer Scheme, have been continued and extended to new areas in Nyanza, Central and Coast Provinces, the trials being sited with particular reference to important local soils, and the test crop used being selected mainly from important local cereals: residual as well as primary effects were measured wherever possible. Muriate of potash at rates up to 1 cwt. per acre produced no important benefits but, on some soils, sulphate of ammonia and the superphosphates at rates up to 2 cwt. per acre and boma manure at rates up to 10 tons per acre produced useful and, at present prices, economic returns: on other soils, no measurable effect has been obtained from applying any of these materials. Placement of phosphate has been found to have no advantage over broadcasting, even at a rate of application as low as 0.48 cwt. double superphosphate per acre and this has been taken as indicating that with placement yet lower rates of phosphate application are justifiable. Studies in the nutrients requirements of the relatively thinly populated upper Kikuyu bracken lands have indicated a particular effectiveness of light dressing of boma manure and a relative ineffectiveness of major fertilizers and amendments. In European areas, Neubauer-type laboratory experiments established that, provided the fertilizer is placed below the seed, soda phosphate and the superphosphates have a similar availability to wheat seedlings but that as the concentration of the fertilizer in the fertilized zone decreases, so the plant appears better able to use the phosphate from double superphosphate than the phosphate from soda phosphate in producing dry matter. Further Neubauer-type trials established for a number of soils that the early availability of the citric soluble in Sychelles phosphate depends to a limited extent on the fineness of the fertilizer. Field trials have established that even with measure of drainage, the yield and response levels of the Kinangop loam to double superphosphate are markedly lower when natural drainage is inferior than when natural drainage is normal. Long-term field trials concerned with the use of Uganda rock phosphate have been initiated. A field trial aimed at extending the applicability of the Highland Fertilizer Scheme results on wheat to barley and oats has been attempted: while detailed quantitative examination of the results is still required, the preliminary showing is that barley is relatively much more and oats less sensitive to its environment and to fertilizer treatment than wheat. Field trials not specifically involving phosphates have been concerned with the rotting-down of stubble: the crop succeeding incorporation of a large quantity of stubble has been found to benefit from sulphate of ammonia application provided the rate of application at least approaches 1 cwt. per acre, though even then benefit is small and uneconomic at present prices. Fertilizer and liming studies of minor importance on a miscellany of crops have also been carried out. Proposals for the future are a continuation of the present investigations, examination of means for economizing in the cost of phosphate in areas where phosphate responses have been established, examination of the relative effectiveness of different nitrogenous fertilizers and an intensification of work on liming, on suspected minor element deficiency in wheat land in Njoro and on the problem of the infertility of the upper Kikuyu bracken land.

Bellis E. (1953). Fertilizer responses in relation to soil types. Field recommendations. East African Agricultural and Forestry Journal

Robinson has demonstrated a considerable increase in precision which a simple soil classification makes possible in the predicting of the response of wheat in the Kenya Highlands to phosphate, though even within a soil type, the variability which he finds may be so great that even though on average the soil may show a good response to phosphate, the probability of obtaining poor responses can be quite high. Again, while Birch has established overall correlation between site data and the response of wheat to phosphate, these correlations become so much less clear when soil type is taken into consideration that a negative relation between response to phosphate and yield without phosphate on normally drained Kinangop loam becomes the only relation between recorded site data and phosphate effect which remains important: work outside the Highland Fertilizer Scheme has shown even the Kinangop loam relationship not to hold where drainage is poorer than normal. On the other hand, within a soil type, while site appears to operate through factors which find no general reflection in the Highland Fertilizer Scheme data, it is site which plays the dominant part in determining the response of wheat to phosphate, and while an overall assessment of fertilizer in respect of soil type provides a guidance which is essential to sound recommendations regarding the use of fertilizer on any given soil type, the Advisory Officer in making recommendations regarding a given piece of land will find it necessary frequently to modify, in the light of conditions prevailing on the site, any general recommendation which has been calculated for the soil concerned. In making such modification the soil data accumulated under the Highland Fertilizer Scheme will provide him with little guidance and he will necessarily have to fall back on his own knowledge and experience of the area, and of factors which likely to have a bearing on fertilizer response there but which find no clear expression in the Highland Fertilizer Scheme data. He will also need to take into consideration the financial background

of the farmer and the terms in which he will measure his returns. As a general rule recommendations below the calculated optimum for the soil type will be given, as such recommendations can be made with greater confidence of being satisfactory than recommendations as great as or exceeding the calculated optimum. On established grass both the double superphosphate and the sulphate of ammonia should be applied early in the growing season while trial of further application of the sulphate of ammonia after each cut or grazing should be undertaken.

Doughty L.R. (1953) The value of fertilizers in African agriculture field experiments in East Africa. East African Agricultural and Forestry Journal 1953

Over the period 1947-1951 fertilizer experiments were carried out fairly extensively in African areas bordering Lake Victoria and in the northern coastal belt of Tanganyika. Numerous explanatory experiments using sulphate of ammonia and triple superphosphate in simple factorial combination were undertaken, and, in areas where fertilizer responses were recorded, more elaborate experiments involving various combinations of levels, forms and methods of applying phosphate, levels and times of applying sulphate of ammonia and potash and dung were undertaken, the experiments in some instances being carried on for two or three years on the same sites. The potash studies were confined to Tanganyika and the detailed nitrogen studies to Uganda. The crops used were the land holder`s choice and were mainly cereals. The experiments were undertaken only during the main rains each year. Plot size ranged from 1/40th to 1/120th acre, 1/80th acre being the minimum preferred: large plot sizes were found to be particularly desirable when the experiment was carried on for a number of years. Fresh head weights were taken in all trials harvested, the results being connected to dry grain weights by samples from each experiment. Owing to the mosaic of African cultivation on which the trials had to be imposed and to the inadequacy of supervision which was possible, a proportion of the experiments failed, others were only partially successful, and the error factor was high. In areas where rainfall was inadequate or soils excessively open-textured, drought was sometimes severely damaging, pests, diseases and vermin were particularly troublesome, catching the rain for planting (which was essential for success of an experiment) was particularly difficult, and failures and errors were consequently particularly high. To the north-east of Lake Victoria, moisture availability during the growing season was adequate. Here on volcanic soils and on deep, stable, mature granite soils such as occur in South-East of the Eastern Province of Uganda and nearby in the northwest of Nyanza Province, the response of maize sorghum, and finger millet to sulphate of ammonia was general. The responses of maize and finger millet promised to be economic but the economy of the sorghum response was less certain. The biggest yield increases were obtained with application of sulphate of ammonia of up to 0.95 cwt. /acre sulphate of ammonia, or 0.2 cwt. /acre N: further increase in the rate of its application only exceptionally gave marked further yield increases. Time of applying sulphate of ammonia was unimportant at least during the period of vegetative growth. Broadcast application was effective provided rain fell reasonably soon after fertilizing. Phosphate sometimes exerted beneficial effects on early growth but these generally disappeared before harvest. On soils of the basement complex such as occur in north-eastern Nyanza Province, response of maize, the only crop tested, both to phosphate and sulphate of ammonia was high and economic. On laterized, deeply dissected granite soils and on ancient sediments such as occur in and immediately south of the Nzoia Valley, response to phosphate is of major and economic importance. Nitrogen effects are smaller and are frequently sub-economic. Boma manure effects also are small. Where phosphates are generally effective- (1) repeated applications of triple superphosphate have a pronounced accumulative effect; (2) the superphosphates are about 5 percent more effective than soda phosphate; (3) Uganda rock phosphate has a valuable effectiveness: in most experiments where benefits from its use have been recorded, the benefits have become apparent only after the second or third season's application. Uganda rock phosphate was most effective in the area south of the Nzoia Valley; (4) in terms of crop, sorghum responds better than maize, maize better than finger millet, and sweet potatoes very little, to phosphate; (5) the optimum rate of phosphate application seems to be around the equivalent of 1 cwt. triple superphosphate per acre, particularly if the dressing is given annually for a few years. At the same time broadcasting has been found as effective as placement at a rate of application as low as 0.48 cwt. triple superphosphate per acre and this has been taken as indicating that even lower rates than this may be effective provided that the fertilizer is placed. A rough estimate gave the potential phosphate consumption for the responding areas north-east of Lake Victoria as initially the equivalent of 5,000-7.500 tons per annum triple superphosphate, though in course of time this high level of consumption would be expected to decline somewhat: fertilization at this rate would increase crop yields by some 30%. Again, provided it could be produced cheaply, a quick-acting nitrogenous fertilizer could be used beneficially each year on some 1,600-2,800 square miles of cultivation in the area. To the south and south-east of Lake Victoria, rainfall during the growing season is variable and in some areas frequently inadequate. The information obtained here applies in main only to the lighter-textured uplands soils which are the soils most extensively used for cultivation. Responses on these soils to single applications of phosphate varied widely from place to place, from crop to crop and from year to year and frequently were apparent only during early growth, later to become less and to disappear before harvest. Repeated applications, however, led to much greater, more consistent and significant yield increases. The responses were most apparent on red loams of good depth over murram in drier areas and were least apparent on hill sands in the moister areas. The yield increases promise to be economic with cotton, but the risk of loss of crop makes the economy of applying phosphates uncertain for sorghum and millet. The superphosphates were more

effective (particularly in the drier areas) than soda phosphate, and soda phosphate was more effective than Uganda rock phosphate. All crops except sorghum responded to sulphate of ammonia, the response of maize in the north being the most economic. All crops responded to dung better than to fertilizer: in one instance only was an N.P. fertilizer application as effective as the equivalent dressing of dung. In the dry areas phosphates were somewhat less effective when applied in the presence of dung than when applied in its absence. Potash effects generally were small. The high efficiency of dunging associated with a consideration of the nutrient status of the soils in Lake Province, Tanganyika, suggests that increasing the productivity of the cultivated soils there is not mainly a matter of providing adequate plant nutrients. On the coastal belt, though rainfall is usually abundant, the soils are very porous and drought is severely damaging. Nevertheless, phosphate responses particularly in the second and third cropping season were found to be fairly general on the coastal sands and on the red soils of the hinterland. Some instances, particularly in the northern part of the area, were observed of important potash effects in the second and third season. Moderate responses to dung and to nitrogen were observed. Proposals for future work arising from these trials are:- (1) Much more exploratory work in needed, and in areas where fertilizer responses have been established, further investigations of appropriate dosages and methods of application are required. (2) The phosphate placement method adopted in ridge cultivation in Lake Province is believed not to be fully satisfactory and alternative methods of application (particularly broadcasting followed by ridging) need testing. (3) The low-lying, heavy black (Mbuga) soils which are extensive in the cultivation steppe in Lake Province, Tanganyika, and have a high potential for mechanized cultivation, require further investigation of their phosphate status. (4) The reason for the superiority of dung over equivalent fertilizer treatments on the cultivation steppe of Lake Province needs investigation.

Gethin Jones G.H. (1953) The history of artificial fertilizers in the European highlands of Kenya, with special reference to soda phosphate. East African Agricultural and Forestry

During the years before the war there was a growing realization of the need of better farming methods with increased yields per acre. This involved the adsorption of some soil conservation measures, the starting of mixed husbandry and a small but increasing use of artificial fertilizers, mainly phosphates applied to wheat. Some bone meal was given to high yielding, old-established coffee lands in the Thika and Kiambu districts. No artificial fertilizers and indeed very little organic manure were used in African areas. The increasing use of phosphatic fertilizers on cereals, and on wheat in particular, was based on the frequent good response shown by simple field experiments on many of the main wheat-growing soils. There were many instances of relatively small dressings of 80 to 100 lb. per acre of double supers, applied with the seed-drill to long-cultivated wheat lands, resulting in greatly increased yields which made possible continued war-time wheat production on such lands. It happens that the elevated regions which are climatically the most suitable for wheat have the most leached and highly unsaturated soils, which are very deficient in "available" phosphate, and these generally gave good responses in farmers` strip trials: placement of the fertilizer was found to be essential. War-time food-production demands increased the need for phophatic fertilizers at a time when the importation of superphosphates was severely restricted. Seychelles phosphate was imported in greater amounts; the collecting and grinding of animal bones from the game reserves and African settled areas made available over 1,000 tons of bone meal per annum; more than 4,000 tons of cotton seed ash were obtained from Uganda, and local scattered supplies of bat guano were exploited wherever possible. With very limited importations of double superphosphates, the supply of phosphatic fertilizers did not meet the growing demand. Steps were therefore taken to exploit the deposit of a primary phosphate which was known to occur along the eastern border of Uganda. It was proved that there are vast reserves of readily mined are carrying 8 percent to 35 percent phosphoric oxide, with a working average of 25 percent, mainly in the form of fine-grained francolite. The true manurial value of ground rock phosphate from Uganda was tested by chemical analyses, by a pot culture technique, and by a few field experiments. The results indicated that only about half as much "early available" phosphate was liberated from it as compared with other commercially worked rock phosphate deposits, and it became apparent that the Uganda phosphate rock was not suitable for application by itself to annual crops. In the search for a method of processing by which the phosphate in the raw rock could be made more available to plants, the obvious preference lay in calculation with crude sodium carbonate from Lake Magadi, and a suitable method was worked out, first in the laboratory and then in a pilot plant. In laboratory studies the new soda phosphate showed great promise. Though it has very little "water-soluble" phosphate, it does contain a high proportion of "citric-soluble" phosphate, the amount depending mainly on the proportion of ingredients used and the temperature and length of heating. Eventually it was found that 80 percent to 90 percent of the total phosphate could be economically converted into the citric-soluble form. Pot culture trials showed that cereal seedlings could absorb roughly five times as much phosphate from soda phosphate as from raw Uganda rock phosphate, using the same dressings. Comparative tests with other phosphatic fertilizers such as Seychelles phosphate and bone meal showed that soda phosphate was more available to plants. It was found to be almost as effective as the phosphate in materials of the superphosphate class, provided that it was mixed in the soil within the placement zone. During the war it was not feasible to carry out long-scale field experiments, but in 1945 the Kenya Department of Agriculture was able to arrange for a few field trials, using soda phosphate prepared in the pilot plant of the East African Industrial Research Board: these trials gave fair to very good responses in different lands, thus tending to confirm the indications given by

the earlier pot culture trials. The demand for the new local processed phosphate was immediate and large, but there remained certain technical difficulties in large scale calcinations in a rotary kiln which delayed the building of a suitable plant for commercial production. Meanwhile a method of small-scale calcinations on the farm was worked out and used by several farmers to produce a rather crude product of varying composition. Most of the technical difficulties in large-scale production have since been overcome and two commercially owned plants are now in operation. At this stage the whole problem of fertilizer requirements was placed on an East African basis. A fertilizer scheme staffed by the East African Agriculture and Forestry Research Organization and wholly financed by Colonial Development and Welfare funds was inaugurated. It worked in close association with the territories, and conducted an extensive three-year programme (subsequently extended to a fourth year) on a wide variety of soils in the African reserves, especially in the densely populated areas around Lake Victoria. The Kenya Government inaugurated and financed a parallel programme of experiments in the Kenya Highlands under a team led by an I.C.I officer. The two schemes worked in the closest co-operation throughout. Their results are reported in separate papers.

Holme R.V., Sherwood E.G.P. (1953) Abridged report of the highland fertilizer scheme, covering wheat and maize only. East African Agricultural and Forestry Journal

These experiments were carried out over a period of three years, from 1948 to 1950, primarily with the object of obtaining information on the comparative value of the three forms of phosphate, Uganda rock, soda phosphate and superphosphate in the European highlands of Kenya, and to see whether nitrogen, phosphate and lime would assist their action. In 1948 the experiments included the three forms of phosphate, each at 0, 1 and 2 levels, in the presence and absence of nitrogen, potash and ground limestone. The ground limestone was broadcast at 30 cwt. per acre and harrowed, or raked, into the soil: it had no effect except in five experiments where the soil pH was below about 5.0 in which it gave an uneconomic average yield increase of 100 lb. per acre. The remaining fertilizers were applied in drills which were opened mid-way between alternate pairs of seed drills. This method of application proved unsatisfactory as a strong weed growth which developed immediately over the fertilizer furrow tended to crowd the wheat in the early stages and it is also probable that the crop roots took some time to reach the fertilizer. This probably accounted for the relatively small responses which were obtained, even to phosphate, in 1948. In the 1949 and 1950 experiments the fertilizers were drilled with the seed. The treatments were soda phosphate and double superphosphate, each at four levels, with and without potash and with and without nitrogen, the latter applied either “early” (with the seed), or “late” (at piping time). In 1948, Uganda rock phosphate at 2.3 and 4.6 cwt. per acre gave negligible responses except in one experiment on the Kinangop, and even there it was much less effective than the other two phosphatic fertilizers. Soda phosphate and double superphosphate produced considerable yield increases in all seasons except on the lower slopes of Mt. Elgon, in an area near and in the Njoro “deficiency area”. In the latter area there is evidence of a need for phosphate but some other factor, possibly a deficiency of a trace element, prevents normal growth of wheat, especially when phosphate is added. The same amount of citric soluble P_2O_5 was markedly more effective when applied as double superphosphate than as soda phosphate except in the Kipkabus area where the two fertilizers were about equal in their effect on an equivalent citric-soluble P_2O_5 basis. In all responding areas both fertilizers had a marked effect on early growth of wheat, the growth measurements at this stage and the yields harvested being strongly correlated. This indicated a fallacy in the common assumption that the water-soluble superphosphate would give the plants an initial kick-off and then become unavailable, whereas the citric-soluble soda phosphate would be less readily available for a longer time. In 1948, potash at 50 lb. per acre of muriate, gave an overall average response of about 100 lb. per acre, a positive response being obtained in 25 out of 30 experiments and a significant response in 13. In 1949 and 1950 the overall response to potash was negligible. The lack of effect in the two latter years may have been due to a seasonal difference or to the change in mode of application of the fertilizer. Nitrogen at 106 lb. per acre of sulphate of ammonia, gave an average response of only 20 lb. per acre. Even on the slopes of Mt. Elgon, where it was most effective, the response to nitrogen was not large. It is rarely worth applying more than 10-20 lb. of sulphate of ammonia per acre. The treatments and experiments and experimental methods used for maize in the three years were the same as those described for wheat except that in 1948 fertilizer was placed in a separate furrow four inches from each seed furrow and in 1949 and 1950 it was placed below the seed, either separated from the seed by a thin layer of soil or mixed lightly with the soil at the bottom of the furrow. With this method of placement there was some reduction in germination where soda phosphate was used, especially under dry conditions, a slight reduction with potash and nitrogen, and, on the average no reduction with superphosphate, although even this fertilizer had a deleterious effect in some experiments. The reduction in germination did not affect the stand of plants after thinning. In these experiments, which were carried out in the Uasin Gishu, Trans Nzoia and Nakuru districts, soda phosphate and superphosphate consistently increased yields, chiefly through increasing the number of cobs produced, although there was also a small increase in weight of grain per cob. In each area the increase produced by a given dressing of double superphosphate was about the same as that produced by double that dressing of soda phosphate on a citric-soluble P2O5 basis. In the Nakuru area both the response to phosphate and the superiority of superphosphate were greater than in the Uasin Gishu and Trans Nzoia. Uganda rock phosphate, used in 1948 only, had no appreciable effect. The effect of sulphate of ammonia (106 lb. per acre) at sowing time was variable. In some cases quite large, economic and significant yield increases

were recorded, especially in the Uasin Gishu and Trans Nzoia, but in other cases the response was unimportant. Application of nitrogen at tasselling time had a more consistently beneficial effect particularly in the Uasin Gishu and Trans Nzoia. More detailed investigations are needed before sound recommendations can be made for nitrogen fertilizing, but it is suggested that, on the average dressing of 1/2 to 1 cwt. of sulphate of ammonia per acre both at planting and tasselling time would be economic. Nether muriate of neither potash nor ground limestone had any effect. The residual effect of phosphate was partly studied by inspection of experimental sites in the following year at a time when it was considered that effects were most likely to be seen. Residual yields were also accurately recorded from a few experiments. The residual effect of phosphate was found to be similar on a citric-soluble P2O5 basis irrespective of the form of phosphate originally applied. The small amount of statistically valid evidence indicates that residual effects may be expected in some areas. The residual effect of phosphate requires further study since the experimental programme was not designed to examine this aspect. Residual effects of ground limestone were measured on two of the five sites where initial responses were obtained. There were no residual responses to potash or nitrogen.

Robinson P. (1953). Responses of wheat and maize to phosphate on different soil types in the Kenya Highlands. *East African Agricultural and Forestry Journal*

Even following a detailed survey for the best possible site for representative plots, there are often appreciable differences in temporary soil fertility which cannot readily be observed but which are reflected in the vigour of growth. In the African settled areas there is the added difficulty that small units of land have been subjected to different cropping treatments over varying periods. The best that can be done is to select representative sites which have the greatest degree of apparent uniformity within an estimated mean fertility level. In the Highland Fertilizer Scheme, the results of which are summarized by Holme and Sherwood elsewhere in this report, the soils of some 80 experimental sites were grouped into eight main types. The statistical analysis of the responses was based on these. The relationship between the described soil types and phosphate responses showed that the variation within each of seven classified soils carrying wheat (Mean Standard Error of 1.68 bags per acre) is much smaller than the variation (Mean Standard Error of 4.91 bags per acre) between different soils. The relationship is not entirely due to similar intrinsic soils, as the breakdown into soil types tends to group together areas with similar incidence of disease and about the same time of planting, usually the same variety of wheat. These factors as well as the soil itself are accounted for in the responses and in the recommendations made. The named soil types and their phosphate requirements are as follows:- The Kinangop brownish-grey silt loam with seasonal impeded drainage contains 20% to 30% of a siliceous clay and 35% to 45% of silt with a poorly developed soil structure, below which there is a compact horizon with black and orange mottling and murram pellets: underneath this layer there is an impervious chocolate to greyish-black clay. Without added phosphate the yields of wheat are very low and uneconomic but there is a marked response to phosphatic fertilizers. On comparing dressings of 500 lb. per acre soda phosphate with 160 lb. double superphosphate, statistical analysis indicates that, at present prices of fertilizers and of Grade I wheat, increases of 81/2 bags of wheat per acre could be expected from the soda phosphate, giving a profit of Sh. 367, whereas superphosphate should give an increase of 91/2 bags with a profit of Sh. 419. These are expected responses computed from the data available from nine field trials, and they will of course, be affected by seasonal variations of climate and local variations of soil: they cannot be treated as accurate forecasts. The Uplands dark brown to orange-brown mellow loam is a leached soil with 40% to 50% of lateritic clay and 20% to 30% silt overlying a brownish-orange to orange-red heavier sub-soil, locally with iron and manganese mottling, derived from tuff and trachytic tuff on slight slopes. This type includes two soil series, the one naturally well drained on the upper slightly steeper slopes, and the other with slightly impeded drainage at lower levels, but it would be difficult for farmers to separate them. On this soil, using 430 lb. soda phosphate or 130 lb. double superphosphate per acre, it is expected that soda phosphate should give an increase of 51/2 bags of wheat per acre, with a profit of Sh. 218 while superphosphate should also give about 51/2 bags per acre response, with Sh. 234 profit. The Njoro dark brown loam is a comparatively young, little leached soil with 30% to 35% clay, over an orange-brown, gritty loam derived from black tuff and fine ash. It is rich in bases, with high amounts of magnesium and potash and also of soluble silica. The colour of the surface soil becomes a slightly orange-brown after prolonged cultivation, but it still contains a high amount of total soil nitrogen. Although yields of wheat have fallen following long cultivation, this soil gives no response to phosphate. The Rongai reddish-brown to greyish-brown, gritty (ashy), coarse sandy loam to gritty, sandy clay-loam is similar to the Njoro type in being little leached, well supplied with bases, and with good values for exchangeable calcium, magnesium and potash and also for total nitrogen. It gives slightly better yields than the Njoro soil without phosphate, varying according to fertility levels, but it differs in that there is a fairly good response to added phosphates. There is also a small response with maize. Statistical analysis suggests that, with wheat,350 lb. per acre of soda phosphate should give an increase of over 3 bags per acre with a profit of Sh. 112, whereas 110 lb. double superphosphate should increase the yield by 31/2 bags with a profit of Sh. 139. The profits with maize are rather lower; 180 lb. soda phosphate giving 21/2 bags per acre extra, with Sh. 67 profit and 110 lb. double supers giving nearly 5 bags extra with Sh. 118 profit. The Kipkabus brownish-red loam behaves as a friable loam, even although it contains 50% to 70% of lateritic clay on dispersion; it overlies a dark red friable clay-loam. In the lower subsoil there are soft iron and manganese pellets, with more secondary manganese deposits near the weathering parent rock, a phonolite.

This soil type has been highly leached and is low in all bases except magnesium,. It shows a fairly good to good response to added phosphates, and with wheat it can be expected that 440 lb. soda phosphate should increase the yield per acre by 51/2 bags with Sh. 226 profit, while 120 lb. double super should give an increase of over 4 bags with Sh. 126 profit. The Plateau orange-brown loam overlying murram is an easily recognized orange-brown loam over a gritty orange-red loam, with increasing amounts of iron and manganese concretions below the first foot, and with earthy laterite or "murram" about 3 ft. below the surface. It is moderately leached, with a fair amount of bases, but it is low in nitrogen. After long cultivation this soil type gives low yields of wheat and only a fair response to added phosphate. By adding 330 lb. soda phosphate an increase of 21/2 bags of wheat per acre can be expected, with a profit of Sh. 96; by adding 100 lb. double supers roughly the same response and profit are likely. The Moiben soil type is a reddish-brown, brown and grey-brown sandy loam to loam and contains at least three soil series but all have the common property of being derived from a mixture of lava and gneiss rock in varying proportions. All are naturally well drained, deep, resorted soils with weathering rock fragments of lava and gneiss and without any marked soil horizons or mottling. Their content of bases is fairly high, and they give good yields of wheat with only small responses to phosphate. By adding 260 lb. soda phosphate an increase of about 13/4 bags of wheat per acre and a profit of Sh.53 could be expected, whereas with 90 lb. double supers over 2 bags per acre and a profit of Sh. 73 is the estimated response. Smaller dressings of phosphate give some profit with maize, in that 80 lb. soda phosphate will give an increase of nearly a bag an acre and Sh. 19 profit, while 70 lb. superphosphate should give 2 bags per acre more and Sh. 40 profit. The Kitale reddish-brown to brownish-red compacting coarse sandy loam to coarse sandy clay-loam is mainly derived in situ from gneiss rock with locally a shallow mantle of similar-looking locally resorted material. There is a great depth of a slightly heavier, uniform red loam to fine sandy clay-loam subsoil without any mottling. It differs from the lava derived soil towards Endebess in that although it contains about 40% coarse sand, it readily sets hard on drying out, when cultivation becomes difficult. The surface soil is high in bases. Wheat is not usually grown on this soil type. Maize gives some profit to added phosphate, 100 lb. soda phosphate giving an additional bag per acre at a profit of about Sh. 23, while with 80 lb. double supers about 23/4 bags and a profit of Sh. 60 can be expected. The Endebess red loam is a chocolate-red to red loam to fine sandy clay-loam, which overlies a great depth of dark red, friable clay-loam derived from Mount Elgon lava and tuff. It is high in bases, particularly in magnesium and potassium. It produces very good yields of wheat with a low response to phosphate. The dressings given above were calculated as the mean theoretical dressings which would give the farmer the most profit on present prices. Because of differences in season, site, condition and management, the above calculated optimum dressings are only approximate. Dressings some 20% to 40% lower will probably be preferred by the farmer in most cases because of the smaller initial outlay, and less chance of a large loss if the crop fails due to poor rains. In addition this large reduction in application will result in only a small percentage drop in profit: a 20% reduction gives only about 3% less profit and a 40% reduction only about 8% less profit. The African Fertilizer Scheme, which is described (by Doughty) elsewhere in this report, was also examined and the soils of the experimental sites were classified as far as possible. Although ten main soil types were identified, including variants, there were many instances of too few representative experimental sites within a recognized soil type, and in consequence the number of soil types that could be usefully correlated with a sufficient number of completed experimental trials had to be reduced to six. There were not sufficient data to work out optimum dressings and only general observations can be made, based on the response of maize, sorghum and finger millet to the common dressing of 1 cwt. of triple supers per acre. In general terms, it can be stated that the pallid-coloured soils showed only small responses to phosphate, and that the need for this class of nutrient increases with the development of red and orange-red colours, first when this occurs in the subsoil, and that it is greatest when the whole soil profile is highly coloured. These latter more leached soils have good supplies of other plant nutrients, and, though they carry fair to good crops without phosphate, they give the greatest response to such applications. In these African Fertilizer Scheme trials, there was a frequent response to a top-dressing of 1 cwt. per acre of sulphate of ammonia with both maize and sorghum, whereas in the Highland Fertilizer Scheme trials the mean response was negligible. In this connexion it can be noted that the response to nitrogen in the African Fertilizer Scheme was greater in the pallid-coloured, more sandy soils where phosphates were less needed, and least with the more highly coloured soils where the response to phosphate was greatest. Immediate soil conditions showed a fair response to both nutrients.

Doughall H. W. (1926) Fertiliser experiments on ley establishment and on permanent grassland in the Kenya highlands. *East African Agriculture and Forestry Research Organization crop responses to fertilizers conference proceeding*, Nairobi, Kenya

In 1926 attention was directed by the Committee of Civil Research to the grasslands of Kenya, when this colony was selected by it as the most suitable for pursuing an inquiry into the mineral content of natural pastures. Boyd-Orr, who directed this investigation, selected four districts (Naivasha, Athi Plains, Nakuru, and Molo), in which he studied the chemical composition of natural herbage as affected by soil and climate. Results of preliminary work indicated clearly that, in three of the four districts, pastures were deficient in all mineral nutrients and also in protein. Phosphorus was the element most deficient and he considered it to be the factor limiting the assimilation of other minerals by the plant. Boyd-Orr inclined to the view that if Phosphorus were supplied by fertilizers, the amount not only of phosphorus but also of calcium would be increased in the pastures. However,

when the most deficient area was treated with fertilizers, the first direct effect to be measured was productivity and yields of herbage were increased from 25% when common salt was used, to well over 300% where nitrogen and phosphate were used together. It is unfortunate that the composition of the herbage harvested was not reported, but we may infer that its mineral status was enhanced, for it is recorded that when stock were allowed access to the plots at the end of the test. They "showed a marked preference for those which had been fertilized, while controls were left practically untouched". It was observed that where phosphates had been applied the herbage maintained its green appearance for a longer period during the subsequent dry weather. This pioneer work of Boyd-Orr and his colleagues was not advanced to any marked extent in the years which followed, but nevertheless, it does seem that a proper appraisal of grass was being sought. It was beginning to be regarded in all its forms as: (1) the "raw-material" factor limiting the formation of milk, meat, mutton, wool e.t.c and (2) in the form of a ley, as an integral and probably pivotal crop in a suitable system of alternate husbandry. The need for field experimentation to test these views became more urgent in recent years and in 1950,under the Government-sponsored "Highland Fertilizer Scheme", a restricted number of field experiments were carried out with the object of examining the effect of certain out the object of examining the effect of certain fertilizers on the productivity of natural pastures and established grass, and on the establishment of suitable ley swards. These experiments demonstrated beneficial effects of phosphate on ley establishment, and marked herbage-yield responses to nitrogen on established leys and certain natural pastures. Lime and Potash at the levels applied appeared to have appreciable effect on the productivity of the few permanent pastures investigated. In 1951 the Department of Agriculture extended the scope of this work and studied the role of a phosphatic fertilizer (P) and a nitrogenous fertilizer, sulphate of ammonia (N) on ley establishment and on the productivity of established grass and natural pastures, including rough grazing. These studies were undertaken on different kinds of soil, with different herbage species, and in areas of varying altitude and climate, with the object of (1) obtaining an assessment of optimum dressings of these fertilizers, and (2) determining responses to P and N as measured by productivity and nutrient value of the herbage. In ley-establishment trials, factorial combinations of P (18% Citricsoluble P_20_5) and N (20%) were used. There were 16 treatments and two replications. Fertilizer dressing applied at the time of seedling down were: 0, 30, 60, 120 1b. N per acre and 0, 36, 72, 144 1b P_20_5 per acre; and each of the following grasses-Rhodes, Molasses, Cocks foot and Kentucky fescue-were sown in combination with a legume-Lucerne or Seradella. In the permanent grassland trials, factorial combinations of the same fertilizers were arranged in the form of a quasi-Latin square, with 18 treatments and two replications. Fertilizer dressings were: 0, 15, 30, 60, 90, 120 1b.N per acre and 0, 36, 72 1b.P_20_5 per acre, broadcast at the beginning of the growing season. Nitrogen was re-applied at the same levels after time the herbage was cut. Herbage was cut when it had reached a stage growth considered suitable for stock grazing. Yields of fresh material were recorded and samples were taken for dry matter determinations and chemical analysis. Soil samples to a depth of six inches were obtained from plot of each plot of each experiment prior to the initial application of the fertilizers and again after each herbage cut; with permanent grassland, however, the soil samples were taken before re-applying nitrogen. Final samples were obtained in December, 1951. Herbage samples obtained from the first cut in each kind of trial were analysed for crude protein, phosphoric oxide (P_20_5) and lime (CaO).

Organic Fertilizers

Overview

Organic fertilizers refer to materials derived from organic resources like animal and plant matter. The animal sources could include blood meal, borne meal, chicken litter, and animal excreta. On the other hand plants sources include the compost, green manure and crop residues. Generally, organic fertilizers are important sources of carbon/soil organic matter which in addition to improving soil nutrient status is crucial for soil physical and biological functions. This section presents abstracts in regard to studies that have been carried to understand the physical, chemical and biological functions of organic fertilizers across various soil types in arable agro-ecosystems of Kenya.

Mutegi J. K., Jama B. A., Silim S. and Ameru J. N. (2014). Potential of grain legume fallows to address food insecurity and boost household incomes in western Kenya. *International Journal of Development Research. Vol. 4, Issue, 5, pp. 1154-1161, May, 2014;* ISSN: 2230-9926

A pigeon pea fallow-maize crop rotation trial was carried out over a period of 4 seasons in western Kenya. The trial compared six high altitude long duration pigeon pea varieties i.e. ICEAP 00020, ICEAP 00040, ICEAP 00048, ICEAP 00053, ICP 9145 and ICP 13076 and a medium duration variety i.e. ICP 13211 for productivity, post fallow maize crop yield and financial returns indicators. Long duration pigeon pea varieties take 140-180 days to mature while medium duration varieties take >200 days to mature. Continuous maize cropping acted as a control. Depending on the variety, pigeon pea grain yield ranged between 1.3 and 1.9 t ha-1. Post fallow maize grain yield from each of pigeon pea variety plot was approximately 3 fold higher than yield from continuous maize plots. The medium duration pigeon pea plots yielded significantly higher maize grain than the long duration (ICEAP 00053, ICEAP 00040) pigeon pea variety plots. Relative to the control, incremental returns to land were highest for medium duration pigeon pea fallow plots (619 USD/ha) and lowest for ICEAP 00040 fallow plots (305 USD/ha). We estimated that by selecting an appropriate pigeon pea variety for a fallow-maize rotation system, a household could produce sufficient food for consumption and remain with a surplus of approximately 2.8 tons for sale. For widespread adoption of pigeon pea based technologies in western Kenya, there is a need for policy improvement on issues related to improved seed production systems, cost of fertilizers, extension services, and market for the end products.

Omondi J. O. (2013). Effect of tillage on biological nitrogen fixation and yield of soybean varieties. Msc. Thesis, Egerton University, Kenya

Low soil fertility has become a major impediment to crop production in most parts of sub-Saharan Africa. Over the years technologies have been generated to combat this problem and the most used application of organic and inorganic fertilizers. However, inorganic fertilizers are not always available to most smallholder farmers due to their high costs and poor accessibility. Use of legumes to fix biological nitrogen is a viable option. However, the biological nitrogen fixation is influenced by soil moisture availability and consequently the type of tillage used. The aim of this study was to determine the effect of tillage methods on biological nitrogen fixation and grain yields of three soybean varieties. The study was conducted in four sites representing four agro-ecological zones of western Kenya. The treatments were laid in a randomised complete block design in a split plot arrangement. Tillage methods (No tillage and conventional tillage) were the main plots and soybean varieties (Nyala, SB19 and SB20) were subplots. Determination of N fixed was conducted using ^{15}N abundance method. The results showed that Nyala fixed higher amount of nitrogen under no till at Alupe (28.7 kg/ha) and Bungoma (11.3 kg/ha). At Ugunja and Rarieda the interactions between variety tillage were no significant. Overall amounts of N fixed in no till plots were higher than till plots for all sites combined. Soybean grain yield between the tillage methods was not different in all sites and also between varieties. Alupe site had the highest grain yield (1543.0 kg/ha) and Nyala fixed high nitrogen across the four sites. No till should be encouraged to increase biological nitrogen fixation.

Kamau M. S. (2012). Evaluating quality of composts made from organic agro-wastes and their influence on maize yield and soil fauna in Western Kenya. Msc Thesis, University of Eldoret, Kenya

Degradation of soils' physical, chemical and biological properties in arable lands of sub-Saharan Africa mostly results from little or no organic resource application coupled with sub-optimal fertilizer application. A study was conducted in Buyangu and Ivakale villages, Kakamega over three seasons from March 2020 to August 2011 to evaluate the potential of six locally available organic biomasses namely; cow manure, maize stover, Tithonia diversifolia, Sugarcane straw, baggasse and filter mud for compost production and their effect on soil quality, soil fauna diversity and on maize yields. Treatments consisted of six composts made from six organic biomasses inorganic fertilizer treatment and no-input control and these were replicated four times in randomized complete block design (RCBD). Soil samples were analyzed for chemical and biological properties. Earthworms were collected using soil monoliths while nematodes were sampled and extracted using steel core samplers and Baerman pan technique, respectively. Data obtained were subjected to analysis of variance using GENSTAT statistical software while treatment differences were evaluated using least significant difference (LSD) at 5% level of significance. Strength and statistical significance of soil chemical properties with microfauna abundance and taxonomic richness was conducted using the programme CANOCO 3.1. There was no significant difference in chemical properties of the different composts types. Amending soils with composts significantly ($p<0.001$) increased soils N, C and P compared to no-input control plots. In these C, N and P increased soils by 90, 21 and 2% respectively upon addition of composts. The no-input control plots recorded a 37% increase in C, but a decline of 15% and 40% in N and P, respectively. Fertilizer treated soils recorded an increase of 92, 26 and 81% in C, N and P respectively. Earthworm abundance and biomasses were significantly($p<0.001$) higher in compost amended soils(38 individuals m^{-2} and 1.2 g/m) compared to fertilizer and no-input control plots which had no

average 10 individuals/m^2 and a biomass of 0.3 g/m^2 . The positive relationship between macro fauna abundance and soil chemical properties were highly significant (P=0.007). Generally, plant-parasitic nematodes decreased with addition of composts, while bacteria-feeding nematodes increased with the application of composts. Similar to macro fauna, the positive relationship between soil chemical properties and nematode density were also highly significantly (P=0.001). Maize yields over the three seasons were significantly (P<0.001) highest in fertilizer treated plots (4.4 t/ha) followed by composts (2.8 t/ha) and lowest in no-input controls (1.4 t/ha). However, the benefit cost ratio obtained from yields was highest on composts treated plots followed by fertilizer treated plots and lowest in control plots. Results of this study demonstrate the potential of composts in improving soil fertility and health and therefore an increase in crop productivity.

Ndung'u-Magiroi K. W. (2012) Screening and Evaluation of Phosphate Solubilizing (PS) Commercial Biofertilizers. PhD Thesis, Chapter four. University of Eldoret, Kenya

Many Plant Growth Promoting rhizobacteria occur in soil. However, their numbers are not sufficient to compete for space and nutrients with other bacteria commonly established in the rhizosphere. Hence, for agronomic utility, inoculation of plants with target microorganism at a much higher concentration than those normally found in soil is necessary to take advantage of their crop yield enhancement. Positive and sometimes negative effects of laboratory cultures have been reported when inoculated in different crops. Although several commercial biofertilizers are available, their efficacy in maize and soybean growth promotion has not been documented. This study aimed at screening several phosphates solubilising (PS) biofertilizers under green house and field conditions and determines if addition of external P improves the efficacy of these biofertilizers in maize and soybean production. Ten commercial PS biofertilizers were evaluated with addition of their Minjingu PR or water soluble P in two constraining soil types under green house conditions. The biofertilizers with >30% increase in Biomass were then considered as effective and subjected to field testing in Rarienda, Bondo County, Chuka, Meru South and Luhya, Bungoma County. The results showed that in Maize, the Biofertilizer responses were noted after 5 weeks of growth portraying the need for external soluble P for synchronized P uptake. Although Myco tea® Soluble Maxx® and PHC Biopak® had significant uptake on soybean and maize growth under controlled conditions, the biofertilizers' efficiency was very low for maize and soybean production in the field. This implies that commercial PS biofertilizers may not be effective in replacing conventional fertilizers.

Macharia P. N., Gachene C. K. K., Mureithi J. G., Kinyamario J. I., Ekaya W. N. and Thuranira E. G. (2011). The effect of introduced forage legumes on improvement of soil fertility in natural pastures of semi-arid rangelands of Kajiado district, Kenya. *Tropical and subtropical Agroecosystems Journal* Vol.14 pp. 221-227

A two phase study was carried out from 2002 to 2005 in the semi-arid rangelands of Kajiado District, Kenya to determine the effect of introduced forage legumes on soil fertility improvement of natural pastures. During legume evaluation phase, *Neonotonia wighitii* (Glycine), *Macroptilium atropurpureum* (Siratro) *Lablab purpureus* cv. Rongai (Dolichos), *Mucuna pruriens* (Velvet bean) and *Stylosanththes scabra* var. Seca (Stylo) were screened for adaptability and growth performance under the semi-arid conditions for two years. Results of soil analysis showed there were significant increases in soil pH (4.92 to 5.36), organic carbon (1.17 to 0.22%), nitrogen (0.17 to 0.22%) and potassium (1.23 to 1.68 me %) probably due to the large amounts of organic residues produced by the legumes (particularly Glyine, Siratro and Stylo which are perennials). The calcium content decreased significantly from 7.97 to 4.50 me% (which was attributed to plant uptake) while the decrease of phosphorous was not significant. During the second phase for 1.5 years Glycine, Siratro and Stylo were integrated into natural pastures. The results showed that only the soil pH significantly increased from 5.23 to 5.31 while all the other nutrient decreased results, which were attributed to production of less organic residues by the legumes compared to the residues produced during the legume evaluation phase. The study concluded that Glycine, Siratro and Stylo were capable of improving the soil fertility of semi-arid natural pastures only if the respective dry matter production was 10.31, 7.81 and 3.52 t/ha amounts which were able to produce large amounts of organic residues.

Opala P. A. (2011). Management of organic inputs in east Africa: a review of the current knowledge of future challenges. *Archives of Applied Science Research Journal*. 3(1) 65-76

Organic inputs in Africa are used mainly as sources of crop nutrient but most of the ones available on the farms such as crop residues, animal manures and composts are of low quality and insufficient quantity. Proper management of such organic inputs to ensure sustained crop productivity poses a major challenge. Current research efforts aim to increase the understanding of the interactions between organic inputs, the soil and crop with developing predictive management guidelines. The factors influencing nitrogen mineralization in various plant residues have been identified and a decision support system (DSS) which makes practical recommendations for their appropriate use of nitrogen sources has subsequently been developed. This DSS has, however, not proved useful when applied to animal manures. To increase nutrient use efficiency, synchronization of nutrient release from the organic materials with crop demand has been attempted but attainment of perfect synchrony appears

unlikely. Given that neither organic nor inorganic fertilizers alone can achieve sustainable crop productivity, focus has now shifted to the integrated soil fertility management paradigm that advocates for combined use of organic and inorganic sources of nutrients. Whereas the biophysical aspect of organic input management have been studied in detail, social and economic analyses are rare. Our knowledge of organic input systems, therefore, remains imprecise. This has made development of economically and socially acceptable guidelines for organic input management difficult. Adoption of the organic input technologies is consequently disappointingly low and biggest challenge is to have these technologies adopted by farmers.

Chivenge P., Vanlauwe B., Gentile R., Six J. (2010) Organic resource quality influences short-term aggregate dynamics and soil organic carbon and nitrogen accumulation. Soil Biology & Biochemistry 43 (2011) 657e666.

Organic C inputs and their rate of stabilization influence C sequestration and nutrient cycling in soils. This study was undertaken to explore the influence of the combined application of different quality organic resources (ORs) with N fertilizers on the link between aggregate dynamics and soil organic C (SOC) and soil N. A mesocosm experiment was conducted in Embu, central Kenya where 4 Mg C/ha of Tithonia diversifolia (high quality), *Calliandra calothyrsus* (intermediate quality) and *Zea mays* (maize; low quality) were applied to soil compared to a no-input control. Each treatment was fertilized with 120 kg N/ha as urea [(NH2)2CO] or not fertilized. The soils used in the mesocosms were obtained from a three-year old field experiment in which the same treatments as in the mesocosm were applied annually. No crops were grown in both the mesocosms and the thee-year field experiment. Soil samples were collected at zero, two, five and eight months after installation of the mesocosms and separated into four aggregate size fractions by wet sieving. Macro-aggregates were further fractionated to isolate the micro-aggregates within-macro-aggregates; all soils and fractions were analyzed for SOC and N. The addition of Ors increased soil aggregation and whole SOC and soil N compared to the control and sole N fertilizer treatments. There were no differences among different OR qualities for whole SOC or soil N, but maize alone resulted in greater mean weight diameter (MWD), macro-aggregate SOC and N than sole added Calliandra. The addition of N fertilizer only influenced SOC and soil N dynamics in combination with maize where SOC, soil N and aggregation were lower with the addition of N fertilizer, indicating an increased decomposition and loss of SOC and soil N due to a faster aggregate turnover after addition of N fertilizer. In conclusion, compared to high quality ORs, low quality ORs result in greater aggregate stability and a short-term accumulation of macro-aggregate SOC and N. However, the addition of N fertilizers negates these effects of low quality ORs.

Gacheru E, Rao M.R. (2010). Managing striga infestation on maize using organic nutrient sources in western Kenya. *International journal of pest management*. Vol. 47 pp. 233-239

Although the use of foliar biomass (organic residues) of trees and shrubs as a source of nutrients to food crops has been recommended in many countries in sub-Saharan Africa, the effects of biomass quality on striga (*Striga hermonthica*) infestation and yields of maize are not known. Organic residues of six species *Tithonia diversifolia*, *Sesbania sesban, Senna spectabilis, Calliandra calothyrsus, Lantana camara* and *Croton megalocarpus* were compared with inorganic nutrients applied through fertilizers at five rates of phosphorus (0,10,25,50 and 150 Kg P/ha) in combination with 120 Kg N/ha, and 150 Kg P/ha applied alone. The study was conducted in western Kenya over 2 years (four cropping seasons) on a farm severely infested with Striga hermonthica and deficient in P. The fresh foliage of species at 5t (dry weight)/ha and fertilizers were applied every season to the respective plots. Striga infestation was lowest when 120 Kg N/ha was applied with or without P. Phosphorus application alone did not influence Striga infestation. Reduction of Striga by organic residues depended on their rate of decomposition and N mineralization, which in turn was determined by quality in terms of C: N and lignin+ polyphenol to N ratios. With a high tissue concentration of N and low lignin and polyphenols, Tithonia biomass rapidly mineralized N and reduced Striga, similar to inorganic N. Although Sesbania biomass also decomposed rapidly, it reduced Striga only in the fourth season. Other organic residues did not affect Striga infestation probably because of slow decomposition and slow release of N. Crop yields were primarily affected by P deficiency, so the reduction of Striga alone did not result in increased yields unless P deficiency was corrected. Although biomass of Croton and Lantana had limited effect on Striga, they increased yield on this P-deficient soil by supplying 10-13 Kg P/ha per season. Only the high quality organic residues such as Tithonia can suppress Striga infestation, besides supplying nutrients for increasing crop productivity on smallholder farms. Keywords: Striga, biomass, maize, nutrients, soil fertility, Kenya.

Gitari, J. N, Mureithi, J. G, Mugendi, D. N, Kungu, J. B. (2010). Decomposition pattern of mucuna residues as moderated by high carbon residues to synchronize nutrient release for maize growth. *Proceedings of 12th KARI Biennial Scientific Conference*. 8 – 12 November, 2010. pp 403-409

Land productivity in central highlands of Kenya is mainly constrained by low and declining soil fertility. The use of combined low and high quality plant residues could ensure timely nutrients release for enhanced crop uptake. A field study was therefore carried out at Embu, Kenya to investigate the decomposition dynamics of mixed mucuna: stover residues. Litter bags with similar contents to those of the maize-mucuna plots were superimposed in the respective plots. The mass loss results for the mucuna: stover residues followed the first-order exponential decay pattern with a decomposition half life of (t50) of 7.3 days compared to 6.0 days for the pure mucuna residues. The inclusion of these low quality residues was beneficial in improving the overall nutrient release by the fast-decomposing mucuna green manure legume residues. The resultant maize grain yields from the treatments with mixed residues were higher than those after pure legume residues suggesting that the presence of these low quality residues was synergistic. The five seasons' average maize grain yields in plots with legume residues mixed with the highest quality (6.0 Mg/ha) of the high carbon residues were 17% higher than those of the pure mucuna residue plots.

Kiiya W. W., Mwonga S. M., Obura R. K. and Ngugi J. G. (2010). The Effect of incorporation of legumes on selected soil chemical properties and weed growth in a potato cropping system at Timboroa, Kenya. *Journal of Agronomy* Vol. 5(17), pp. 2392-2398

The effect of incorporation of lupine and garden pea on selected soil chemical properties and growth of weeds in potato cropping system was evaluated in North Rift, Kenya. The study was carried out in a well drained, extremely deep, dusky red to dark reddish brown, friable clay, acidic humic top soil. Two weeding regimes (at legume incorporation stage and/or at 50% potato flowering stage), Three nitrogen levels (0, 60 and 120 kg N/ha) applied as CAN and two legumes plus a control (garden pea, lupine and none) were evaluated in a split-split plot design with weeding regimes as the main plots, N as sub plots and legumes as the unit plots. Incorporation of legumes significantly ($p<0.05$) raised soil pH from 3.6-3.9 and to 4; increased soil available P from 15mg/kg to 25 and to 29 mg/kg for garden pea and lupine, respectively. The two legumes interacted with weeding regime and N reducing sheep sorrel weed density biomass. That legumes may best improve soil fertility and reduce soil acidity when incorporated in the soil as green manure.

Mutinda, G. K. (2010). Legume fallow for fuel wood production and soil fertility improvement in Sauri millennium village, Saia district, Kenya. Msc. Thesis, Kenyatta University, Kenya

This research was conducted between March 2008 (before start of long rains) and August 2008 (the season for harvesting maize), in Sauri Millennium Village, sub location of Yala division, Siaya District, Kenya. The general objective of this study was the adoption of legume fallows in Sauri millennium village with specific objectives;-(i) To study the current status of legume fallows in Sauri millennium village (ii)To investigate the leguminous tree species for high fuel wood production, (iii) to find out the role of leguminous tree species for high fuel wood production, (iii) To find out the role of leguminous tree species for the improvement of soil fertility and food production in the study are, and (iv) To asses rudimentary economic implications on households from the use of legume fallows. The methodology used was a field survey based on stratified random sampling on households with and without legume fallows. The size of the Sample frame was based on the Millennium villages project households (three hundred (300) households, out of which ninety (90) households were selected for sampling. Structured questionnaire combined with observation and existing documentation were used to gather data for objectives, i, ii, and iii, while soil tests, fuel wood quantification and maize yield estimates were done to gather data for objective .iv) Social variables were analyzed by use of SPSS package, and t-test used to compare average costs and average savings from fuel wood. Soil spectral analysis was done and calibration models developed from existing Sauri soil spectra and used to make predictions of the new soil samples, and principle components analysis (PCA) model developed to compare the distribution of the two sets of soil spectra within the same spectral space. Analysis of variance (ANOVA) tests were used to compare statistical differences between treatments i.e. means of treatments for soil attributes and means of maize yield. The results showed that, soil fertility and fuel wood production were the motivating reasons for adopting legume fallows. *Tephrosia candida* is the most recommended for fuel wood and together with *Macuna pruriens* and *Tephrosia vogelli* showed better soil attributes. Mixed intercropping with *Tephrosia candida* produced 2.2 t/ha of fuel wood compared to *Crotalaria paulina* 0.8 t/ha. All fallowed treatments produced high maize yield up to 5.5 t/ha compared to none fallowed at 4.6 tonnes per hectare and the controls at 3.6 tonnes per hectare. IN conclusion the study has shown that, combining legume fallows with crops has enabled farmers to spend less t buy fuel wood from market, while producing high crop yields on their farms. This has generally improved the livelihood of the rural community. This study recommends a thorough economic analysis of the intervention introduction of other leguminous tree species, provision of credit facilities to farmers and the promotion of agricultural productivity which is among the key strategies in Sauri, in order to ensure sufficient fuel wood and food security in the area.

Muya E. M. and Mutsotso B. (2010). Characteristics of below-ground biodiversity sites in Kenya. The constrains, interventions and emerging issues. In: *Ouda et al* (Eds) *Proceedings of the 12th Kenya Agricultural Research Institute Biennial Conference. KARI Hqts November 8-12, 2010*. PP 8-12

The physical and socio- economic characteristics of BGBD sites and their constraints were investigated a basis of formulating the integrated management strategies for improved soil fertility and biodiversity. Both soil and socio-economic surveys were conducted across land use gradients using the standard methods and structured questionnaires respectively. The below ground bio diversity sites in Kenya were in Irangi and Ngangao forest in Mt Kenya region in Embu District and Taita hills area of Taita taveta district respectively. The two sites were found to be located in biodiversity hot spots that support rare and endemic plant and animal species. The Embu site was found to be situated mainly on the uplands and volcanic footbridges while Taita Taveta was found on mountain hills upper level uplands. Both sites were characterized by the steep slopes, sharp land use intensification gradient hills and upper level uplands. The combination of these factors were found to be the main and its role in sustaining agricultural productivity loss of spoil structure reduced water efficiency increased acidity and decline in soil productivity. The identified and demonstrated best - bet intervention packages caused an improvement of soil fertility by at least 2%. However the emerging issues were found to be the need to be the need to establish the cause of increasing acidity particularly in cambisols which are generally characterised by plenty of weatherable minerals improve soil structure for enhanced water uptake and retention carry and extend assessment of the watershed characteristics in terms of the environmental flows and water quality and extend the use of BGBD in improving the ecosystem functions and service in the areas beyond the biodiversity hot spots.

Mwangi P. W. (2010). Composition, decomposition and influence of butter bean, grass pea, chickpea and common bean residue on soil nutrients and maize performance. PhD Thesis, Chapter six, University of Nairobi, Kenya

Declining soil fertility due to cropping without soil fertility replenishment has led to low crop yields in the cold semi-arid region of Laikipia plateau. Incorporation of legume residues into the soil is a low cost option for soil fertility replenishment. a study was conducted in two contrasting seasons. (a wet 2007 short rains season and a dry 2008 long rains season) to determine composition, decomposition rate and influence of butter bean, grass pea, common bean and chickpea residues on soil nutrients and maize performance in the cold semi-arid district of Laikipia, Kenya. To determine decomposition, rate and nutrient release, chopped legume residues were placed in 2mm nylon mesh bags and incubated in the soil at a depth of 15 cm. Dry matter and chemical composition of the residues was determined before incubation and at 2, 4, 6, 8,10,12, and 14 weeks after incubation. Dry matter and nutrient disappearance rates were calculated, respectively, as the difference of percent dry matter and nutrient remaining between two consecutive sampling periods over time. Soil was analysed for nutrients at planting, flowering and immediately after harvesting maize in both seasons. To determine the influence of the legume residues on maize performance, the residues of the four legume species were buried in soil at a depth of 15cm in furrows spaced 90cm apart at the rate of 1 kg/m^2. Maize hybrid DHL4 commonly grown in the area was planted above the residue layers at a spacing of 90x30cm and supplied with either 60 or 0 kg N/ha. The experiment was 4x2 factorial arrangements in a randomized complete block design and replicated three times. Half of the nitrogen in the supplemented treatments was applied at planting and the other as a top dress 6 weeks after planting. Collected data included: plant height, leaf area index, growth rate, nitrogen concentration and accumulation, biomass yield, and grain yield and yield components. Chickpea residue had significant higher initial % lignin/nitrogen ratio than butter bean residue. All the crop residues had similar levels of cellulose, C/N ratio, N, CP, K and Ca. Butter bean residue had significantly higher magnesium content than the other residues than the other incubation periods. Mean dry matter disappearance rate constants from grass pea residue (0.8% and 0.51% week-1 in the first and second trial, respectively) were significantly higher than observed in residues of the other crops. Nutrient loss from the residues was in the order K>P>N>Mg>Ca. Combination of these residues and nitrogen significantly increased soil total nitrogen, phosphorus, and organic carbon at different times during the two seasons. A progressive decline in soil nutrient status and pH was observed in the control plots. Significant difference in maize performance indices and significant residue X nitrogen interaction were only observed during the wetter 2007 short rains season. During this season, residue and nitrogen application significantly increased maize growth parameters (plant height, LAL growth rate) and yield parameters (seed size, Dry matter yield, Nitrogen yield and grain yield). Percent increase in maize growth and yield parameters was highest when maize was supplied with butter bean or grass pea residues and lowest when chickpea residue was applied. Butter bean and grass pea crop residues have potential of providing soil N, P, K and Mg in the cold semi-arid region. However, when moisture is limiting as in the case of 2008 long rains season the yield benefits of residue application are less obvious in terms of crop performance.

Oyoo, J., Nyongesa M., Mbitu M., Lung'aho (2010). Organic farming: effect of kelpak and earthlee on the yield of Irish Potatoes. In: Ouda et al (Eds) Proceedings of the 12th Kenya Agricultural Research Institute Bienniaal Conference. KARI Hqts November 8-12, 2010. pp 253-256

Enhancing soil health is the cornerstone of organic farming. A variety of methods are employed, including crop rotation, green manure, cover cropping, application of compost, mulching and use of processed natural fertilizers such as kelpak and Earthlee. Kelpak an extract from the species Ecklonia maxima which contains a level of 11mg/litre of auxins and 13 µg/litre of cytokinins and Earthlee, an ultra concentrated and ultra fine 80% humate powder were evaluated to determine their effect on the fresh tuber yield of Irish potatoes (*Solanum tuberosum*) during the short rains season 2008 using clone 393385.39 (Sherekea). Treatments were laid out in a randomised complete block design replicated three times and consisted of DAP (18:46:0) At 500 kg/ha; Kelpak (11 mg/ltr of auxins and 31 µg/ltr of cytokinins) at 5 ml/L;Earthlee (80% humate powder) at 200 kg/ha, DAP (18:46:0) At 500 kg/ha+Earthlee (80% humate powder), DAP (18:46:0) At 500 kg/ha + Kelpak (11 mg/ltr of auxins and 31 µg/ltr of cytokinins) at 5 ml/L + Earthlee (80% humate powder) at 200 kg/ha and zero fertilizer (control). Kelpak was applied by dipping tubers into the kelpak solution of 5ml/L followed by two subsequent foliar fertilizers applied every two weeks starting at emergence while Earhlee was applied by coating the tubers with the powder, all the processes done before planting. Significant differences were observed for total tuber weight at P=0.05. DAP plus Kelpak dipping yielded the highest total number of tubers of 8.33t/ha. The control yielded 4.67 t/ha while DAP yielded 7.67 t/ha. Kelpak should be used together with DAP in order to realize high production of fresh tuber weight of Irish potatoes. Kelpak or Earthlee when used in isolation do not yield significantly.

Basweti C. N. (2009). Effect of organic matter quality, soil temperature and Moisture on soil Organic Matter Decomposition of a forest - Cropland Chronosequence. Msc. Thesis University of Nairobi, Kenya

Temperature sensitivity of soil carbon decomposition is a key factor in determining the response of the terrestrial carbon balance to climate change. However, the effect of substrate on temperature sensitivity of decomposition has not been incorporated into the carbon cycle models because the differences between recalcitrant and labile carbon cycle models because the differences between recalcitrant and labile carbon pools have not been demonstrated. The objective of the study was to evaluate the interaction of organic matter quality, soil temperature and water content on soil organic matter (SOM) decomposition. To obtain organic matter, with varying quality attributes, a chronosequence approach was used to sample soils from a from-cropland chronosequence in Kakamega, Western Kenya. The conversion periods were young conversion (12 years old), mid conversion (42 years old) and old conversion (77 years old). A paired design was used to pair a forest and cultivated field in the same conversion time. From each conversion time, soil was sampled to a 10 cm depth from the paired sites in three replicates in January 2009 and taken to ICRAF Laboratory where they were incubated for carbon dioxide (CO_2) Evolution at different temperatures (10^0 C, 25^0 C and 33^0 C) and soil water contents (0%, 50%, and 100% water holding capacity - WHC). The bulk sample was also analysed for total carbon (C) and nitrogen (N) using dry combustion method while SOM quality characterized by Mid-infrared spectroscopy. Total C and N loss for the past 77 years of cultivation was found to be 60% with recalcitrant carbon observed soils. Decomposition rates increased linearly (R2 =0.99; P<0.001) with temperature for both forest and cultivated soils with higher emissions coming from the forest soils. The effect of water content on the rate of CO_2 Emission had a parabolic fit with lowest emission recorded at 0% WHC and highest at around 50% WHC while the rates started declining as was content approached 100% WHC. Both labile and recalcitrant organic matter pools were found to influence (P<0.05) temperature sensitivity of SOM decomposition at different incubation periods subject to water content levels. This study clearly indicates that soil organic matter decomposition is significantly affected by soil temperature, water content and soil organic matter quality which is influenced by the land -use change and the cultivation period. Incorporation of the three factors; temperature, water content and organic matter quality into carbon cycle models will help in predicting the effect of climate change on SOC storage. It will help also in managing SOC content in various landscapes through improved land management that will also reclaim C released to the atmosphere due to land use change.

Kiiya W. W. (2009). Screening legumes for adaptability in the cool highland areas of the North rift. PhD thesis, Chapter four, Egerton University, Kenya

The purpose of this study was three-fold: to identify a legume or legumes that could perform well in the cool highlands of the North rift, and identify the legumes that fitted into the potato farming system so that when intercropped or subsequently incorporated as green manure, could benefit the potato crop through reduced soil acidity and improved fertility and lastly, if not incorporated as green manure, the legume could be effective as a smother crop to suppress weeds. Lupine and purple vetch formed relatively high ground cover, flowered early and accumulated high biomass at the initiation of flowering. These legumes also formed nodules under the cool high altitude climatic conditions in Timboroa area. However, although the study showed that all the legumes had poor nodulation and nitrogen fixation potential at 75 days after planting the legumes with high biomass accumulation may be suitable for use in soil acidity amelioration and improved soil fertility. The study also showed that high

ground cover development by the legumes corresponded with high biomass production, the two considered essential in weed suppression. Based on these parameters, lupines and purple vetch were the best legumes for growing in the cool highlands.

Kiiya W. W. (2009). Effect of legume in selected soil chemical prosperities and growth of weeds in potato cropping system. PhD thesis, Chapter five, Egerton University, Kenya

The study showed that legumes produced high herbage yields and had therefore the potential of accumulating high biomass. When incorporated into the soil, the high biomass could probably increase soil organic matter and through increased organic matter raise soil pH due to enhanced P availability following the decomposition of legume residues. However, the positive effects of the green manure legumes may not necessarily be realized in one season since the decomposition rates of various legumes probably varied due to differences in tissue carbon to Nitrogen ratio, lignin, and polyphenolic contents (palm et al., 1997). The positive effects of legumes on soil acidity could however be compromised if applied in localised areas such as in pot experiments due to accumulation of organic acids realised by the decomposing legumes which may instead contribute to increased soil acidity (White et al., 1989). When incorporated into the soil, lupine and garden pea interacted with weeding regime and inorganic nitrogen fertilizer significantly reducing sheep sorrel weed density and biomass. The highest reduction in weed density and biomass was obtained with lupine which was attributed to the higher lupine biomass accumulated and incorporated into the soil as compared to garden pea. The development of quick and effective ground cover by legumes was considered important in limiting accessibility of weeds to light, an essential requirement for photosynthesis. The high ground cover developed by butter bean was attributed to its fast growth and formation of tendrils which enabled the plant to intertwine on itself to completely cover the ground. This legume and lupine were also the earliest in attaining 50%ground cover. Purple vetch had an initial slow growth but picked up with time and continued to grow until about 20 WAP. This meant that in terms of weed, butter bean and lupine could be the best bets followed by purple vetch.

Muema E.K. (2009). Comparative effects of different quality organic resources on total soil bacterial diversity under two different environments in Kenya. Msc. Thesis, Moi University, Kenya.

Microorganisms play a vital role in restoring depleted soils and maintaining long term soil fertility in both natural and managed agricultural soils. A two year experiment was conducted across two different environments (Embu $0^0$30'S, $37^0$30'E in Central Kenyan highlands and Machanga $0^0$47'S, $37^0$40'E in Eastern semi-arid Kenya) to compare the effect of different quality organic resources on total soil bacterial diversity. Residue treatments consisted of a control (no residue input), high quality tithonia (*Tithonia diversifolia*) medium quality Calliandra (*Calliandra callothyrsus*), low quality maize stover and *Grevillea robusta* sawdust, and goat manure) at a rate of 4 ton C/ha. Subplots of each residue treatment received either 0 or 120 Kg N/ha in a split-application, and maize was cultivated each season. A blanket application of phosphorus and potassium fertilizers was done at the rate of 60 Kg P/ha and 60 Kg K/ha. Total soil bacterial diversity was assessed using PCR-DGGE fingerprinting technique was used to assess soil microbial diversity. *Grevillea robusta* and maize stover treatments with mineral N fertilizer gave the highest diversity (1.05 and 1.02), respectively. There was a decrease in diversity of bacterial communities at Embu and Machanga with application of different quality organic resources. Nitrogen application in combination with different quality organic resources had positive interactive effects on total soil bacterial diversity in plots treated with sawdust in Embu site and sawdust and maize stover in Machanga site. Different quality organic resources and mineral N therefore affect soil microbial communities. High diversity of total soil bacterial communities with *Grevillea robusta* and maize stover (low quality resources) with mineral N fertilizer forms an integral part with the integrated soil fertility management (ISFM) technology in sustainable management of soil resource. Reduced total soil bacterial diversity overtime with continuous monocropping raises a need for intercropping systems.

Jama B. A., Mutegi J. K., Njui A. N. (2008). Potential of improved fallows to increase household and regional fuelwood supply: Evidence from western Kenya AGROFORESTRY SYSTEMS · MAY 2008; DOI 10.1007/s10457-008-9132-7.

Fuelwood is the main energy source for households in rural Africa, but its supply is rapidly declining especially in the densely populated areas. Short duration planted tree fallows, an agroforestry technology widely promoted in sub-Sahara Africa for soil fertility improvement may offer some remedy. Our objective was to determine the fuelwood production potential of 6, 12 and 18 months (the common fallow rotation periods) old *Crotalaria grahamiana, Crotalaria paulina, Tephrosia vogelli* and *Tephrosia candida* fallows under farmer-managed conditions in western Kenya. Based on plot level yields, we estimated the extent to which these tree fallows would meet household and sub-national fuelwood needs if farmers planted at least 0.25 hectares, the proportion of land that is typically left under natural fallows by farmers in the region. Fuelwood yield was affected significantly (P\0.05)

by the interaction between species and fallow duration. Among the 6-month-old fallows, *T. candida* produced the highest fuelwood (8.9 t/ha), compared with the rest that produced between 5.6 and 6.2 t/ha. Twelve months old *T. candida* and *C. paulina* also produced significantly higher fuelwood yield (average, 9.6 t/ha) than *T. vogelli* and *C. grahamiana* of the same age. Between the fallow durations, the 18-month fallows produced the most fuelwood among the species evaluated, averaging 14.7 t/ha. This was 2–3 times higher than the average yields of 6 and 12-month-old fallows whose yields were not significantly different. The actual fuelwood harvested from the plots that were planted to improved fallows (which ranged from 0.01 to 0.08 ha) would last a typical household between 11.8 and 124.8 days depending on the species and fallow duration. This would increase to 268.5 (0.7 years) and 1173.7 days (0.7–3.2 years) if farmers were to increase area planted to 0.25 ha. Farmers typically planted the fallows at high stand densities (over 100,000 plants ha-1 on average) in order to maximize their benefits of improving soil fertility and providing fuelwood at the same time. This potential could be increased if more land (which fortunately exists) was planted to the fallows within the farms in the region. The research and development needs for this to happen at the desired scale are highlighted in the paper.

Macharia, P. N. (2008). Effect of introducing forage legumes on dry matter production nutritive quality and soil fertility of natural pastures of semi-arid rangelands of Kenya.

PhD thesis, University of Nairobi, Kenya

A two phase study was carried out in the semi-arid rangelands of Kajiado District, Kenya, between October, 2002 and February, 2005. The major objective was to determine the effect of introduced forage legumes on production of natural pastures as a means of improving the quantity of livestock feed while improving soil fertility. The specific objectives were: i) to screen potential forage legumes and select best performing ones for integration into natural pastures; ii) to determine the effect of defoliation interval and height on dry matter production of grass/ legume mixed pastures; iii) to determine the effect of forage legumes on quality improvement of grasses in natural pastures; iv) to determine the effect of forage legumes on soil fertility improvement; and v) to determine moisture extraction by grasses and legumes in mixed pastures. During legume screening, five forage legumes were sown as monoculture stands in a Randomized Complete Block Design (RCBD). These were *Neonotonia wightii* (Arn.) Lackey (Glycine), *Macroptilium atropurpureum* (DC) Urb. (Siratro), *Stylosanthes scabra* var. seca Vog. (Stylo), *Lablab purpureus* cv. Rongai (L.) Sweet (Dolichos) and *Mucuna pruriens* (L.) DC (Velvet bean). The legumes were screened for their ability to grow and survive under semi-arid conditions, increase of dry matter (DM) and litter production, and ability to enhance soil fertility. Data on DM production were collected at 2 and 4 months intervals at ground level and 15 cm heights of defoliation. Data on litter production were collected at the peak of long dry season in August 2003. Soil samples for fertility analysis were collected at 0-15 cm soil depth before sowing the legumes and at end of experiment. The screening experiment showed that Glycine, Siratro and Stylo withstood the semi-arid climatic conditions due to their perennial growth habit and produced high DM rate of 10.31, 7.81 and 3.52 t/ha/ yr, respectively. Glycine, Siratro and Stylo produced high organic matter through litter fall which upon decomposition improved soil fertility by increasing soil pH, carbon, nitrogen and potassium. These legumes possessed deep tap roots and withstood heavy grazing and were self-propagating through dispersal of seeds. These three legumes were, therefore, selected for further integration with grasses in natural pastures in line with the first objective. The grass/legume integration experiment was RCBD split-split plot in a factorial arrangement. The factors were namely; two defoliation heights (15-30 cm) and three defoliation intervals (2, 4 and 6 months), and seven treatments. Treatments were natural pasture (NP), monoculture of Glycine, Siratro and Stylo, and grass/legume mixture of NP+Glycine, NP+Siratro and NP+Stylo. Of the three legumes, Glycine had the lowest initial establishment, but by the third season it produced more DM than Siratro because it developed more and longer stems per plant while Siratro developed fewer and shorter stems per plant. In nearly all treatments, the highest DM production was after harvesting herbage at 15 cm height at an interval of two months, results obtained in relation to the second objective. Inclusion of Glycine and Siratro into natural pasture resulted in a combined DM production that was 40 and 42% higher than DM production of natural pasture, respectively. Grasses in natural pasture had lowest crude protein (CP) content of 7.1% but when integrated with Glycine, Siratro and Stylo, the CP went up to 14.3, 11.9 and 10.2%, respectively, during the vegetative stage. Moreover, grasses mixed with legumes had lower fibre content (especially lignin) and higher digestibility than those in natural pastures and especially at the senescent stage. This means that introduction of legumes into natural pastures improves forage quality of grasses and hence quality of livestock feed, results related to the third objective of the study. Results towards the fourth objective showed that except for soil pH, there was a decrease in all the other soil nutrients analyzed which was attributed to production of less organic residues from legumes compared to the screening experiment. Burning and herbage slashing before sowing of legumes had no significant effect on DM production. Burning herbage significantly increased soil P while the increase in pH, K was not significant. Burning resulted in a significant decrease in soil organic C and N. Results towards the fifth objective showed that significant differences in soil moisture extraction by grasses and legumes occurred from 30 cm soil depth down the profile. Monoculture Glycine, Siratro and Stylo extracted more soil moisture as compared to natural pastures and mixed pastures of NP+Glycine, NP+Siratro and NP+Stylo. Establishment of grass/legume mixed pastures through sowing

on well prepared seed beds produced highest DM followed by legumes sown on furrows and bands. The least DM was obtained when legumes were sown after ranking soils as most legume seedlings failed to establish. This study therefore concluded that Glycine, Siratro and Stylo proved to be high quality forage legumes suitable for up-scaling into other similar natural pastures of semi-arid rangelands of Kenya.

Vanlauwe, B., Kanampiu, F., Odhiambo, G. D., De Groote, H., Wadhams L. J. and Khan Z. R. (2008). Integrated management for striga hermonthica, stem borers, and declining soil fertility in western Kenya. *Field crops research Journal*, Elsevier V 107:102-115

Striga hermonthica (Delile) Benth and declining soil fertility are serious threats to sustainable food production in the lake Victoria zone of Kenya .To address this constrains, promising integrated crop management technologies were evaluated using a multi-locational design in four sub-locations in Siaya and Vihiga districts (western Kenya) for six cropping seasons. Technologies evaluated consisted of the traditional maize (*Zea may* L)- bean (*Phaselous vulgaris* L) intercrop maize -Desmodium (*Desmodium uncinatum* ((jacq)DC.) push -pull intercrop ,crotalaria *crotalaria occhroleuca* G. Don) maize- rotation and soybean (G*lycine max* (.) merr) maize rotation. With each of these systems imazapyr-coated herbicide -resistant maize (IR-maize) and fertilizer were super- imposed as sub plot factors. The push-pull system was observer to significantly reduce striga and stem borer damage from the second season onwards .IR - maize reduced and delayed striga emergence from the first cropping season. Differences in emergence and storm borer damage between the other systems were not significantly different. After five cropping seasons the striga seed back was significantly higher in the maize that has been under intercrop than that in the push pull system under both maize varieties while the rotational system had intermediate values not different from day zero values .Under IR -maize the striga seed back was significantly lower than under local maize for all cropping systems .Maize yield varied between seasons districts and cropping systems Yields in the push pull system were higher than in the maize bean intercrop after two seasons and in the absence of mid season drought stress. Both maize soybean responded significantly to fertilizer application for both districts and for most seasons .The various intervention did not substantially affect various soil fertility related parameters after five seasons. In the short term, IR - maize integrated in push -pull system in the most promising option to reduce striga while the rotating system may need a longer inter frame to reduce the striga seed back. Finally farmer led evaluation of the various technologies will determine which of those is really most acceptable under the prevailing farming conditions**.**

Ayuke F. O., Karanja N. K.; Bunyasi S.W. (2007). Evaluating effect of mixtures of organic resources on nutrient release patterns and uptake by maize. In: Bationo A (Eds.) *Advances in integrated Soil Fertility Management in Sub-Saharan Africa: challenges and opportunities. pp. 833-844*

To supplement high costs of inorganic fertilizers, smallholder farmers in the tropics are likely to increase the use of appropriate plant residues as an alternative source of plant nutrients especially nitrogen (N) and phosphorus (P). To maximize benefit accrued from these materials, synchronizing nutrient release patterns of the materials with crop's nutrient requirements need to be understood. Consequently, this study was undertaken to: (1) evaluate the effect of plant residues on mineralization and N-release patterns, (2) evaluate the N release patterns of mixtures of low and high quality organic materials and synchrony with maize uptake. Incubation studies were established for 12 weeks using six selected plant residues: which included *Leucaena leucocephala, Croton macrostachyus, Calliandra calothyrsus, Tithonia diversofilia, Sorghum bicolor* and rice (*Oryza sativa*) husks. Soil samples were taken at 2 weeks interval for ammonium nitrogen (NH_4^+-N) and nitrate nitrogen (NO_3^--N) determination. The organic residues differed in their chemical composition and this was found to influence mineralization rates and nitrogen release patterns. Two distinctive NO_3^--N + NH_4^+ N release patterns were observed over the incubation period. L. *leucocephala*, C. *maocrostachyus*, C. *calothyrsus*, T. *diversifolia* had a net N release throughout while *S. bicolor* and rice husks (*O. sativa*) had a significant N immobilization. Nitrogen-release was best correlated with C: N ratio (r2 = -0.84 to -0.90) for most of the sampling periods. Polyphenol: N ratio also had a significantly high correlation with cumulative N mineralized (r^2 = -0.65 to -0.95). Two organic resource with contrasting C: N and PP: N ratios i.e. C. macrostachyus and *O. sativa* were selected for use and in depth effect of mixing high quality *C. macrostachyus* (Cm) and low quality *O. sativa* (Os) at different ratios on mineralization N release patterns. agronomic effectiveness of the best mixture, which was based on N release, was measured using maize as the test crop in a glasshouse experiment. The dynamics of N-mineralization of the various mixture of C. macrostachyus (Cm) and O. sativa (Os) were in general not significantly different from those predicted from the O. sativa and C. macrostachyus treatments alone with the exception of the 3/4 Cm + 1/4 Os which gave significant N immobilization at 6-8 weeks and the 1/4 Cm + 3/4 Os which enhanced N mineralization at 2 and 12 weeks respectively. Addition of plant residues significantly increased maize biomass in the glasshouse with potted mixtures of plant residues giving the highest maize dry matter yield and N uptake. Keywords: *Agronomic effectiveness, chemical composition, mineralization, nutrient release, nutrient uptake, organic resources*.

Gichangi, E. M., Karanja, N. K. and Wood, C.W. (2007). Managing Manure Heaps with Agro-Organic Wastes and Cover to Reduce Nitrogen Losses on Smallholder Farms. *Soil Science Journal* pp: 611-618

Livestock manure is a valuable source of plant nutrients for crop production in Central Kenya highlands but its quality in terms of available nitrogen (N) is low due to considerable N losses through ammonia volatization. This study aimed at assessing the potential of agro-organic waste to reduce N losses from manure heaps during the storage period. Three organic amendments selected from laboratory simulation experiment were evaluated under farmers' conditions in Karura, Kiambu district for their ability to N losses from cattle manure heaps. The effect of polyethylene sheet covering of manure heaps on N retention was also determined. There were eight treatments that comprised three agro-organic amendments (maize stover, coffee pulp and sawdust) and the control. Agronomic effectiveness of the treated manure samples and N uptake by maize seedlings was evaluated in a glasshouse experiment. Total N content of manure amended with organic materials ranged from 1.26% to 1.85%. The N in manures with organic amendments at the start and at the end of storage was significantly different ($p \leq 0.05$). Cumulative N loss ranged from 1.60 and 6.80 g/kg depending on the type of amendment. Nitrogen lost from non-amended manure was 2.74 g/kg with polyethylene cover and 6.80 g/kg without polyethlene cover, which represented 19%and 46% of the initial N respectively. Maize growth improved significantly ($p \leq 0.05$) with increasing rates of manure irrespective of the organic treatments except for manure amended with sawdust. Treatments that received the recommended rate of N at 100 kgN/ha had significantly higher ($p \leq 0.05$) biomass of (21.55 g/plant) the control which produced only 2.78 g/plant. Nitrogen uptake increased with increasing rates of manure and was higher ($p \leq 0.05$) with manure amended with coffee pulp. Covering manure heaps to reduce moisture loss was also beneficial in reducing N losses.

Mutegi, J. K., Mugendi, D. N., Verchot, L. V. and Kungu, J. B. (2007). Impacts of vegetative contour hedges on soil inorganic-N cycling and erosional losses in Arable Steep-lands of the Central Highlands of Kenya. *In: Bationo et al (Eds.) Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities* pp 679-689; ISBN: 13978-4020-5759-5 (HB)

Moderate to steep landscapes and severe soil, water and nutrient losses characterize over 40% of arable land in the central highlands of Kenya. To study the effectiveness of biological methods in management and enhancement of productivity of these arable steep-lands, we established contour double row hedges of sole Calliandra, Leucaena and napier and combination hedges of either Calliandra or Leucaena with napier. Hedges were established on slopes exceeding 5% pruned regularly and the resulting biomass cut into fine pieces, which were then incorporated into the plots they served. We then evaluated these plots for inorganic-N changes with depth, soil conservation and soil loss/crop growth relationships. We observed accumulation of inorganic-N in the sub-soil in the control and napier plots but a reduction of sub-soil inorganic-N and its re-accumulation in the top soil in the leguminous hedges plots after 20 months of trial. The first season on average, registered higher soil losses ($P=0.004$) than the second season for treatment with hedges and vice versa for the control. During the first season there were significant lower ($P<0.001$) soil losses in plots with hedges relative to the control on slopes exceeding 10% but with the exception of napier, no significant differences among different types of hedges. We observed higher soil loss reduction in the combination hedge relative to individual tree hedges across the two seasons ($P=0.012$). The relationship between cumulative soil loss and any of the four crop growth parameters i.e. grain weight, plant height, stover weight and total above ground biomass was negative, linear and highly significant ($P<0.0001$), indicating decreased crop growth with soil loss. We conclude that there are heavy productivity losses as a result of soil erosion in arable steep-lands of the central highlands of Kenya and that well spaced, managed and combined contour hedges of leguminous trees and napier can reduce soil and nutrient losses from steep arable landscapes while simultaneously enhancing soil fertility.

Saha H. M. (2007). Improving resource use under maize-green manure legume systems in coastal lowland Kenya. PhD thesis, Jomo Kenyatta University of Agriculture and Technology, Kenya

Maize (*Zea mays* L.) production in coastal lowland Kenya is very low due to low inherent soil fertility and high weed infestation. Mucuna (*Mucuna pruriens*) has great potential for replenishing soil fertility and suppressing weeds but has a depressive effect on maize when it is intercropped with the cereal. A study was conducted in coastal lowland Kenya between 2002 and 2004 to assess the impact of plant density and time of intercropping mucuna on ground cover, light interception, soil moisture, root distribution, nutrient uptake, weed infestation, and the subsequent performance of both the legume and maize. Combinations of two legumes (40000 and 20000 plants/ha) and three times of intercropping the legume (0, 2 and 4 weeks after planting maize) were evaluated along with sole cropped maize and mucuna and mucuna-maize ration system. A randomized complete block design was used. Treatments were replicated four times and data were subjected to the analysis of variance using procedures of the Statistical Analysis System (SAS). Means were separated using the Least Significant Difference at $P<0.05$. Ground cover and light interception were highly correlated ($r=0.87$, $p<0.0001$). Maize-mucuna intercropping systems gave better ground cover (69-79%) and intercropped more light (75-79%) that sole cropped maize(36% ground cover; 43% PAR interception).Intercropping systems in which mucuna was sown

at a plant density of 40000 plants/ha at the same time with intercropping of maize and mucuna. When mucuna was planted at a density of 40000 plants/ha, the DM yield of nut grass was reduced by 39%, as compared with 12% reduction under low plant density (20000 plants/ha). Weed DM production was negatively correlated with ground cover ($p<0.05$) ($r=-0.90$). Weed infestation in intercropping systems in which mucuna was intercropped at the same time or with two weeks after planting maize was 53-79% and 21-39% lower, respectively, than that it was when legume planting was delayed by four weeks. A four – week delay in intercropping mucuna with maize led to 26-24% and 24-47% increase in maize grain and stover yields, respectively but reduced mucuna biomass yield by 48%. A similar delay reduced the loss in maize grain and stover yields from 36% to 13% and from 29% to 14%, respectively, as compared with yields from sole cropped maize. Maize Mucuna intercropping systems had consistently high land equivalent ratio (LER>1.5) when mucuna was planted at the same time with maize or two weeks later, indicating high resource use efficiency. Intercropping systems in which mucuna was planted at a density of 20000 plants/ha had higher net benefit (Ksh. 24,645 to Ksh. 26,012) that those systems where the legumes was planted at 40000 plants/ ha (Ksh. 15,654 to Ksh. 22,758) and similar net benefit as sole cropped maize (Ksh. 24,548). The results have shown that a high legume density favour formation of adequate ground cover, increased light interception and weed suppression. Delayed intercropping of mucuna gave maize an added advantage over the legume. While a four-week delay in legume planting led to increased maize yields and N and K uptake by maize, legume biomass yield was depressed. Although a legume plant density of 20000 plants/ ha was more economically suitable than the high plant density (40000 plants/ha), the latter was agronomic ally more suitable than the former since it has greater potential to sustain the quality of maize – mucuna intercropping system to add fertility to the soil. Since the plant density of 40000 plants/ha led to relatively high mucuna biomass and nitrogen yield, this density is most likely to improve soil fertility where continuously intercrop maize and mucuna. Planting mucuna two weeks after planting maize minimized yield loss in intercropped maize and minimized the loss of legume biomass yield.

Waswa B. S., Mugendi D. N., Vanlauwe B. and Kungu J. (2007). Changes in soil organic matter as influenced by organic residue management regimes in selected experiments in Kenya. In: Bationo et al (Eds.) *Advances in integrated soil fertility management in Sub-Sahara Africa*: Challenges and opportunities pp.457-469

The failure to understand the dynamics of soil organic matter (SOM) is a major limitation to the sustainability of smallholder production systems that predominantly relied on organic resources for the maintenance of soil fertility. This study evaluated the influence of organic resource management on SOM in three selected experiments in Central and Western highlands of Kenya. Results showed that soil carbon (C), Nitrogen (N) and Carbon-13 (13C) values in the three experiments were depending on the amounts of the organic residues applied as well as the duration of application indicating that organic residue management practices have profound impact on the final contribution to the SOM pools. Kabete experiment had the narrowest C, N and 13C values pointing to its young age as well as the low quantity of organic residues applied. On the other hand, Embu experiment had soil C values above the critical level of 2.0% indicating a positive effect of continued application of organic residues. In all the three sites, aggregate mineral fraction(MF) size distribution were dominated by macro-aggregates (250-500µm and >500µm) which on average accounted for about 72%,65% and 69% of the dry soil weight for Maseno, Kabete and Embu experiments, respectively. Similarly higher proportions of aggregate light fractions (LF) C and N were observed in macro-aggregates fractions for the three experiments with organic treatments having higher proportions. The 13C signatures of the LF in the macro-aggregates (>250µm) were more negative as compared to the 13C values in the macro-aggregate (53-250µm) LF suggesting a more C contribution from C3 vegetation to the most recently incorporated SOM pool.

Gichangi E. M., Karanja N. K. and Wood, C. W. (2006). Compositing cattle manure from zero grazing system with Agro-organic wastes to minimize Nitrogen losses in smallholder farms in Kenya. *Tropical and subtropical Agro ecosystems Journal* Vol. 6: 57-64

Livestock manure is a valuable source of plant nutrients for crop production in the Central Kenyan highlands but its quality in terms of available nitrogen (N) is low due to considerable N losses through ammonia votalization. This study aimed at assessing the potential of agro-organic waste to reduce N losses from manure heaps during the storage period. Three organic amendments selected from a laboratory simulation experiment were evaluated under farmer's conditions in Karura, Kiambu District for their ability to reduce N losses from cattle manure heaps. The effect of a polyethylene sheet covering manure heaps on N retention was also determined. There were 8 treatments that compromised three agro-0rganic amendments (maize stover, coffee, pulp and sawdust) and the control, with or without a polyethylene cover. Agronomic effectiveness of the "treated" manure samples and N uptake by maize seedlings was evaluated in a glasshouse experiment. Total N content of manure amended with organic materials ranged from 1.26 to 1.85%. The N in manures with organic amendments at the start and at the end of storage was significantly different ($p<=0.05$). Cumulative N loss ranged from 1.6 to 6.8 g/kg depending on the type of amendment. Nitrogen lost from non-amended manure was 2.74 g/kg with polyethylene cover and 6.8 g/kg without the polyethylene cover, which represented 19 and 46 % of the initial N respectively. Maize growth

improved significantly (P≤0.05) with increasing rates in manure irrespective of the organic treatments except for manure added sawdust. Treatments that received the recommended rate of Nat 100 kg N/ha had significantly higher (p≤0.05) biomass (21.55 g/plant) than the control which produced only 2.78 g/plant. Nitrogen uptake increased with increasing rates of manure and was higher (P≤0.05) with manure amended with coffee pulp. Covering manure heaps to reduce moisture loss and was also beneficial in reducing N losses.

Gichangi, E. M., Karanja, N. K. and Wood, W. (2005). The potential of agro-organic wastes to reduce nitrogen losses from cattle manure used by smallholder farmers in the central Kenyan highlands. *Proceedings of the 21st Annual Conference of The Soil Science Society of East Africa* 1st -5th Dec. 2003. Eldoret, Kenya. pp 217-228

Livestock manure is a valuable source of plant nutrients for crop production in the central Kenyan highlands but its quality in terms of available nitrogen is low due to considerable nitrogen losses through ammonia volatilization. This study aimed at assessing the potential of agro-organic wastes to reduce nitrogen losses from manure heaps during the storage period. Three amendments selected from a laboratory simulation experiment were evaluated under farmers' conditions based in Karura, Kiambu District for their ability to reduce nitrogen losses from cattle manure heaps. The effect of a polyethylene sheet covering of manure heaps on nitrogen retention was determined. There were eight treatments that comprised three agro-organic amendments (maize stover, coffee pulp and sawdust) and the control. Agronomic effectiveness of the treated manure samples and N uptake by maize seedlings were evaluated in a glasshouse. Total nitrogen content of manure amended with organic materials ranged from 1.26% to 1.85%. The N in manures with organic amendments at the start and at the end of storage was significantly different (P<0.05). Cumulative nitrogen loss ranged between 1.60 and 6.80 g/kg depending on the type of amendment. Nitrogen lost from non-amended manure was 2.74 g/kg with polyethylene cover and 6.80 g/kg without the polyethylene cover, which translated to 19% and 46% of the initial nitrogen respectively. Maize growth improved significantly (P≤0.05) with increasing rates of manure irrespective of the organic treatments except for manure amended with sawdust. Treatments that received the recommended rate of nitrogen at 100 kg N/ha had significantly higher (P≤0.05) biomass of 21.55 g/plant only. Nitrogen uptake increased with increasing rates of manure and was higher (P≤0.05) with manure amended with coffee pulp. Covering manure heaps to reduce moisture loss would also be beneficial in reducing nitrogen losses.

Obanyi S. and Gicheru P. T. (2005). Effects of the application of four contrasting Nitrogen source Inputs on changes in soil nutrient pools and crop yields: An approach of Nitrogen re-capitalization through use of improved fallows in Kenya. Kenya Agricultural Research Institute –National Agricultural Research Laboratories. Annual Report

All the practices replenished the nitrogen content above the original levels that were either below or near the critical soil N level (0.09-0.11% N) The best N replenishment material was poultry manure (+ 0.18% N)> compost manure (+0.06% N)> Tithonia (+0.04% N). The poultry manure treatment indicated that the mega dose application replenished more N (+0.29 % N) than the annual application (+ 0.09% N). An opposite trend was observed with respect to SOC depletion. The depletion trend was in the order of poultry manure (- 0.32% C) > Tithonia (-0.18% C) > Compost (-0.13% C). From the fore going results we can therefore conclude that the mega dose approach have only short-term benefits (at the start of the N recapitalization exercise). The annual dose application strategy is an overall better approach. For a majority of the smallholder farmers, the amount of organic material advocated for in this study are 7.1, 3.8, and 2.2 tonnes dry matter of tithonia, compost and poultry manure against availability of 3, 2, and 1 t/ha, respectively. These studies show that the gradual rebuilding of N capital is a worthwhile objective to provide buffering against uncertainty in the farmers ability to supply N inputs to every crop. However, it is important to emphasize that in N replenishment, it is not the size of the capital N stocks but the cycling rate. Therefore appropriate strategies are those that provide sufficient levels of N inputs while the crops are growing and at the same time slowly rebuild N stocks. As a follow up to this experiment a proposal was written on the use of improved fallow to recapitalize N and recycle other nutrients. *Tephrosia vogelii*, a legume shrub was chosen for this study.

Kihanda, F. M., Warren, G. P., and Atwal S. S. (2004). The influence of Goat manure Application on Crop Yield and Soil Nitrate Variations in Semi-Arid Eastern Kenya. *In: Bationo A (Ed) Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa. Academy Science Publishers (ASP) in association with the Tropical Soil Biology and Fertility Institute of CIAT* 2004 pp 173-196; ISBN: 9966-24-075-6

The effect of manure on crop yield and soil nitrate -N was measured during the 1994-5 cropping season at three sites in Mbeere and Tharaka-Nithi districts of eastern Kenya. The sites were Machang'a in Mbeere district and Mutuobare and Kajiampau in Tharaka Nithi district. The treatments were goat manure applied at rates of 0.5 and 10 t/ha (dry weight basis), annually since 1989, and 5 and 10 t/ha annually from 1989 to 1992. The plots were intercropped with sorghum (*Sorghum bicolor*) and cowpea (*Vigna unguiculata*). The grain yields of sorghum varied widely from 0.3 to 3.9 t/ha, depending on site and manuring. Differences were most marked at Machang'a

site. For example, where manure was continuously applied at 10 t/ha, sorghum yield of more than 3 t/ha was realized as compared to 1.5 t/ha from the residual plots. Topsoil nitrate concentrations were highest at the start of the season and within about 15 days, most nitrates had been lost. For example, at the Mutuobare site, nitrate N concentration at the start of the season was about 78 mg/kg in the recently manured plots but decreased to less than 10 mg/kg 20 days after onset of the rains. A high manure rate of 10 t/ha resulted in surplus nitrate at the end of the season, hence a maximum manure rate of 5 t/ha, is suggested to reduce losses of N. Nitrate N correlated well with N taken up by crops at Kajiampau, where N was the main limiting nutrient, but not at Mutuobare and Machang'a, where P was the limiting nutrient. The wide variations of measured nitrate between sites and sampling dates make it unsuitable as a practical indicator of N requirements for crops. Total soil N was correlated with N taken up by the sorghum at all sites and is an appropriate parameter to assess crop requirement to N.

Kimani S. K, Gachengo C.; Delve R. (2004). Simulated partitioning coefficients for manure quality compared with measured C: N ratio effects. *In: Bationo A. (Eds.) Managing nutrient cycles to sustain soil fertility in Sub-Saharan Africa*. pp. 200- 206

Livestock manures comprise an important source of nutrients in many farming systems. However, the quality of manure is generally variable depending on composting, storage and handling. This in turn results in different manure responses with regard to the release of nutrients for crop uptake. Recent studies have shown that there is a wide scope to better manage manures to improve quality, and the field performance. Simulation modelling, for example using APSIM, is a useful tool in exploring improved strategies for management of manures, with regard to enhancing fertiliser quality. This paper discusses some concepts behind APSIM Soil-N module and attempts to simulate responses for different quality manures. the manures were collected from farmer`s fields in central Kenya and compared with a feedlot-managed manure. The C: N ratios of these 9 manures ranged from 13 to 32. Fresh organic matter (FOM) in manures was partitioned into different pools of carbohydrate; cellulose and lignin of 10, 15 and 25, using APSIM were done. The measured responses were compared for manures with different C: N ratios of these manures, against net N mineralisation as determined in a laboratory incubation study. Whilst the measured responses showed an initial nitrogen immobilisation, the simulated responses showed net N mineralisation from time 0 up to 100 days, for manures with a C: N ratio of 13-22. Manures with C: N ratio above 30 showed net immobilisation throughout the experimental period for the simulated responses.

Kimani S. K. and Lekasi J. K. (2004). Managing manures throughout their production cycle enhances their usefulness as fertilizers: A Review. In: Bationo A (Ed.) *Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa* pp. 187-197

Per capital food production lags behind population growth in most parts of Sub-Saharan Africa. One of the reasons for this situation is the decline in soil fertility, arising from continuous cultivation where the levels of soil replenishment, by whatever means, are too low to redress the process of nutrient mining. One of the ways to address the problem of the low and declining soil fertility is by using inorganic fertilisers, but use of these inputs in most of Sub-Saharan Africa is currently low. High cost, unavailability, marketing problems, poor infrastructure, and the absence of enabling policy environment are the major reasons for the low use of inorganic fertilisers. The use of other resources is available on the farm is therefore increasingly gaining importance. These include green manures, farmyard manure, crop residues and composts. Of these resources, farmyard manure is by far the most important. However a major limitation is the effectiveness of organic resources is the quality and quantity of these materials. This review paper attempts to define cattle manure quality and discusses some management factors that influence its quality. The paper also suggests some way forward in better use of cattle manures for enhanced crop production.

Micheni, A., Kihanda, F., Irungu, J. (2004). Soil organic matter (SOM): The basis of improved crop production in arid and semiarid climates of Eastern Kenya. In: Bationo (Eds.) *Managing Nutrient Cycles to Sustain Soil fertility in Sub-saharan Africa* pp 239-248

Soil organic matter (SOM) plays an important role in maintaining physical chemical and biological properties of the soil and therefore the crop productivity. A study was conducted in arid and semi-arid lands (ASAL) of eastern Kenya to assess the influence of SOM on crop productivity after 10 years of application at high quality goat manure. The manure was acquired from a single source where some breeds and flock management were maintained throughout the experimentation period. The manure contained 0.48% P 2.04%N and 25.62% C and was annually applied at 0-5 tones and 10t/ha in soils where continuous cultivation was a common practice. The residual effects of manure were monitored after discontinuation of 4 years manure application. Also inorganic fertilizers to supply phosphorus (P) and Nitrogen (N) were applied to compare the potency of long term maintenance and inorganic fertilizers on crop performance. The observed maize yields were compared with simulated (predicted) values from modelling using the Agricultural productions systems simulator (APSIM) model .The results showed that both the application of manure and mineral fertilizer improved crop total matter and discontinuation of annual manure

application led to red own trends in crop yields. A general conclusion made from that study was that it is worth while crop productivity to maintain SOM through annual application of high quality manure at 5t/ha in ASAL where continuous cultivation is practiced.

Kihanda F.M. (2003). Effect of manures composted with high quality organic residues on dry matter accumulation, nitrogen uptake and maize grain yield. *East African Agricultural and Forestry Journal*. Vol. 69 pp. 63-68

Nitrogen is a major limiting nutrient in the maize-growing areas of central Kenya highlands. Due to the high cost of inorganic fertilisers, the majority of the farmers use farmyard manure (FYM) to improve crop productivity. However, FYM produced in the area is often of low quality particularly in terms of N concentration. Studies previously carried out in the region showed that composting FYM with different proportions of Tithonia (*Tithonia diversifolia*) or Lantana (*Lantana camara*) improved the N content of the manure considerably. This study was conducted to test whether composted manure would improve growth and yield of maize. A field trial consisting of seven treatments: FYM composted with tithonia (1:1 and 3:1 ratios), or lantana (1:1 and 3:1 ratios), FYM composted alone, inorganic N fertiliser and an absolute control was laid out in low N site. Maize (*Zea mays* cv. Hybrid 513) was the test crop. The treatments were arranged in a RCBD replicated 3 times. The various compost types and the inorganic fertiliser were applied at an equivalent rate of 100 Kg N/ha. Above ground maize biomass was taken at 2, 6, 10, 14 and 18 weeks after crop emergence, dried to a constant weight and the N content determined. The plant N uptake for each period was calculated as a product of dry matter yield, N uptake and final grain yield of maize were significantly higher in FYM composted with tithonia or lantana than the control or FYM composted alone treatments. Amongst the composts, the highest dry matter accumulation and N uptake was observed in FYM composted with tithonia at 1:1 ratio. Inorganic fertiliser treatments gave the highest dry matter and N uptake. Based on the growth and N uptake in the fertiliser treatment it was concluded that the N release in all the compost was lower than the crop demand.

Muiru D. M. (2003). Assessing the role of organic soil amendments in control of root-knot nematodes (*Meloidogyne spp*) affecting common bean (*Phaseolus vulgaris* L.). Msc. Thesis, University of Nairobi, Kenya

A study was undertaken to determine the role of organic amendments in suppressing root-knot nematodes the organic amendments used in the study included chicken and cow manures and leaves of *Mucuna pruriens* (velvet bean), *Azadiracta indica* (neem) and *Tagetes minuta* (marigold). An experiment was established to determine the effect of organic amendments on damage caused by nematode to beans. The materials were applied fresh (undecomposed) at the rate of 5% (w/w) in 5 kg pots with untreated soil and soil treated with carbofuran as controls. The soil was infested with 6000 nematodes eggs per pot. All the organic amendments reduced galling and reproduction of root-knot nematodes in beans. Galling indices ranged from 1.5 to 3.8 (on a scale of 1-9) in soils amended with organic materials compared to 6.3 in the control. Chicken manure was the most effective in reducing galling and reproduction of root-kot nematodes followed by *A. indca* and *T. minuta* with cow manure being least effective. All the organic amendments increased plant growth, with chicken manure being superior to the other amendments. Carbofuran (non-fumigant nematicide) was the least potent of all the treatments. A laboratory experiment was conducted to determine the effect of water extracts of the organic amendments on the mobility of second -stage (J2 s) *Meloidogyne* juveniles. The materials were decomposed in water and their extracts used to treat *Meloidogyne* juveniles. Counts of inactivated (immobile) J2 s were taken on an hourly interval for five hours. The extracts immobilized more than 90% of the J2 s treated, with the exception of the extract from cow manure, which immobilized 36% in five hours. All the extracts immobilized a higher proportion of J2 s than carbofuran. All the amendments increased the available NH_4^- N, P and pH with chicken manure giving the highest levels. Correlations between NH_4^- N and nematode egg masses (r=-0.85) and juvenile population (r=-0.55) were negative suggesting the involvement of NH_4^- N in nematode suppression. Phosphorus was negatively correlated to egg masses (r=-0.79) and juvenile population (r=-0.44) indicating that it plays a role in nematode suppression. Fertilizer-treated soil (galling=3.3 at 45 DAI) had a better control level than the controls (galling =-5.8 at 45 DAI) indicating that nutrients have a role to play in nematode management. Microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) and microbial activity were stimulated by all the amendments with chicken manure and Tagetes giving the highest level of stimulation. MBC and MBN were negatively correlated to nematode egg masses(r= -0.68 & -0.81), and juveniles (r= -0.66 & -0.23), respectively. Most of the organic amendments encouraged a high population of *Bacillus* spp., which were used as the indicators of the presence of bio control agents with chicken manure and *Tagetes* spp being the best stimulants. *Bacillus* spp showed a high potential in reducing nematode egg masses since they were highly negative correlated (r= -0.94).

Mureithi J.G, Gachene C.K.K.; Ojiem J (2003). The role of green manure legumes in smallholder farming systems in Kenya. *Tropical and subtropical Agroecosystems*. Volume 1 pp.57-70

Low soil fertility is a major constraint hampering the productivity of Kenyan smallholder farms. Green manure (GM) legume technologies were introduced in 1994 by the Legume Research Network Project (LRNP) as an accessible technology to arrest soil degradation and maintain soil fertility. the Network, with diverse members working across the country, has conducted research to identify promising GM legume species for different agro-ecological zones, to determine inoculation and P fertilization needs of the species, to evaluate GM legumes as a component of integrated nutrient management, and to assess the value of the legumes in controlling striga (Striga hermonthica), a noxious weed common in western Kenya. An overview of the research results is presented here. Also presented are the potential niches for GM legume technologies and the way forward for the LRNP. Keywords: Maize-based cropping systems, soil fertility improvement, green manure legumes.

Kirungu, B. A. M., Kasiti, J., Shiundu, P., Kamwana, S., Mukungo, M., Nderitu, S. and Wamalwa, E. (2002). The effects of legume and maize stover residue management practices on the yield of a subsequent maize crop in Kitale, Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 129-143

A trial focusing on the management of mucuna (*Mucuna pruriens*) and maize stover residues was conducted over two seasons on a low fertility soil in the North Rift region of Kenya. The effects of factorial combinations of legume and/or stover residues and their method of placement on a subsequent maize crop were evaluated. When the maize was harvested, the stovers were either removed or applied as mulch between the rows of mucuna. Mucuna aboveground biomass was removed to stimulate grazing, or applied as surface mulch or incorporated into the soil, 7 days before planting a subsequent maize crop. Mucuna accumulated 5.35 and 1.03 t of above ground dry matter in the first and second year, respectively. The bulk of the DM consisted of low quality woody stem and litter. The aboveground legume residues contained an estimated 148 and 32.5 kg N/ha in the first and second year, respectively. The removal of the aboveground mucuna biomass significantly affected maize yields in the first year. Maize in the simulated grazing plots produced an average of 1.6 t/ha less grain than the treatments in which the biomass was retained (4.1 compared to 5.7 t/ha). Legume biomass retained treatments produced 30% more grain than the no legume unfertilised check. In the second year, however, when mucuna performed poorly, the previous maize crop's stovers depressed grain yield by 16% compared to when the stover was removed at harvest. Incorporated residues produced 13% more grain than residues applied as surface mulch. The between year differences in mucuna DM and biomass total N content seemed to be the main factor affecting the subsequent maize yields. Possible ways in which current cropping system characteristics and the legume's dry season niche are likely to affect the green manure system are highlighted.

Mureithi, J. G., Mwaura, P. M. and Nekesa, C. O. (2002). Introduction of legume cover crops to smallholder farms in Gatanga, central Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 153-164

An on-farm study to evaluate three methods of applying legume residues in maize-based cropping systems in Gatanga, central Kenya was initiated in 1997 and conducted for three years. The legumes involved in the study were velvet bean (*Mucuna pruriens*) and crotalaria (*Crotalaria ochroleuca*) and were planted between maize rows, two weeks after planting the maize. After harvesting the maize, the legumes were left growing in the field until land preparation for the next maize crop. The legume forage was harvested and was either incorporated into the soil, left on the surface as mulch or removed from the field before planting the maize crop. Results indicated that during the first cropping season when green manure legumes were establishing, maize grain yields were depressed by an average of 33% compared to the no in-put control treatment. The legume treatments increased maize grain yields from a mean of 1.0 t/ha in the no input controls to a mean of 1.6 t/ha during the 1998 and 1999 long rains cropping seasons. Over the two cropping seasons, incorporation of legume residue into the soil gave a higher maize yield (2.1 t/ha) compared to leaving the legume biomass on the surface as mulch (1.4 t/ha). The effects of below ground biomass on maize yields were minimal. The legume treatments did not significantly affect soil N, P, K and organic carbon. Farmers identified several niches for the green manure legume technology which included, intercropping the legumes with maize and incorporating legume biomass for soil fertility improvement, growing legumes under coffee bushes and avocado trees as cover crops and planting legumes on steep slopes for soil erosion control.

Njunie M. N. (2002). Evaluation of forage legumes for soil fertility improvement in Maize/Cassava production systems, PhD thesis, North Carolina State University, USA

Crop yields in coastal Kenya are limited by poor soils and erratic rainfall. Legumes as cover crops and intercrops have potential to improve land productivity by increasing soil fertility through N fixation and decomposition of

foliage green manure. A two-year field study was conducted in fine-loamy, kaolinitic, isohyperthermic, arenic Paleustaffs to evaluate the effects of an annual legume (*Lablab purpureus*) cut at 2 or 4 months after planting and a perennial legume (*Clitoria ternatea*) cut every 6 or 10 week for biomass and nutrient accumulation, availability of residue derived nutrients to maize (*Zea mays*) and / or cassava (*Manihot esculenta*), and changes in soil chemical characteristics. In addition, the effects of commercial fertilizer on crop yields and nutrient accumulation were evaluated. Two crops of maize and dolichos were grown per year, utilizing long and short season precipitation. Results from the maize/cassava production experiments revealed that the legumes accumulated nutrients (2-yr avg.) range from 50 to 101 kg N/ha, 4 to 8 kg P/ha, 33 to 83 kg K/ha, 7 to 32 kg Ca/ha, and 5 to 7 kg Mg/ha during the long rain season, with dolichos producing the greater values. Unlike the long rains season, nutrient contents of clitoria were greater than dolichos during the short rain season, with values ranging from 36 to 54 kg P/ha, 26 to 40 kg Ca/ha and 5 to 7 Mg/ha. Intercropping reduced nutrient contents of the legume to <80% of the respective monocultures, and was most pronounced for clitoria intercropped with cassava. Delayed harvest of dolichos from two to four months after planting increased dolichos nutrient accumulation between two and four fold, but harvest management did not influence nutrient accumulation by clitoria. Fertilizer inputs increased maize and stover yields by 70% over maize grown without fertilizer inputs. Intercropping maize with clitoria increased grain and stover nutrient accumulation by values ranging from 50 to 80%, compared to maize monoculture without fertilizer inputs, while intercropping maize with dolichos yielded less grain and stover. Cassava monoculture resulted in the greatest tuber yields (9 Mg/ha), while intercropping of cassava with legume reduced tuber yield by 21%. Soil chemical characteristics were only modestly affected by treatment variables. Positive nutrient balances occurred for maize monoculture systems supplied with fertilizer and for maize/legume intercropping systems with maize stover returned to the system and P supplied to the legume as inorganic fertilizer. Generally, the presence of cassava in a cropping system resulted in negative N and K balances, supporting the need to review N and K replenishment recommendations for maize and/or cassava cropping systems in the region. Calculations of the area by time equivalent ratios (ATER) based on totals of long and short rains seasons' yield of maize, legume, and cassava revealed that intercropping of clitoria or dolichos with maize or cassava resulted in the most efficient way of utilizing land area and time, more so with the longer cutting interval. The ATER for clitoria intercropping with maize and/and or cassava ranged from 1.2 to 1.6, while that of dolichos ranged from 1.1 to 2.0. Generally, greater values of ATER were observed where the basis for the comparisons was the no fertilizer input control, implying that advantages of intercropping would be noticeable in situations where fertilizer inputs are a constraint, as is the case in coastal Kenya. These results demonstrated the legumes potential to supply nutrients for maize grain and cassava tuber production. Further research aimed at reducing nutrient losses by synchronizing nutrient release with principal crop demand is recommended.

Onyango, C., Oduwo, A., Okoko, N., Kidula, N. L. and Mureithi, J. G. (2002). Green manuring to improve soil fertility and reduce striga weed infestation in smallholder farms in south Nyanza, Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Project*, pp 173-176

Maize and sorghum are the major staple food crops in lower South Nyanza. However, their yields have been on the decline mainly due to low soil fertility and high striga weed population. Traditional approaches used to control striga weed population, which included fallowing, use of farm yard manure (FYM) and uprooting are no longer used by farmers. Fallowing is no longer possible due to high availability of FYM, while labour for uprooting striga is too high and is no longer available. Studies were conducted using Sunnhemp (*Crotalaria ochroleuca*) Dolichos (*Lablab purpureus*) and Mucuna (*Mucuna pruriens*) as green manure to improve maize grain yield and control striga population. In the long rains of 1996, the three legumes were grown as sole crops or intercropped with sorghum or maize in five different sites and data on nodulation, dry matter yield and cereal grain yield collected. Results on dry matter yield showed significant (<0.05) differences between cropping practices but not between species and sites. The sole cropped legumes produced dry matter of about 3 t ha-1 and when intercropped the legumes produced yields of about 1 t/ha. The number of nodules per plant was only accurately assessed for sunnhemp and the nodules were higher at the drier site LM5 (110 nodules) than the wetter site LM3 (87) and LM2 (60). Maize grain yield was not affected by intercropping legumes in the maize two weeks after planting of maize. Practical implications of these results and farmer experiences with green manure legumes are discussed.

Rao, M. R., Mathuva, M. N., Gacheru, E., Radersma, S., Smithson, P. C. and Jama, B. (2002) Duration of Sesbania Fallow Effect for Nitrogen Requirements of Maize in Planted Fallow-Maize Rotation in Western Kenya. *Experimental Agriculture* Vol. 38, pp.223-236

The duration of the residual effect of sesbania (*Sesbania sesban*) fallow on subsequent crops will determine the interval at which sesbania must be grown to replenish N in a planted fallow–crop rotation cycle. An experiment was conducted from 1995 to 1998 (seven cropping seasons) on two farms in western Kenya, an area subject to a bimodal annual rainfall pattern. The aim was to compare the effect of a single-season sesbania fallow with continuous annual cropping with and without phosphorus fertilizer, on a P-deficient soil. Phosphorus was applied at a rate of 500 kg/ha in a single application to meet the phosphorus needs of subsequent crops for the next five to

ten years. Sesbania was established simultaneously with maize by direct seeding in the first rainy season of 1995 and allowed to grow as a pure fallow through the second rainy season. Following the harvest of this fallow crop, sole maize in the first post-fallow season and maize-bean intercrops in the subsequent four seasons were grown with and without nitrogen at a rate of 100 kg/ha. Added phosphorus on average increased maize yields by 3.7 times over the control, indicating that phosphorus fertilizer is essential for good yields. The amount of phosphorus recycled by sesbania fallow was inadequate to meet the crop needs in P-deficient soils. While continuously cropped maize in the presence of phosphorus responded to nitrogen in all seasons, the crop following sesbania responded only from the third season. In the first post-fallow season, sesbania increased maize grain yields over continuous maize by 1.4 t/ha with phosphorus fertilizer and by 1.3 t/ha without phosphorus fertilizer. The residual effect of sesbania with phosphorus fertilizer lasted for two seasons, while without phosphorus it lasted for only one. In these Kenyan highlands, farmers who can afford fertilizer should buy phosphorus fertilizer and rely for nitrogen on planted fallow with species such as sesbania grown for one season every two years. For farmers who cannot afford fertilizer, one-season fallow every year may be more attractive because of labour savings and the firewood produced by sesbania.

Serigne T. K., Ogol, C. K. P. O. and Albrecht A. (2002). Influence of some Agroforestry Practices on the temporal Structures of nematodes in Western Kenya. *Soil Biology Journal* pp. 197-203

The influence of agroforestry practices on the temporal fluctuation of nematodes was studied in western Kenya. The experiment comprised a fallow phase, which had the following treatments: (1) maize/beans intercropping; (2) maize beans intercropping with rock phosphate; (3) Crotalaria fallow; (4) Crotalaria fallow with rock phosphate; Crotalaria fallow with rock phosphate (+ Calliandra and Napier hedges); and a cultivation phase when all plots were planted to maize and beans. There were strong seasonal fluctuations in the abundance of both free-living and plant-parasitic nematodes. The abundance of plant-parasitic nematodes did not vary among cropping systems during the fallow phase, but varied significantly during the cultivation phase of the experiment. Pratylenchus ssp. appeared to be stimulated by the application of phosphorus while Scutellonema ssp. had higher populations in the maize crops, which were planted after a Crotalaria fallow. In both the fallow and the cultivation phases, the sampling date had a significant impact on nematode abundance. There were more plant-parasitic nematode species during the fallow phase of the study, but the evenness of the different nematode communities was significantly greater in the cultivation phase of the experiment.

Gema S., Buresh R. J. and Gregory P. J. (2001). Inorganic soil Nitrogen distribution in relation to soil properties in smallholder maize yields in the Kenya highlands. *Geoderma Journal* Elservier 101:87-103

We investigated the influence of soil charge properties on the distribution of inorganic soil N in Maize (*Zea mays*) fields on small holder farms in the sub humid highlands of Kenya. There was little or no fertilizer use in these subsistence farming system. Soil NO_3 was measured to 2m depth in maize fields on 96 farms samples in transects at three physiolografic positions (redgetop, midslope and lower slope) in each of the six soil map units (4 or 8 transect per soil map unit)covering four percent materials acid igneous basic igneous and sedimentary ,Soil NO_3 concentration varied from < 0.1 to 10mg N kg in the top 0.25 and from <0.1 to 16 mg N/kg in the sub soil (0.5 - 2.0m depth) Mean subsoil NO_3^- contents were about two times higher in two soil map units (ferrasols on sedimentary mudstones ,mean = 57kg N/ha) than in the other soil map units (mean ranged from 20 to 30 kg N/ha) subsoil NO_3 concentration was not reflected to effective anion exchange capacity (AEC) plant N content (taken as an indicator of plant N demand) or anaerobic N mineralization (taken as an indicator of N supply) Effective cation exchange capacity (CEC) of < 7.3 cmol/kg clay correctly classified 79% of the farms with high subsoil (0.5-2.0)m NO_3 content of > 70 kg N/ha .It may be difficult to accurately predict the spatial distribution of sub soil nitrate accumulation i maize from routinely measured soil variables but our results indicate that information on parent material and subsoil CEC and clay content may help to provide broad generalization.

Onyango R. M. A., Mwangi, T. K., N'geny, J. M., Lunzalu, E. N. and Barkutwo, J. K. (2001). Effect of relaying green manure legumes on yields of intercropped maize in smallholder farms of Trans Nzoia District, Kenya. *Proceedings of the Seventh Eastern and Southern Africa Regional Maize Conference*, February 11-15, 2001. Vol. 39(3) 330-334

A number of smallholder farmers in Trans Nzoia District are experiencing low maize yields as a result of continuous cultivation without addition of adequate external nutrients. Integrating the use of green manure legumes into the smallholder farming systems may form an important strategy for soil improvement and hence yield. An on-farm trial was designed in 1997 to introduce legume intercrops and green manures in a maize-based cropping system. A randomised complete block design was used and each farmer served as a replicate. Maize hybrid H614 was intercropped with either common bean (*Phaseolus* spp.), soybean (*Glycine max*) groundnuts (*Arachis hypogea*), and cowpea (*Vigna unguiculata*). After harvesting the food legumes these four plots were relayed with green manure legumes, Sunhemp (*Crotolaria brevidens),* Velvet bean (*Mucuna* spp.) or Dolichos (*Lablab purpureus*).

The green manure legumes remained in the field after maize was harvested and were incorporated 2-3 weeks before planting the following season. Maize yields harvested from the plots were compared with yields from control plots. The soils under experimentation were strongly to moderately acidic (pH 5.0 - pH 6.9) with marginal amounts of exchangeable bases. Green manure dry matter (DM) varied for both years. In 1997 Dolichos spp. gave the highest yield of 2.5 t/ha while Mucuna spp. gave the lowest yields (0.38 t/ha). Crotolaria spp gave the highest DM yield (2.80 t/ha) in 1998, followed by Velvet bean (1.20 t/ha) and Dolichos (0.40 t/ha) in that order. There were no significant maize yield differences ($p<0.05$) after one or two years of green manure incorporations and fertilized maize. After one year maize following Mucuna spp. gave yield of 9.3 t/ha while after two years it was Dolichos spp that gave the highest yield of 8.5 t/ha, followed by Crotolaria spp and Mucuna spp. which yielded 6.3 t/ha each. After three years of incorporations maize yields following Dolichos spp continued to give the highest yield of 8.1t/ha. Throughout the four years growing period no fertilized maize gave the lowest significant yields ($P<0.05$). The utilization workshops for soybean and groundnuts were well attended. Initially farmers insisted on growing legumes as intercrops due to land pressure, but after three years exposure, they requested seeds for planting pure stands. Farmers may accept rotating legumes with maize in future to increase and diversify their food supply and at the same time improve their soils.

Ayuke F.O. (2000). Diversity, Abundance and function of soil invertebrate fauna in relation to quality of organic residues. Msc. Thesis, Moi University, Kenya

Although the role of soil invertebrate fauna in decomposition of organic residues and thus nutrient release, soil structure and soil-water relations is well recognized, the scope for their manipulation to derive the potential benefits is little understood. A study was undertaken to test the hypothesis that the diversity, abundance and function of soil fauna are related to quality of organic residues used. The study was conducted during the 1997 short rains (Oct 1997-Feb 1998) on a farm in western Kenya with the following treatments: (1) control without any input, (2) fertilizer at 120 Kg N, 150 Kg P and 100 Kg K/ha, (3) tithonia (*Tithonia Diversifolia* [Hemsely] A. Grey) biomass and (4) senna (*Senna spectabilis* D.C & H.S. Irwin) biomass. The organic residues were applied in fresh condition at 5 t ha-1 dry weight. The treatments were replicated four times in a randomized complete block design. Macro- and meso-fauna diversity and abundance were monitored in soil monoliths (25 x 25 x 30cm) and soil cores (10cm diameter and 30cm depth), respectively, at the beginning of the season, six weeks after sowing maize and at maize harvest. A satellite experiment was conducted simultaneously to quantify the role of soil fauna in the decomposition of organic residues, using fresh senna foliage (5 t/ha) as the test material and maize as a test crop. Two treatments, with and without soil fauna, were evaluated replicated six times. Fauna were eliminated by treating the soil with furadan at 40 Kg/ha at the start of the study, 2, 4, 6 and 10 weeks after crop sowing. The standard litterbag technique was used to monitor litter decomposition at 1, 2, 4, 8 and 12 weeks and N, P and K concentration in the undecomposed material at each of these sampling periods was determined. First order exponential equations were fitted between undecomposed material or nutrients contained therein (y) and time (t), and decomposition constants (k) worked out. Diversity and populations of soil fauna were found to be low in the arable land use system under study. Macrofauna constituted only 10 %. Termites were the most abundant of the fauna (55%) followed by earthworms (31%). Although the two organic residues did not affect faunal diversity, addition of senna increased total population by 200% and tithonia by 140% over the no input control. Fertilizer use did not change either diversity or total population. Soil fauna enhanced decomposition of senna residues although to a negligible extent. While only 45% of the material decomposed by two weeks in the absence of fauna, 60% material decomposed in the presence of fauna in the same period. After 8 weeks, hardly any material was recovered in the presence of fauna compared with 9 to 12% material recovered in the absence of fauna. Nutrient release was not influenced by fauna probably because of the nature of material used. As the secondary compounds were lower than the critical level (<4% polyphenol and <15% lignin), nutrient release progressed rapidly with the microbial action and fauna did not play a significant role. Fertilizer use increased maize grain yield by 63% over the control. Although Tithonia biomass increased maize grain yield by 38% over the control and did not differ significantly from fertilizer treatment, senna increased maize yield by only 6% over the no input control. Higher yield with tithonia than senna was partly because of higher nutrient concentration and hence greater amounts of nutrients added for the same quantity of material applied. Despite less faunal activity compared with that under senna, tithonia decomposed and released nutrients faster than senna probably because of increased microbial activity. The study indicates that (1) the relative effect of soil fauna on decomposition to that of soil microbes is small, (2) several parameters have to be considered in determining the quality of organic residues, (3) organic residues can be used to manipulate soil fauna and (4) high quality residues can be as sources of nutrients to improve crop yields.

Cheruiyot E. K. (2000). Adaptability of some legumes as fallow management species during the short-rains season of the Kenya highlands. Msc. Thesis, Chapter two, Egerton University Kenya

Kenya Highlands is an agricultural high potential zone mainly for the production of wheat and maize. However, decline in soil fertility attributed to prolonged cereal monoculture has greatly depressed potential yields. Typically,

the crops are produced exclusively in the April-August long-rains season and land left fallow during the October-December short-rains season. In an effort to improve wheat and maize yields, a three year study was conducted to evaluate adaptability of five legumes to the traditional short-rains fallow as precursor of the cereals. The objective was to identify a suitably adapted legume whose biomass can be incorporated prior to cropping the cereal for the improvement of soil nitrogen status and crop performance. Their biomass production, nodulation characteristics, residue quality and seed production were observed. Legumes produced low biomass compared to cereal and weedy vegetation in the traditional fallow. Soybean and field bean were among legumes with higher biomass. Despite low biomass, dolichos had good nodulation and better quality residue compared to the other legumes. Although seed yield gain was less consistent with legumes at Rongai, considerably food amount of seed DM in field bean, chickpea and garden pea were obtained at Njoro with better performance in field and chickpea.

Cheruiyot E. K. (2000). Effects of selected grain legumes on nitrogen dynamics and the performance of wheat (*Triculum Aestivum* L.) In A legume-wheat cropping sequence in the Kenya highlands. Msc. Thesis, Chapter three, Egerton University, Kenya

Wheat (*Triticum aestivum* L.) is an important food crop in Kenya with a consumption of 600,000 tons well in excess of a production of about 200,000 tons annually. Insufficient production has forced the Kenya government to import about 60% of local wheat consumption annually. Soil fertility has been cited as a contributing factor to the low yields currently averaged at 1.7-2.0 t/ ha against a potential of 4.0 t/ha. Wheat is traditionally grown during the long-rains season and land left fallow in the short -rains season. An experiment was set up at Egerton University, Njoro and Rongai both within the Kenya Highlands to investigate the contribution of five legumes grown during the short rains season against a continuous wheat and traditional fallow on soil nitrogen status and response of succeeding wheat in the long-rains season. The impact of improved fallow management practices on weed biomass and species distribution was also assessed during early growth stages in wheat. The legumes were chickpea (*Cicer arietinum* L.) field bean (*Phaseolus vulgaris* L, soybean (*Glycine max* (L.)Merril), garden peas (*Pisum sativum* L.), dolichos lab lab (*Lablab purpureus* (L) Sweet). Crop residues were incorporated prior to seeding wheat and soil sampled for N analysis eight weeks after the incorporation. Wheat biomass, days of heading, tiller count, spikeless numbers, seed weight, grain yield and total grain-N and vegetative tissue-N were determined. Wheat succeeding short rains season crop gave 1.6-2.7 t/ha against a proceeding fallow with 1.5-2.1 t/ha. Improved yields were recorded in wheat fallowing legumes where a corresponding increase in soil N was observed. Higher tiller count, spikelet numbers, grain-N, grain yield and delayed heading, was observed in wheat succeeding legumes generally and more significantly with dolichos. Besides, reduced weed biomass and species sere observed in legume-managed fallow. Hence the growth of legumes particularly dolichos, during the short-rains fallow can improve soil N status and the yield of succeeding wheat in the Kenya Highlands.

Cheruiyot E. K. (2000). The Effect of selected grain legumes on nitrogen dynamics and the performance of maize (*Zea Mays L.*) in a legume-maize cropping sequence in Kenyan highlands. Msc. Thesis, Chapter Four, Egerton University, Kenya

Maize (*Zea mays* L) is a primary food crop in Kenya and is cultivated country wide. Its production is slightly less than consumption and is produced mainly in agriculturally high potential zones of the Kenya Highlands. Production is mainly limited to the long rains season occurring in April-August. After harvest, majority of farmers fallow their land during the October-December short rains season as they wait for next cropping. The average maize yield is 1.5 t/ha against a potential of 7 t/ha. High input costs especially fertilizers coupled with declining soil fertility have contributed to the low yields. In an effort to improve maize yields through sustained soil fertility, a field experiment was set to study the contribution of five legumes grown in the short rains season to soil nitrogen status and performance of succeeding maize crop. The experiment was set up at Egerton University, Njoro and Rongai both within the Kenya Highlands and included a fallow, five legumes and maize (H513) grown during short-rains and each followed by maize in the April-August long-rains season. The legumes were chickpea (*Cicer arietinum*), field bean (*Phaseolus vulgaris* L), soy bean (*Glycine max* (L) Merril), garden pea (*Pisum sativum* L), dolichos lablab (*Lablab purpureus* (L) Sweet).Their crop residues including the cereal and vegetation in the fallow were incorporated in the soil during seedbed preparation. The influence of the short-rains management system on soil nitrogen status and response of succeeding maize was determined by soil sampling for N analysis, crop biomass, leaf area index, ear count, grain yield, vegetative tissue N and grain -N. Results show improved soil N status following legumes, with dolichos giving highest available N. Grain yield in maize succeeding legumes was 24-68% higher than maize succeeding weed fallow and in absence of N fertilizer input, maize succeeding dolichos 20-40% higher yield than maize after weed fallow treated with recommended 60kg N/ha fertilizer rate. Reduction in weed incidence was observed in maize following legume-managed fallow. Use of legumes, particularly dolichos in rotation with maize has large benefits as reflected in improved grain yields and reduction of fertilizer inputs.

Kihanda, F. and Rimui, C. M. (2000). N mineralization from farm yard manures. Kenya Agricultural Research Institute-Regional Research Centre –Embu. Annual Report pp 13-14

Farmers in the sub-humid highlands of Central Kenya use very little or no inorganic N-fertilizers and rely heavily on farm yard manure produced at the farm level to improve soil fertility and crop productivity. Studies conducted in the semiarid areas of Kenya and in other parts of sub-Saharan Africa have shown that farm yard manure is very variable in nutrient composition. A pot experiment was set up to test N-uptake of wheat at harvest. The results showed a wide variation in the nutrient composition of the farm yard manure samples. The farmyard manures collected were found to be low in phosphorus. There was immobilization of mineral N derived from all the farm yard manure tested in the first four weeks of incubation, higher immobilization being observed in farm yard manure of high C: N ratio. The N mineralization from the farm yard manure was between 0-40% of the total in the farm yard manure, the high mineralization being observed in the farm yard manure of low C:N ratio and immobilization being observed in farm yard manure of high C:N ratio during a 12-week incubation period. The soil type appeared to influence the mineralization of the three farm yard manure types; higher mineralization being observed in the near neutral soil than the acidic soil. The effects of the soil on the mineralization of the farm yard manure were more pronounced in farm yard manure of high C: N ratio.

Lekasi J. K. (2000). Manure management in the Kenya highlands: Collection, storage and utilisation to enhance fertiliser quantity and quality. PhD thesis, Coventry University, United Kingdom

One consequence of decreasing the size of land holdings in the central Kenya highlands is a shift from extensive to more intensive mixed crop/livestock farming systems including acquisition of external inputs to feed livestock and replenish soil nutrients. Inorganic fertilisers are too expensive for most smallholders. The scope of this study was to evaluate manure management options that could best conserve nutrients. Two surveys documented current and potential manure management options and evaluated manure physical and chemical characteristics that could be associated with manure quality. The quality of composted manure after 144 days of collection and composting, based on high N content and low C: N ratio, varied depending on the manure collection strategy. The order of effectiveness in conserving nutrients after composting was (1) faeces + maize stover feed refusals > (2) faeces + urine + maize stover feed refusals, hand mixed > (3) faeces + urine + maize stover feed refusals, animal mixed underfoot> (4) faeces alone >(5) faeces + urine , hand mixed. Generally, manures with feed refusal additions were of superior quality to those without. Urinary N was not conversed by any of the strategies that contained urine as a constituent. When steers were fed with a basal diet of napier grass and diary meal concentrate at 0.5 or 1% live weight, high concentrate levels resulted in both faeces and urine of significantly higher N than the low concentrate levels. It was possible to conserve urinary N when wheat straw was applied at the relatively high amount of 1.8 Kg/Kg live weight per year, about 720 kg per 400 Kg cow live weight per year. An experiment in which faeces was mixed with wheat straw or not and either covered with a clear plastic sheet or not showed no significant differences between the covered and uncovered manure heaps whether straw was included or not, under the prevailing dry experimental conditions at the time. Experimental manures were tested in maize (*Zea mays*) production field trials at Kariti and Gatuanyaga of Maragua and Thika Districts, respectively. Maasai manure (kraal or boma manure) obtained from the pastoralists of Kajiado in the Rift valley and a farmer`s own manure were also tested. All the manures increased maize yield. Maasai manure, with a lower N concentration and higher C: N ratio than the experimental manures, surprisingly, gave the highest yield. Among the five experimental manures, yield increased with increasing N concentration and decreasing C: N ratio although all manures were applied at 75 Kg/ha. The farmer manure performed the poorest of the manures. In the first season, maize grain yield for the manured plots was 789-1251 Kg/ha and 2287-4336 Kg/ha for Gatuanyaga and Kariti sites, respectively, while the unmanured controls yielded 636 and 1371 Kg/ha, respectively. First season maize stover dry matter yields, which represents nutrients that can be recycled through the livestock, were 1789-3112 Kg/ha and 2155-4471 Kg/ha for Gatuanyaga and Kariti, respectively. Second season yields for Kariti sites were lower than the first season but followed the same trend. Therefore, manure management can affect manure quality, which in turn is translated in maize yield. Finger millet (Eleucine *coracana*) dry weight production in a greenhouse pot trial was examined for correlation with laboratory N-mineralisation and manure lignin, polyphenols, NDF-N and the C: N ratio. Millet yield was influenced by manure quality parameters. In conclusion, the diet fed to the animals and the type of organic materials added to the manured had an effect on the manure quality as assessed by nutrient content. Conservation of manure nutrients could be attained by manipulation of composting strategies to include organic material additions to the animal excreta during collection and storage periods. Manure that attained low C: N ratios and maintained high N concentrations at the end of composting promoted higher maize yields. However, a linear positive relationship was also established between the maize yield and initial manure lignin content, suggesting that lignin might have played a role of achieving and maintaining synchrony between manure nutrient mineralisation, especially N, and plant nutrient demand. Appropriate manure management could significantly improve nutrient conservation on smallholder farms in the Central Kenya Highlands.

Nziguheba G., Merckx R., Palm C. A. and Rao M. R. (2000). Organic residues affect phosphorus availability and maize yields in a Nitisol of western Kenya. *Biological Fertility Soils Journal*

Vol. 32 pp.328-339

The effects of organic residues and inorganic fertilizers on P availability and maize yield were compared in a Nitisol of western Kenya. Leaf biomass of *Calliandra calothyrsus*, *Senna spectabilis, Croton megalocarpus, Lantana camara, Sesbania sesban*, and *Tithonia diversifolia* were incorporated into the soil at 5 Mg/ha for six consecutive seasons in 3 years and responses compared with those following the application of 120 kg N/ha, 0 kg P/ha (0P); 120 kg N/ha, 10 kg P/ha; and 120 kg N/ha 25 kg P/ha as urea and triple superphosphate (TSP); K was supplied in all treatments. Addition of Tithonia, Lantana and Croton increased soil resin-extractable P over that of fertilizer amended soil throughout the first crop, but the amounts in the former treatments became similar to those for soils amended with inorganic fertilizers for subsequent crops. Addition of Sesbania, Calliandra and Senna had a similar effect on resin P as inorganic fertilizers. Total maize yields after six seasons were tripled by the application of Tithonia compared to 0P, and were higher than those of the Calliandra, Senna, Sesbania and Lantana treatments, and similar only to that of the Croton treatment. P recovered in the aboveground biomass and resin P, immediately after the implementation of the treatments, was higher in the Senna, Sesbania, Croton, Lantana and Tithonia (35–77%) treatments than in the inorganic fertilizer treatments (21–27%). The P content of organic residues, and the soluble: total P ratio, were the main residue parameters predicting soil P availability and maize yield. All organic residues used in this study can replace inorganic fertilizers for the enhancement of P availability and maize production, while an additional benefit could be obtained from the use of Croton, Lantana and Tithonia.

Rao M.R., Mathuva M.N. (2000). Legumes for improving maize yields and income in semi-arid Kenya. *Agriculture, Ecosystems and Environment, Elsevier* Vol. 78 pp. 123-137

An experiment was conducted at the research station of the International Centre for Research in Agroforestry (ICRAF) at Machakos, Kenya from November 1989 to February 1996 to evaluate the effect of annual and perennial legumes on soil fertility, cereal yields and economic returns. The study evaluated six cropping systems: (1) continuous sole maize, (2) maize rotated with short-duration legume, cowpea (*Vigna unguiculata* L. Walp.), (3) maize rotated with long-duration legume, pigeon pea (*Cajanus cajan* L. Millsp.), (4) maize intercropped with pigeon pea, (5) hedgerow intercropping of maize and a perennial legume, gliricidia (*Gliricidia sepium*), and (6) continuous sole maize, green-manured with gliricidia prunings produced from an equivalent area outside the crop field (`biomass transfer technology`). Maize-cowpea sequential and pigeon pea/maize intercropping systems produced, respectively, 17 and 24% higher maize yields than continuous sole maize, but maize-pigeon pea rotation yielded only marginally better. Hedgerow intercropping did not increase maize yields because increased yields during the few high rainfall seasons did not compensate the yield losses in other seasons due to the competition of hedgerows for water with crop. Green manuring with gliricidia prunings increased maize production by 27%, but this technology was not economical because of high labour costs for production and application of prunings to the crop. The annual grain legume-based cropping systems were 32-49% more profitable than continuous sole maize, making them attractive to small farmers in semi-arid tropics. Both cowpea and pigeon pea were affected by pests and diseases, which indicated the need for integrated pest management for realising the potential benefits of these legume-based systems. Keywords: Cowpea, gliricidia, hedgerow intercropping, legumes, maize, pigeon pea, semi-arid tropics, soil fertility, Kenya.

Hanan O. A. (1998). Effects of cow dung manure on some physical and chemical properties on saline-sodic soils in Kiboko, Makueni district. Msc. Thesis, University of Nairobi, Kenya

The effect of cow dung manure on some physical and chemical properties of saline-sodic soils in Kiboko, Makueni district were examined. Two soil types, namely, chromo-haplic Lixisols for site 1 and mollic and sodic Solonchaks for site 2 were selected in two different levels of cow dung manure (0, 10, 20, 30 and 40 tonnes/ha) in three replicates. After 18 weeks of application of cow dung manure, soil samples were taken from the top two horizons for physical and chemical analysis. In addition, water samples used for irrigation were analyzed to determine their chemical characteristics and their suitability for irrigation. At site 1, there was little evidence of improving the physical and chemical properties of the soil, notably bulk density, antecedent moisture content, organic carbon, soil pH, EC, CEC, % total N, ESP and SAR when compared with the control. However, after the application of 40 tonnes/ha there was significant difference in aggregate stability ($p \leq 0.05$) among treatments and the two top horizons when compared with the control. Similarly Ksat significantly improved ($P \leq 0.05$) after the application of 20 and 40 tonnes/ha. The highest final infiltration rate was obtained from the plots which received 20 tonnes/ha of cow dung manure. This was significantly different ($P \leq 0.01$) from the control. At site 2 there were significant improvements in aggregate stability, infiltration rate and available water. In the two top horizons, aggregates stability improved with increasing rate of cow dung manure. There significant differences in aggregate stability among treatments ($P \leq 0.01$) when compared with the control. After the application of 30 tonnes/ha the final infiltration rate were significantly different ($P \leq 0.05$) from the control, while the other physical

and chemical parameters improved slightly. The irrigation water from the boreholes in the two sites fall under very high saline class (EC=4.08 and 5.10 d/Sm at 25 c for site 1 and 2 respectively) and low to medium sodium hazard (SARadj=15.27 and 11.92 for site 1 and 2 respectively. The Kiboko river, which was also used in site 2, falls under medium saline class (EC=2.04d/Sm at 25° C) and low sodium hazard (SARadj=3.92)

Bunyasi, S. W. (1997). Effects of Chemical Composition of plant Residues on Nitrogen Release and Crop Uptake. Msc Thesis, University of Nairobi, Kenya

To supplement high cost of inorganic fertilizers, smallholder farmers in the tropics are likely to increase the use of plant residues as a sustainable source of plant nutrients especially nitrogen (N) and phosphorus (P). Management of these organic N- sources demand that their N-release patterns coupled with synchronisation of the released N with crop growth be fully understood. Consequently, this study was undertaken to evaluate the effect of chemical composition of various residues on N- release, improve the N- release pattern of low quality organic materials by mixing them with those of high quality and synchronize the N released with crop production. The objectives were achieved through a series of controlled experiments. The experiments involved incubation, in the laboratory for 12 weeks, of six selected plant residues which involved leaves of *Leucaena leucocephala, Croton macrostachyus, calliandra calothrysus, Tithonia diversifolia, Sorghum bicolor*, and husks of *Oryza sativa*. Parallel to this, mixtures of C. macrostachyus (Cm) and O. sativa (OS) in various ratios were also incubated. Finally maize was grown in the glass house in pots whose soil had been amended with *C. Macrostachyus, O. sativa, T. diversifolia* (TS) and 1/2 : 1/2 mixture of Croton macrostachyus , Oryza *sativum*. In the Laboratory incubation, soil samples were taken after every 2 weeks for analysis of ammonium nitrogen (NH_4^+-N) and nitrate nitrogen ($N0_3^-$-N), while in the glass house experiment, harvesting of maize tops was done at 2 weeks intervals 8 weeks and the shoots dry matter as well as N content determined. Two patterns of N ($N0_3^-$-N + NH_4^+-N), release were observed during the 12 week incubation period. Levels of C. *macrostachyus, L. leucocephala, T. diversifolia and C. Calothrysus* had a net release throughout the incubation period while *S. bicolor* leaves and *O. sativa* husks showed significant net immobilisation. Due to concurrent nitrification over the 12 week incubation period, 65 - 80% of the accumulated mineral N was in nitrate form. The dynamics of N mineralisation of the various mixture of Croton macrostachyus (CM) and *Oryza sativa* (OS) were in general not significantly ($p \geq 0.05$) different from those predicted from the isolates of *Oryza sativa* (OS) and *Croton macrostachyus* (CM) alone with the exception of the 3/4 Cm + 1/4 Os having depressed the incubated N-release in weeks 6-8 significantly while the 1/4 Cm + 3/4 Os stimulated the incubated N-release at weeks 2 and 12 weeks of incubation respectively. Addition of plant residues increased maize biomass in the glass house significantly ($P < 0.05$) throughout the growth period. However, the study showed sharp contrast of maize response from the results of the incubation. Mixture of plant residues in the pots had the highest contribution to maize dry matter yield and N uptake. It could be speculated that high C: N ratio Oryza sativa material in the mixture stimulated microbial activity in the rhizosphere leading to high organic material decomposition. Of the chemical variables studied, initial contents of N and P as well as C: N and polyphenol: N ratios were significantly correlated with cumulative N mineralized nitrogen - release was best correlated with C: N ratio having r= - 0.84 to -0.90 for the most of the sampling periods. Polyphenol: N ratio also gave high correlation with cumulative N mineralisation with correlation coefficient (r) ranging from -0.65 to -0.95. Initial N and P contents showed positive significant correlation but not as high as those of the two ratios. These results show that the predictors for N mineralisation were residue C: N and polyphenol: N ratios.

Mugendi D. N. (1997). Tree biomass decomposition, nitrogen dynamics, and maize growth under agroforestry conditions in the sub humid highlands of Kenya. Msc. Thesis

University of Florida, USA.

Declining crop yield, consequent to continuous cropping without external addition of adequate nutrients, is a major problem facing smallholder farmers in the tropics. The high cost of inorganic fertilizers has led to increased interest in the use of leafy biomass from woody species as a source of nutrients to annual crops. This dissertation reports the results of a study, conducted in the sub humid highlands of Kenya since 1992, on the influence of soil-incorporated leaf prunings of two agroforestry tree species incorporated leaf prunings of two agroforestry tree species (Calliandra calothyrsus--calliandra and Leucaena leucocephala) on maize yield and soil fertility status in sole cropping and alley cropping systems. Inclusion of calliandra hedges on cropland (alley-cropping) adversely affected crop yields during the four-year study period, whereas alley cropping with leucaena increased crop yields. In all the treatments, mineralization of soil N was at its peak four weeks after maize planting. Cumulative mineralized N at week 20 ranged from 115 to 360 kg N/ha/season; the non-alley-cropped, non fertilized control giving the lowest, and the prunings-incorporated treatments giving the highest amounts of N. Total N uptake by maize, ranging from 40 to 160 kg/ha/season, was lowest in the alley-cropped, prunings-removed plots, and the highest in the prunings-incorporated plots. Studies with ^{15}N indicated that soil application of N-rich biomass contributed more to the long-term build up of soil N than to meeting the nutrient build up of soil N than to meeting the nutrient requirements of the current cropping season, 8% to 3% in the tree hedges; 20% to 30% could not be accounted for. A separate study on decomposition of tree-leaf biomass of some commonly used

agroforestry tree species in the region revealed that the prevailing general assumption that decomposition of tree biomass is determined predominantly by plant quality factors was not always true; during seasons of erratic climatic changes (e.g. fluctuating temperatures), climatic factors were more important than plant quality factors in influencing the rate of biomass decomposition.

Onwonga R. N. (1997). The Effects of Incorporating Chickpea Residue on Soil Nutrient Status, Nitrogen Availability and Wheat Yield In A Chickpea-Wheat Rotation. Msc. Thesis, Egerton University, Kenya

The experiment on the effect of Chickpea residue incorporation on soil nutrient status, nitrogen availability and wheat yield in a chickpea wheat cropping sequence was conducted at Field 7 of the department of Agronomy. The experimental design was a randomized complete block design with a split plot arrangement. Chickpea above ground residue after harvest of dry pods contained 5412 kgN/ha compared with a pre-wheat fallow, chickpea residue increased wheat grain yield by 0.46 t/ha when no urea -N was applied to wheat Chickpea residue substituted for 38.1 kg urea-N/ha on wheat. In the absence of urea the residue increased total above ground N in mature wheat by 26.1 kg N/ha. This increase corresponded to a plant recovery of 48.01% for applied residue N. Chickpea residue incorporation had significant effect ($P<0.05$) on N for applied residue N contribution to wheat, and had an additional advantage of 1.0 t/ha grain yield of protein rich chickpea, compared to pre-wheat fallow. Preliminary measurements of decomposition rate and N-mineralization of the chickpea residue was carried out using litter bags. The chickpeas residue showed two phases of decomposition an initial rapid phase followed with a slower one. The phases of decomposition rate constant of the residue were estimated at -11.05/yr with a half life of 17 days. The pattern of N release from the residue was similar to that of mass loss. The cumulative residue N released after 90 days was 60% of the original N in the incorporated residue. The calculated N mineralization constant was -3 10/yr with a half life of 58 days. Soil nitrate N in the top 60 cm soil layer before wheat sowing was not affected by the pre-wheat treatments. At 15 and 30 days after sowing (DAS), soil nitrate-N was higher for the chickpea residue treatment than for the pre-wheat fallow treatment. At 30 DAS soil nitrate increased by 10.72 kg/ha in the residue treated plots above the pre-wheat fallow plots. This increase corresponded to 20% of the N added as residue. Soil mineral N in the top 60cm soil layer fallowed increased from 2.01 kg/ha to 13 kg/ha at 30 DAS. The corresponding recovery of residue N increased from 3.7% to 24% at 30 DAS. There was no significant effect on soil chemical properties by the pre-wheat treatments across sampling periods and depths.

Kihanda, F. M. and Warren, G. P. (1995). The effect of manuring on soil nitrate in semi-arid Eastern Kenya. Kenya Agricultural Research Institute-Regional Research Centre -Embu, Annual report pp 6-8

Nitrate is the main form in which plants take nitrogen (N) from the soil. It is released from soil organic matter by mineralization, but is then subject to several processes by which it can be lost before plant roots can take it up. In semi-arid climates, nitrate concentration is normally highest at the start of the season. Soil nitrate was measured on selected occasions during the 1994-5 cropping season at three sites in Mbeere and Tharaka-Nithi Districts, Kenya. The treatments were goat manure applied at 0, 5 and 10 t/ha annually since 1989 and 5 t/ha and 10 t/ha annually from 1989 to 1992. The plots were intercropped with sorghum and cowpea. The objective of the study was to examine nitrate dynamics under different manure regimes at three sites of contrasting fertility characteristics. The results showed that, changes of nitrate in the manured and unmanured soils in different sites appeared to parallel each other and there were major losses early in the season. Thus, mineral fertilizer N should only be applied as a top dressing to avoid its being lost as well. To conserve fertility value of manure, it was suggested that no more than 5 t/ha per year of manure should be applied, because at higher rates there was surplus nitrate at the end of the season in February and this nitrate would probably be lost at the start of the next season.

Itabari, J. K, Watiki, J. M, Karuku, A. M, Nguluu, S. N, Nixon, D. J. (1995). Yield response of maize to rate and placement of boma manure. *Proceedings of the 4th KARI Scientific Conference*. 25th to 28th October 1994 at Silver Springs, pp 222-230

A field study was conducted to determine the yield response of maize (*Zea mays* L., Katumani composite B) to rate and placement of boma manure. Yield response to banding was consistently higher than that of broadcasting up to around 75 tonnes per hectare, after which response to broadcasting became higher. However, these differences were not significant at any rate of application. The highest yield obtained with banding was 1.9 t/ha at the application rate of 40 t/ha while that obtained with broadcasting was 2.2 t/ha at the application rate of 100 t/ha. Rates of application above 40 t/ha had no significant effect on yield.

Macharia P. N. (1994). Effect of *desmodium uncinatum* on soil nitrogen and herbage yield of *chlotis roxburghiana* in Kibwezi area. Msc. Thesis, University of Nairobi, Kenya

The effect of *Desmodium uncinatum* on *Chloris roxburghiana* in Kibwezi area was situated at the University of Nairobi Dryland Field Station. The station falls under the agro-ecological zone V. The study was conducted under both filed and greenhouse conditions during two seasons in 1991/92. The main objective of the study was to assess the interactions between the two species in increasing primary productivity of rangelands to facilitate livestock production. Treatments consisted of growing Desmodium alone, Chloris alone, Desmodium/Chloris mixture and a control. The effect of treatments in greenhouse pots indicated significant (P<0.05) differences with legume treatment having more total N. In field plots, significant differences occurred only in watered plots. These plots had more total N (albeit non-significant) than the unwatered plots. The top soil (0-15) had more (P<0.05) total N than the subsoil (15-30cm). The treatments had non-significant (P=0.05) results on the available P concentration in the greenhouse. The effect of seasons showed significant (P<0.05) differences in the greenhouse with a decrease at the end of season 2. In field plots, significant (P<0.05) effect of treatments and depth occurred only in watered plots. The effect of watering showed significant differences at the end of season 2 in the top soil. There was a rise of P concentration at the end of season 1 and a decrease of P at the end of season 2 in both watered and unwatered plots at both depths. The DM, CP and P content in the greenhouse study, the effects of treatments and stage of growth showed significant seasons. The field experiment indicated that D. uncinatum increased DM production of C. roxburghiana during the first season (short rains season). The CP and P content of Chloris grown in mixture was more (P<0.05) than that of the grass grown in monoculture. The effect of watering increased the P content of both the legume and grass plants. Both greenhouse and field studies showed that there was a decrease of CP and P content of both legume and grass as the plants approached maturity. The results indicated that the herbage quality and quantity of *C. roxburghiana* can be enhanced by growing it in mixture with *D. uncitam* under the semi-arid environment of Kibwezi area. Desmodium will also enhance soil fertility levels. These qualities can have a positive effect on the cattle, goats and sheep that graze in that area.

Esilaba, A. O, Kilewe, A. M, Ikombo, B. M, Mwangi, D. M, Odongo, N. O, Miriti, J. M, Metto, J. K, Ademba, J. S, Kamau, F. N, Kaiyare, J., Wanyama, E and Gachui, M. (1993). Evaluation of Sesbania sesban, Leucaena leucocephala and Leucaena K28 for Maintenance of soil fertility. Kenya Agricultural Research Institute-Muguga South, Annual report pp 47-53

Decline in soil fertility and increased soil erosion are major problems in the food based land use systems in the high and medium potential regions of Kenya. Alley cropping is an agroforestry system in which food crops are grown in alleys formed by hedgerows of trees and shrubs which are preferably legumes (nitrogen fixing). The hedgerows are cut back after planting and periodically pruned during cropping to produce green manure or mulch for the crops, prevent shading and to reduce competition with the associated food crops. It allows longer cropping period with increased land-use intensity, rapid and effective soil fertility regeneration and more intensive cropping with reduced requirements for external inputs. Thus multipurpose trees and shrubs in alley farming provides green manure and mulch for companion crops, weed suppression, favourable conditions for macro and micro-organisms, better soil conservation, fodder, staking material and firewood. A study was carried out to determine the effect of farmyard manure (FYM) and hedgerow prunings of *Sesbania sesban, Leucaena leucocephala*, Leucaena K28 grown in alleys on soil productivity. The results showed that, the total biomass yield varied between 11-17 t/ha (*Sesbania*), 5-7 t/ha (L. *leucocephala*) and 4-6 t/ha (Leucaena K28). Sesbania was the most productive tree in terms of wood and prunings and consistently out yielded the Leucaenas. There was no significant effect on farmyard manure on tree biomass yield. It was observed that the no input control had higher bean grain yield than the sesbania prunings, giving an indication of nutrient immobilization by the biomass.

Kanampiu, F. K, Njiru, E. N, Njakuthi, N. N, Mwangi, I. N. and Muriithi, C. W. (1989). Effects of soil amendments on maize yield in acid soils. Kenya Agricultural Research Institute-Embu-Regional Research Centre, Annual Report pp 20-22

Maize production has been difficult in the highly acidic soils of both central and eastern Provinces, Kenya. The yield potential of maize genotypes developed for these areas is high; however, maize yields rarely achieve their potential. The most common method of reducing the aluminium concentration (lowering of pH) in the soil is by liming which also eliminates calcium and magnesium deficiencies. It is also known that applications of manure, phosphorus and maize stovers increase maize plant growth (by 210% with manure, 129 with lime, 53% with phosphorus and 9% with maize stover). A trial was conducted in Kianjokoma, Embu District during the 1989 long rains and was an on-going project. Prior to planting, site was ploughed to a depth of 25 cm using hand hoes. Maize stover was chopped, broadcasted, and incorporated, while lime and manure were broadcasted and incorporated. Maize variety H625 was planted two seeds per hill at a spacing of 75 cm x 25 cm in a randomized complete block design and replicated twice. The results showed that, high rates of cow manure and lime gave higher yield and maize growth than low rates of the same materials. Maize stover increased the C: N ratio and this could have resulted in nitrogen unavailability due to immobilization and hence low yields. Both high and low

rates of cow manure gave less grain yield than the control. Except for stover plus manure combined at 7.5 and 5 t/ha, respectively, all other treatments with stover yielded less than control. The highest grain yield was obtained with the combination lime and manure 5 t/ha. Other treatments with lime gave higher grain yield than the control except the combination of lime and stover at 5 and 7.5 t/ha respectively. Lime could have increased the pH and provided magnesium which could have resulted in high maize growth and hence high grain yields.

Chui J. N., Waweru E. and Kungu N. K. (1983). Evaluation of Effects of Rhizobium phaseoli strains on bean plant parameters. Kenya Agricultural Research Institute Muguga, Annual Report

Some soils in Kenya have indicated lack of bean rhizobia and need for inoculation. This greenhouse experiment was conducted to determine the availability and effectiveness of indigenous rhizobia compared to known rhizobium strains. Two bean (Phaselous *vulgaris* L.) varieties, Mwezi moja and Zebra were used. Two local rhizobium strains, NUM 405 and NUM 439 and their combination, 2-NUM was applied. An exotic strain, 3-NS from NIFTAL project, Hawaii, was included for comparison. The soils were Oxic paleustalf, pH 5.0 from National Dryland Farming Research Station, Machakos. Data showed that staem sterilization of soil was no successful. Hence results reported were those of unsterile soil. There were effective indigenous rhizobia in the soil for nodulating the bean varieties. At pod filling, although inoculation did not affect nodule number of Zebra beans, some of the inoculants reduced nodule number of Mwezi moja. Nodule dry weights of both varieties were not affected by inoculation. Nodule pod filing was negatively correlated (r=0.61) with seed yield but positively correlated with nodule number (r=0.80). Comparisons showed that only NUM 439 was able to significantly increase shoot dry weight of Zebra beans at pod filing by 98.7% over the control. At maturity, strains NUM 439 and 3-NS increased the haulm dry weight of Mwezi moja by 9% and of Zebra by 8.7% respectively. Seeds had more total nitrogen content per plant than haulms. Mwezi moja beans had more haulm total nitrogen content than zebra beans by 17%. The combined strains, 2 NUM, treatment caused the highest haulm total nitrogen content for both varieties. The 2-NUM increased haulm total nitrogen content of Mwezi moja by 37.7% and of Zebra by 25.2% over their controls. The distribution of nitrogen to various bean components is shown. Seed had the highest percentage nitrogen content compared to tops, empty pods or roots. On the average, inoculation increased percentage nitrogen content of taps and seeds but seemed to have a small negative effect on pods and roots percentage nitrogen content. The two bean varieties responded to inoculation differently. Mwezi moja seemed to have a better response to NUM 439 strain and Zebra to 3-NS on haulm dry weight, seed yield and seed total content. However, both bean varieties had a similar response to 2-NUM for haulm total nitrogen content.

Birch U.F. (1956). Organic matters decomposition in E. African soils. *Conference on Nitrogen status of soils-Muguga*, Kenya, 25th April, 1956.

Evidence is presented to show that under moist conditions appreciable quantities of potentially decomposable organic material interact with the clay fraction of the soil and are held in a form resistant to microbial attack. The amount retained depends on the kind and amount of clay, its degree of saturation with organic compounds and the supply of organic material. When the soil is dried some of the material is liberated and is rapidly decomposed by micro-organisms when rewetted. The amount liberated depends on the intensity and period of drying. The effect is repetitive with successive wetting and drying. Studies with clay minerals showed that montmorillonit protected gelatine from microbial attack. Gelatine to about 5% of the weight of the clay was so protected. Under comparable conditions kaolinite was singularly ineffective. These observations have a bearing both on the C and N status of tropical soils and the pattern of organic matter breakdown. The kind and amount of clay will affect the equilibrium level of C and N under various conditions, while the ability of the clay to protect (when moist) and to release (when dry) rapidly decomposable organic material is obviously an important factor in regions having marked wet and dry periods. During the rains some of the macro organic matter decomposition products (which must be of lower C/N material (conducive to nitrate formation) together with a more prolonged breakdown of macro organic matter (crop residues etc) whose decomposition products can replace those effect of drying on organic matter breakdown patterns is reported in the text, and the theory affords a satisfactory explanation for the nitrate flush (particularly as affected by exposure and shading of the soil) and the beneficial effect of burning where this occurs. The organic matter associated with the clay fraction is not as inert as is generally imagined.

Dougall H. W. (1953). Fertilizer experiments on Ley-establishment, established Leys and natural pastures in the Kenya Highlands. ***East African Agricultural and Forestry Journal, EAAFRO***

The composition of natural pasture herbage was first studied in Kenya by Boyd-Orr [1], who considered phosphorus to be the element most deficient, and he inclined to a view that if phosphorus were supplied by fertilizers, the amount not only of phosphorus but of calcium would be increased in the pastures. In 1950 the Highland Fertilizer Scheme demonstrated promising herbage-yield responses to phosphorous and to nitrogen by certain natural and established pastures. Marked beneficial effects of phosphorus on ley-establishment were demonstrated also. In 1951 the Department of Agriculture sought to obtain a preliminary assessment of optimum dressings of a phosphatic fertilizer (single superphosphate) and a nitrogenous fertilizer (sulphate of ammonia) for natural and established pastures, and for establishing leys, on different kinds of soil and in areas of varying altitude and climate. In this paper an attempt is made to summarize the main results obtained from these latter investigations. The field trials on natural and established pastures were composed of replicated factorial combinations of three levels of single superphosphate (P) and six levels of sulphate of ammonia (N). The fertilizers were broadcast at the beginning of the 1951 growing season and nitrogen was applied at the appropriate level after each herbage cut had been taken. Ley-establishment trials were composed of replicated factorial combinations of four levels of P and four levels of N, the fertilizers being placed in the seed bed only. One of the following grasses-Rhodes, molasses, cocksfoot, K31 fescue-was sown with Lucerne or with serradella. The herbage in all trials was cut at intervals when the sward reached a stage of growth considered suitable for stock grazing. Soil samples to a depth of six inches were taken from each plot of each experiment for pH determinations. The nitrogenous fertilizer applied to natural and established pastures and to the seed bed of newly sown leys was found to increase the yield per acre of dry matter, crude protein, lime (CaO) and phosphorous (P_2O_5). In respect of natural and established pastures, dry matter response to N conformed to a calculated logarithmic curve. The system adopted of reapplying N to these pastures after each herbage cut was found to enhance their productivity during the growing season. No interval application of N was made to newly sown leys but a single dressing to the seed bed in adequate amount (approximately 11/2 cwt. sulphate of ammonia) usually assisted establishment. Measurable residual effects were rarely obtained from subsequent cuts except occasionally at higher levels of application. Applications of the phosphatic fertilizer to natural and established pastures and to the seed bed of newly sown leys were found to increase the yield per acre of dry matter, crude protein, lime (CaO and phosphorous (P_2O_5). Calculated response curves to P in respect of dry-matter yield from natural and established pastures and from newly sown leys resembled closely those given by Crowther and Yates [2] for root and cereal crops in England. The main effect of P on newly sown leys was undoubtedly to promote their establishment. An adequate dressing depended on soil and locality but rarely was required to exceed 3 cwt. of single superphosphate. A residual effect after the first cut was reflected in the phosphorus content of the herbage but seldom in dry matter production. With natural and established pastured, however, some evidence of residual effect was obtained through its enhancement of yield increases obtained by reapplying N approximately 1-11/2 cwt. sulphate of ammonia per acre. A known effect of adding sulphate of ammonia to a soil is to cause, eventually, an increase in soil acidity [3]. This effect was demonstrated clearly in the soils of newly sown leys and of natural and established pastures, when the fall in pH was related directly to each increment of N applied. E.M. Crowther [4] has related pH to response to P for crops such as swedes and turnips. A similar relationship between pH and response to P was found for natural and established pastures in Kenya: a less convincing relationship was found for newly sown leys. Evidence was obtained in 1952 which suggested that the amount of phosphorus taken up by the herbage of natural and established pastures may be also be related to pH. Rainfall in Kenya is neither well distributed nor reliable yet the need for adequate moisture in relation to normal plant growth in the presence or absence of fertilizers is obvious. In 1951 it was found with newly sown leys that at every increment of N applied to the seed bed, yields of herbage could be related directly to the rain which had fallen during the month prior to cutting. No corresponding relationships were found with natural and established pastures, and this may be ascribed, in part at least, to the presence of more favourable soil-moisture regimes. The efficiency of the phosphatic fertilizer in herbage production was found also to be dependent on rainfall. For newly sown leys, and for natural and established pastures, responses over control yield were related directly to the rain which had fallen during the month prior to cutting. At high altitudes, plant growth tends to be slow and the Kenya Highlands are no exception. In 1951 it was possible to relate altitude directly to the number of days required to obtain an initial cut from newly sown leys. Available information suggests that under a given environment, a dominant species in a ley sward or in a natural sward will behave similarly in its response to N and to P.

Organic And Inorganic Fertilizer Combinations

Overview

Often circumstances demand combination of organic and inorganic fertilizers. In general, organic fertilizers have low nutrient concentrations and their nutrient release pattern does not synchronize with the crop demand. However, they provide soil organic matter that is crucial for the soil physical and biological characteristics needed for transformation and uptake of nutrients. The inorganic fertilizers supply nutrients in the available form but the amounts required to meet crop demand is not affordable by most of the smallholder farmers in Kenya. Furthermore, inorganic fertilizers lack the capacity to improve the soil physical and biological characteristics. A combination of organic and inorganic provides optimal conditions and better supply of nutrients throughout the various stages of crop growth. The understanding of the amounts of organic/inorganic fertilizer combinations required for various regions in Kenya is limited. This section presents outputs of various studies that have attempted to determine the yield potential of various organic/inorganic fertilizer combinations.

Ademba J.S., Kwach J. K., Esilaba A. O. and Ngari S. M. (2015). The effects of phosphate fertilizers and manure on maize yields in South Western Kenya. East African Agricultural and Forestry Journal. VOL. 81, NO. 1, 111

Phosphorus, nitrogen and Strigahermonthicaare the majorconstraints to maize production in the Nyanza Province of Kenya.Field trials were conducted on-farm in Nyanza Province toinvestigate the effects of phosphate fertilizers and manure onmaize yields. The experimental design was a RandomizedComplete Block Design (RCBD) with maize as the test crop. Themaize was top dressed with calcium ammonium nitrate (CAN)fertilizer at a uniform rate of 30 kg N/ha diammonium phosphate(DAP), Minjingu rock phosphate (MRP) and triple super phosphate (TSP) fertilizers were applied at 60 kg/ha P2O5, farmyard manure(FYM) at 10 t/ha and a non-phosphorus (P) treatment (control)plus lime only. Responses (P ≤0.01) from grain yield, total drymatter yield and harvest index to phosphate fertilizers andmanure treatments were found. Nutrient uptake and removal bythe crop increased (P ≤0.01) due to fertilizers and manure application. Phosphate fertilizers and manure applicationincreased (P ≤0.01)) available soil P, agronomic phosphorus useefficiency (APUE) and Physiological P use efficiency (PPUE). The results indicate that phosphate fertilizers and manure applicationsare essential to improve maize yield and nutrient P use efficiency.

Abuom P.O., Nyambega L. A., Ouma G. (2014). Effect of Mavuno Phosphorus-Based Fertilizer and Manure Application on Maize Grain and Stover Yields in Western Kenya. Journal of Environment and Earth Science Vol.4, No.17, 2014; ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) www.iiste.org

Low crop productivity in western Kenya can be attributed to low soil fertility and limited use of organic and inorganic fertilizers. This is attributed to high costs of fertilizer, inconsistent application and duration of use. Efforts to improve and maintain soil productivity through use of manure and fertilizer among others has been ongoing in western Kenya for years. Despite these efforts low crop yield associated with limited use of common compound fertilizers is still prevalent. Remarkable increases in yield have been noted with compound fertilizers which offer additional benefits in terms of nutrient supply. *Mavuno* a locally blended fertilizer promoted in western Kenya offers such benefits. The objective of this study was to evaluate the effect of *mavuno* phosphorus based fertilizer and manure on maize and stover yields in Nyalgunga, Nyabeda and Emusutwi sub-locations, western Kenya; where low soil fertility, coupled particularly with low available phosphorus has been pointed out as the major factor limiting crop productivity. The study was carried out on fields where *mavuno* fertilizer at 20kg P/ha and manure at 2t/hahas been applied for six years. A randomized block design was used and maize grain and stover yields calculated from the four treatment fields; control (no input), manure (2t ha-1), *mavuno* (20kg P/ ha) and manure (2t/ha) + *mavuno* (20kg P/ha). There was a remarkable increase in maize grain yield (control 904 kg/ha, manure+ *mavuno* 2238 kg/ha) a 148% increase in yield above control plot (p=<0.001) and stover yield (control 825 kg/ha, manure+*mavuno* 1381 kg/ha) a 67% increase above control plot (p=<0.001). *Mavuno* phosphorus-based fertilizer and manure have a positive effect on maize grain and stover yield and can sustain soil productivity under long term use, their application in soils improves availability of phosphorus to plants resulting in high yields and improved soil properties. Understanding the effect of continuous application of phosphorus-based fertilizers and manure is essential for sustaining soil productivity among small holder farms of western Kenya to meet the high food demand, which is currently forcing farmers to continuously grow maize on the same piece of land resulting to soil degradation. **Keywords**: *Mavuno*, manure, Maize grain yield, Maize stover and Western Kenya

Mwadalu, R. U. (2014) Improving sorghum grain yield through use of mineral fertilizers and farm yard manure for smallholder farmers in Makueni and Machakos counties. Msc. Thesis, Kenyatta University

Reduced food productivity in smallholder farms is the principal cause of food insecurity in semi-arid parts of Kenya. This is mainly attributed to decline in soil fertility, low and unreliable rainfall, land degradation and adverse effects of climate change. The solution lies in the efficient use of nutrients and planting of drought tolerant crop varieties that can cope with the low rainfall in the ASALs. The aim of this study was to evaluate the effect of FYM, mineral fertilizers and their integration on the production of Gadam sorghum and change in soil properties in Makueni and Machakos counties. The experimental design was a factorial arranged in Randomized Complete Block Design. The study consisted of two experiments in each site. The first experiment was a pure mineral fertilizer experiment with two factors (nitrogen and phosphorus) each at four levels (0, 25, 50, 75 kg/ha). The second experiment tested a combination of FYM (0, 5 & 10 tons/ha) and NP fertilizer in form of CAN and TSP, respectively, at 0 and 50kg/ha each. The first experiment involved 16 treatments while the second experiment involved 6 treatments. The results of grain yields in the first experiment were significantly different in the various treatments (p=0.02) at Kampi ya Mawe and (p=0.04) at Katumani. Nitrogen increased sorghum yields more than phosphorus, but not significantly. However, combining N at 75 kg/ha and P at 50 kg/ha gave the highest yields of 4859.1 kg/ha at Kampi ya Mawe, which was an increase of 135% above the control. At Katumani, combining 50kg/ha N and 25 kg/ha P gave the highest grain yield of 2485.1 kg/ha which was 68.3% above the control. In the second experiment, combining

FYM with NP fertilizer at 50kg/ha NP and 10 tons/ha FYM gave the highest yield of 5393kg/ha compared to the control treatment (4233.1 kg/ha) at Kampi ya Mawe, which was 13.7% more. At Katumani, however, combining FYM and NP fertilizer had less yields as compared to the control. FYM at 10ton/ha and NP 50 kg/ha gave 1566.4 kg/ha which was not significantly different compared to 1669.4 kg/ha for the control. The amount of available N in the soil increased proportionately with N application and declined gradually throughout the growing season. Nitrogen uptake by sorghum also increased with increased N application while soil microbial population was increased with the application of FYM. Nitrogen use efficiency (NUE) was optimal at 50 kg/ha N and declined with increased application of N while Phosphorus use efficiency (PUE) was highest at 50 kg/ha P. Sorghum was more efficient in utilizing nitrogen than phosphorus. Based on the results, a combination of FYM and NP fertilizer can be recommended for sorghum production both at Kampi ya Mawe and Katumani. The findings of this study will be valuable in extension efforts towards increasing sorghum productivity and awareness by farmers of best ISFM practises in semi-arid eastern Kenya.

Opala P. A., Nyambati R. O. and Kisinyo P. O. (2014). Response of maize to organic and inorganic sources of nutrients in acid soils of Kenya. *American Journal of Experimental Agriculture. 4(6): 713-723, 2014.* SCIENCEDOMAIN *international*

Maize yield in Kericho County, Kenya is limited by infertile acidic soils. The effect of inorganic sources of nutrients and amendments; triple superphosphate (TSP), calcium ammonium nitrate (CAN) and lime, were compared to a range of organic nutrient sources; Farmyard manure (FYM) of low and high quality, dried cow dung, goat manure, Tithonia applied as green manure or dried, in a greenhouse and field experiment. Two soils collected from two farmers' fields in Sigowet and Litein locations (Hereafter referred to as Sigowet and Litein) were used in the greenhouse where maize was grown for six weeks and its biomass yield determined. The treatments that showed promise were used in a subsequent field experiment where maize was grown to maturity and grain yield determined. In the greenhouse, maize responded to application of all the sources of nutrients and amendments, except lime when applied without TSP, on Sigowet's soil. On Litein's soil, maize did not respond to application of lime alone or with TSP, TSP and dried tithonia. High quality FYM gave the highest increase (136%) in dry matter yields on Litein's soil. In the field experiment, goat manure gave the highest grain yield. Maize failed to significantly respond to either CAN or TSP when applied alone but the application of the two in combination (TSP + CAN) effected a significant response indicating that both N and P were deficient in this soil. All the manures, except low quality FYM, gave yields that were higher or comparable to the standard recommended fertilizer practice (TSP + CAN) and could be economically attractive substitutes as they are locally available. There was a poor correlation between dry matter biomass yield in the greenhouse and grain yield in the field. Extrapolation of greenhouse findings to different fields should therefore be treated with caution.

Achieng J., Ouma G. and Odhiambo G. (2013). Use of Organic Inputs in Management of Alfisols and Ultisols for Sustainable Maize Production in Western Kenya. *American Journal of Experimental Agriculture. 3(4): 884-895, 2013*SCIENCEDOMAIN *international*

Maize (*Zea mays* L.) is an important food crop in western Kenya, mostly grown by smallholder farmers in complex and risky cropping systems. Trends in population growth in the country indicate that the demand for maize is projected to increase 3-4% annually. Production is however hampered by the predominance of fragile ecosystems (acidic soils), low soil fertility and low use of chemical inputs. The average grain yield is less than 1.0 t/ha instead of a reachable 5.0 t/ha, leading to vicious cycle of food insecurity. An on-farm experiment was conducted in two soil types (Alfisols and Ultisols) in Kakamega, western Kenya, between February and September 2007 to test effects of various organic inputs (Farmyard manure, Tithonia biomass and Desmodium cover crop) in combination with inorganic fertilizers (N, P, K, Mg, B and Zn) on yield of maize. The design was Randomized Complete Block Design, replicated 5 times and the data was subjected to ANOVA and DMRT tests. Soil analysis before planting indicated that pH was 5.0 and 5.4 in Alfisols and Ultisols, respectively. Both soils were deficient in N and P but adequate in exchangeable bases (K, Ca and Mg). Maize grain yield was higher in Ultisols compared to Alfisols. In Alfisols, organic inputs in combination with 30 kg N/ha gave maize grain yield improvement of nearly 100% over farmer's practice (non improved maize variety, wider plant spacing, inorganic fertilizer applied at the rate of 20 N + 20 P/ha, one weeding). When inorganic fertilizer (60 kg N + 60 kg P/ha) was applied to maize/banana intercrop, maize yield increased by about 40%. In contrast, in Ultisols, organic inputs increased maize grain yield by between 85% and 115%, while maize/banana intercrop (plus 60 kg N + 60 kg P/ha) increased maize grain yield by only 4% over the farmer's practice. Banana intercrop reduced maize population resulting in low maize grain and stover yield. Use of either farmyard manure, tithonia biomass or desmonium cover crop in combination with 30 kg of N/ha (from inorganic source) can enhance maize production among smallholder farmers in acidic soils who ordinarily cannot afford to purchase adequate quantities of inorganic fertilizers.

Cebula P. (2013). Long-term effects of organic and mineral fertilizer application on physical soil properties and maize yield in western Kenya. Msc. Thesis Swedish University of Agricultural Sciences

To evaluate the effects of long-term application of organic and mineral fertilizers on maize yield and soil properties and further investigate differences in soil fertility gradients, the Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture (TSBF-CIAT) conducted an 8-year experiment on 12 farms in the districts Nyalgunga, Nyabeda and Vihiga in the western province of Kenya. The study was designed as a split plot model where each farm was split into high and low fertility plots on which the following treatments were applied: T2-no fertilizer application (control), T4- application of farmyard manure (FYM) alone and T5-combined application of FYM, Mavuno fertilizer and top dressing. In scope of this thesis the physical soil properties such as bulk density (BD), soil texture, infiltration rate (IF) and aggregate stability (AS) as well as the soil organic carbon content in the soil (OC) were determined. Further crop Evapotranspiration (ETc) and water use efficiency were analyzed. The ETc, varied between 2.34 and 4.84 mm/day and was highest during the development and late stage of the growing season. The rainfall was able to cover the water crop requirements of maize in all locations. Maize yield was highest at T5, followed by T4 and T2. Further, yield was strongly affected by the clay content and soil type and resulted in significant differences between the locations (Nyalgunga> Nyabeda > Vihiga). Other physical soil parameters (IF, BD, AS) did not influence the maize yield. IF varied between 1.3 and 1.9 m/day. BD was generally low with an overall mean of 1.16 g/cm3. The aggregate stability was widely ranged and significantly higher in Nyabeda and on T4. OC was significantly higher on T5. The results indicated that mineral fertilizers contribute more to the increase of OC than organic fertilizers and that OC might not be the main driver of aggregation in tropical soils. AS seemed to be positive affected by organic fertilizers but IF and BD were not influenced by, neither organic nor inorganic fertilizers. The results did not indicate any differences between high and low fertility plots, neither in maize yield nor in any of the physical soil properties.

Kifuko-Koech M. N. (2013). Maize growth response and phosphorus availability following Busumbu phosphate rock application in a *Desmodium*-maize rotation system. PhD Thesis University of Eldoret; Eldoret, Kenya

Phosphorus (P) is cited as a frequently limiting macronutrient after nitrogen (N) for plant growth in western Kenya. It has been demonstrated that in soils deficient in plant available P, legumes supplied with phosphate rocks (PR), increase P availability and uptake by the succeeding crop. The aim of this study was to assess the extent to which Desmodium spp fertilized with Busumbu phosphate rock (BPR) can increase soil available P, P uptake and biomass yield of maize planted after Desmodium spp in a greenhouse experiment conducted in two phases. In the same plots, sole maize and two Desmodium spp: (*D. intortum and D. uncinatum*) with and without BPR were grown separately in the first phase of the experiment followed by sole maize with no P application in the second phase of the experiment. Plots were arranged in a completely randomised design replicated four times. Reference treatments with soluble P (KH_2PO_4) were included. Results showed that in the first phase of the experiment, application of BPR significantly increased above ground dry matter yield (DMY) of Desmodium spp but not of maize, suggesting enhanced BPR solubilisation in Desmodium grown soils. When BPR was not applied, soil available P was higher in soils with D. intortum compared to either D. uncinatum or sole maize an indication that this legume was efficient in absorbing sparingly soluble P in the rhizosphere. In the second phase of the experiment, above ground maize DMY, P concentration and available P were higher in maize following Desmodium spp compared to maize following maize whether BPR had been applied or not. D. intortum previously fertilized with BPR gave the highest and significant above ground maize DMY (6.05 g/container) and P concentration (16.15 g P/container). This study demonstrated that Desmodium spp receiving BPR enhances yield and P availability of the following maize crop compared to sole maize systems.

Kihanda, F. M., Warren, G. P. and Muriithi, C. (2013). Effects of fertilizer Phosphorous and crop residues on crop Biomass, soil carbon and Phosphorous in a ten-year field trial in semi-arid Kenya. *East Africa agricultural and Forestry Journal* Vol. 79(3) 151-159

The possibility of improving soil fertility with a high "recapitalization" dose of phosphorous (P) fertilizer in conjunction with crop residue was assessed in a severely P-deficient soil. The experiment comprised of three treatments cropped to sorghum (*Sorghum bicolour*): (1) crop residues returned to the plot, (2) residues returned plus additional residues, (3) residues removed and added to the treatment (4); and bare and fallows. All treatments were repeated with and without an initial triple superphosphate application of 250 kg P/ha. After 17 seasons (8.5 years), soil organic carbon (SOC) increased significantly under grass and declined under sorghum and bare fallow. Residue transfer treatment gave no significantly under grass and declined under sorghum and bare fallow. Residue transfer treatments gave no significant effect on sorghum biomass extractable (Olsen) P. Removal of residues caused a decline in SOC. P fertilizer increased crop biomass only in five of the first eight seasons and SOC was unaffected. In the 18th to 20th seasons, sorghum was replaced by maize (*Zea mays*) in an N×P factorial design within each of the initial P treatments. Biomass increased only when both N and fresh P were supplied but initial P had no effect. P recapitalization was inefficient because P recovery was low, so a "little and often" regime for fertilizer P appears better.

Mangale N. and Mzingirwa A. M. (2013). The effects of some soil fertility improvement technologies on the chemical characteristics of a sandy soil and yields of two maize varieties. *East African Agricultural and Forestry Journal* Vol. 79 pp.209-215

Low and declining soil fertility has been shown to be the fundamental root cause of low food per capita in sub-Saharan Africa (SSA). Coastal Kenya is therefore not an exception. Soil fertility improving technologies have therefore been developed in the region to increase crop yields and reduce food poverty levels in coastal Kenya. The long time effects of these technologies on the environment or their sustainability have however not been evaluated. The 4 soil fertility improving technologies included: 1) application of 5 t farmyard manure (FYM)/ha, 2) application of 2.5 t FYM/ha plus green biomass of velvet beans (*Mucuna*) as a relay crop, 3) application of full rate of recommended inorganic fertilizers (60 kg N/ha + 46 kg P_2O_5/ha) and 4) application of 2.5 t FYM/ha plus half the rate of recommended inorganic fertilizers (30 kg N/ha + 23 kg P_2O_5/ha). This study carried out on a sandy soil classified as Acrisol to Luvisols therefore looked at the long time effects of the four (4) soil fertility improving technologies. The study was conducted at KARI`s Regional Research Centre (RRC) - Mtwapa with Pwani hybrid1 and 4 (PH 1 & 4) maize varieties were the test crop. The experiment was conducted for a period of 6 seasons or 3 years. Continuous use of inorganic fertilizers (technology3, (DAP and CAN) lowered the soil`s cation exchange capacity (CEC), pH and organic matter (OC) content while extractable P was increased. Total nitrogen (N) does not seem to be a good parameter to measure the effect of inorganic fertilizers on soil N levels. Since soil OC is necessary for a soil to have a good workability and increased CEC, the results appear to confirm farmers` observations that continuous use of inorganic fertilizers adversely affects soil physical characteristics (hard to till). The other 3 technologies resulted in increased soil CEC, phosphorus (P) levels and OC content. The soil pH either remained the same or was slightly increased by the 3 soil improving technologies. Therefore the 3 soil improving technologies boosted or sustained the soil chemical characteristics which are vital for sustained crop productivity. Pwani hybrid 4 grain yields decreased with seasons reaching levels almost similar to those of PH 1 in the final season. On the other hand PH 1 yields remained the same except during the first season where inadequate rainfall lowered them. The continued decrease in yields of PH 4 with successive seasons even when soil fertility improving technologies are used calls for further investigation on the nutrition of the maize variety. Nutrients needs of PH 1 are shown to be adequately supplied by the 4 technologies used.

Muthuri J. K. (2013). Effect of different soil fertility amendments on the nodulation and yield of two soybean varieties. MSc. Thesis, University of Nairobi, Kenya

Soybean (*Glycine max (L*) Merill) is referred to as the golden crop of the future. There is a concern in Kenya on its production due to the fact that the country remains a net importer of this vital food to the tune of 100,000 tons annually yet the country has the potential to produce that capacity locally. The major impediments in local production are singled out as: Expensive farm inputs in form of fertilizer and use of inferior soybean varieties in terms of effective nodulation. The nodulation of soybean is influenced by the inoculation, soil fertility, agro-ecological zones and soybean varieties. This study was carried out to achieve the following objectives, to investigate the effect of different soil fertility alteration on soybean nodulation and yield to analyse symbiotic effectiveness between fast and slow growing rhizobia in nitrogen fixation in the soybean. Two soybean varieties (promiscuous and non-promiscuous) were planted in experimental plots at Kisii, KARI during the months of April to August 2008. There were five main treatments: Control, Poultry manure, Farmyard manure (FYM), di-ammonium phosphate (DAP) and inoculants strain USDA 1011. Sub-treatments were the two soybean varieties, the promiscuous variety was SB19 TGx 1740 2F while the non promiscuous was Gazelle. The experiment was carried out in a split to split design and replicated 4 times at Kisii, KARI station. The greenhouse experiments were carried out to analyze the symbiotic effectiveness of fast and slow growing rhizobia isolated from Kisii while the laboratory experiments were used to rhizobia isolated from the field. Nodulation status, plant biomass production, height of the plant and yield were used to generate the data for the main field experiments. For greenhouse experiment, nodulation status, plant dry weight and acetylene reduction activities were used to generate the data. The transformed data was subjected to analysis of variance (ANOVA) and means were separated using Turkey's sigh significant difference (HSD). The effects due to soil amendments on nodulation status were significantly different at $P \leq 0.05$. There was a significant difference in terms of nodule numbers and acetylene reduction assay for both soybean varieties when symbiotic effectiveness of the isolates was assessed. From this study it was concluded that the soybean treated with the inoculants had high nodulation and yield. The study also showed that FYM had slow mineralization. Fast growing rhizobia were more effective in nitrogen fixation in T.Gx variety than in Gazelle variety while slow growing rhizobia were more effective in Gazelle.

Serafim V. B., Oginga D. B. and Mugwe J. N. (2013). Effects of manure, lime and mineral P fertilizer on soybean yields and soil fertility in a humic nitisol in the Central Highlands of Kenya. International Journal of Agricultural Science Research Vol. 2(9), pp. 283-291, Available online at http://academeresearchjournals.org/journal/ijasr; ISSN 2327-3321

Soybean (*Glycine max* (L.) Merrill) is one of the most important legume crops being introduced into the smallholder farming systems of the Central Highlands of Kenya (CHK) to improve income and household nutrition of farmers. However, phosphorus fixation, depletion of soil nutrients and soil acidity are major causes of low yields. The objective of this study is to evaluate effects of manure application, liming and phosphorus application on soil properties and soybean performance. The study consisted of 8 treatments: manure (0, 5 and 10 t ha-1), lime (0 and 2 t/ha) and P fertilizer (0, 30 and 60 kg P/ha). The experiment was laid out in a randomized complete block design (RCBD) with 4 replicates in plots of 4 m × 4.5 m. Manure and lime significantly reduced exchangeable acidity and increased soil pH. Application of manure alone or combined with lime or P fertilizer also increased Mg and K. Treatments that had sole lime, lime combined with manure and manure combined with P applied gave a significant increase in exchangeable Ca. Soybean responded well and significantly to application of manure either alone or combined with lime, P or both. These results showed the potential role of lime, manure and P fertilizer in improving soil fertility and soybean yields.

Sibusisiwe C. K. (2013). Effect of organic and inorganic fertilizers on soil properties, striga density and maize yield in Vihiga and Siaya counties, Kenya. Msc. Thesis, University of Nairobi, Kenya

Continual soil fertility depletion and the increased infestation of weeds such as striga in smallholder farming systems are two of the main processes amplifying reduction in food production across Sub-Saharan Africa (SSA). These conditions are aggregated even further by the existence of soil fertility gradients in small-holder farmer fields resulting in varying crop yields in a single farm. Against this backdrop, this study aimed to assess the effects of fertilizer application on soil properties, striga density, and maize yield in small-holder farmer fields resulting in varying crop yields in a single farm. Against this backdrop, this study aimed to assess the effects of fertilizer application on soil properties, striga density, and maize yield in small-holder farmer fields with existing soil fertility gradients. The study was conducted in Emusutswi in Vihiga county, and Nyabeda and Nyalgunga in Siaya County. Twelve farmers; four from each site were selected using Y frame sampling and their field demarcated into low and high fertility status. The experiment was set in a completely randomized block design in a split plot arrangement. The fertility gradients were the main plots and the treatments; IR maize + mavuno + manure were the sub-plots. The farmer fields were the replicates. The means of the four farmer fields explained the response of test crop (IR Maize) to applied treatments. The study was conducted during the short rains season. Soil was collected from all the treatments for the analysis of chemical properties-pH, cation exchange capacity (CEC), mineral nitrogen, total N, organic carbon, phosphorus, exchangeable bases, (K, CA, and Mg), and biological properties- soil respiration and physical properties- soil fractionation. Striga weed was sampled at week 6, 8, 10 and 12 for striga emergence. Maize yield was determined at crop maturity by sampling from an area of 7.08m^2. Results indicated that there were significant differences in P levels across treatment means, ($P<0.01$) and the mavuno + manure treatment had the highest mean P levels (11.8%) showing superiority over the control and the manure only treatment. Organic Carbon showed significant differences across sites. Mineral N showed significant differences across treatments. Exchangeable bases potassium (K) and calcium (Ca) showed significant differences across sites. There were significant differences observed in CEC across treatments. There were however no significant differences in the measured soil chemical properties across fertility gradients. Soil respiration showed significant differences in the land measured soil chemical properties across fertility gradients. Soil respiration showed significant difference across fertility gradients but not across treatments and sites after 7 and 14 days of incubation. Elemental combustion showed significant differences in %C and %N in the fractions with the highest % C (2.052) and % N (0.1816) found in the silt and clay fraction across treatments. Significant differences were further observed in the carbon fractions distributions across treatments and fertility gradients ($P<0.01$). Significant in striga density across treatments ($P<0.01$) were observed with the control (54,389 plants/ha) having the highest. There were no significant differences across sites and treatments means with the highest yield observed in Nyalgunga (mean =4330 kg/ha) but no significant differences were observed across fertility gradients. Lack of significant difference in the measured parameters across fertility gradients may necessitate further investigation on the farmer perceived fertility status of their farms. Combined application of FYM and mavuno and the use of IR maize could enhance soil properties, reduce striga occurrence and increase maize yields.

Suge, J. K. (2013). Effect of organic and inorganic fertilizer on the growth, yield and fruit quality of Egg plant (*Solanum melongena* L). Msc. Thesis University of Eldoret, Kenya

Egg plant (*Solanum melongena L*) is one of the important Asian Vegetables grown in Kenya for local and export market; hence effort to improve its productivity and quality should be emphasized. Declining soil fertility due to continuous cultivation of small holder farms and escalating cost of imported fertilizers and the need to conserve and build natural resource capital and biodiversity, has renewed interest in the use of local nutrient resources for soil fertility management in Kenya. The study was conducted at Bukura Agricultural college farm during the short (SR) and long rain seasons (LR) of the year 2009 and 2010 respectively. Eggplant seedlings were raised and transplanting 42 days after sowing. During transplanting, DAP and compost was applied while CAN was applied three weeks later. The experiment aimed at evaluating the effect of combination between two levels of the recommended inorganic fertilizers (50% and 100 % of research recommended rates (RRR) of 220 kg/ha DAP and 600 kg/ha CAN)) with three types of organic manures on growth, fruit yield and quality of egg plant (*Solanum melongena L*) var. Black beauty. Split plot design with three replications was used, where two levels of inorganic fertilizers treatments (50% RRR and 100%RRR) were randomized in main plots while three types of organic manures; FYM, Compost (10-15 t/ha) and Tithonia (6 t/ha) and control treatments were randomized within the subplots. Topsoil (0-20cm depth) and organic manures were sampled before transplanting seedlings and analyzed for chemical properties, pH, N, P, K, OC and CEC. 75 days after transplanting, determination of and plant height (cm) and fresh weight (g) of the plants was done and in the third picking the fruit length and diameter determined. Results showed that there was a significant interaction between of the two inorganic fertilizer levels and the organic manures. Increasing inorganic fertilizer from 50% to 100% of the research recommended rates (RRR) encouraged the vegetative growth of eggplants shown by plant height and fresh weight. Besides increasing the total fruit yield, fertilizer enhanced the fruit quality. The farm yard manure was considered the superior source of manure for obtaining the highest value of the parameters under study compared to compost and Tithonia (*Tithonia diversifolia*). Soil fertilized with 100% recommended NPK combined with organic manures produced the superior growth of plants and the highest amount of total fruit yields. Farmers would benefit by incorporating 10-15 t/ha (1-1.5 Kg/M2) of FYM combined with 110 kg/ha DAP and 300 kg/ha CAN (83 kg N/ha and 61.5 kg P /ha) to improve on the growth, yield and quality of eggplants. Hence training farmers on how to increase availability and preservation of FYM is critical.

Verde B. S., Danga B. O. and Mugwe J. N. (2013). The Effects of Manure, Lime and P Fertilizer on N Uptake and Yields of Soybean (*Glycine max* (L.) Merrill) in the Central Highlands of Kenya. Journal of Environmental Science and Engineering B 2 (2013) 111-116. Formerly part of Journal of Environmental Science and Engineering, ISSN 1934-8932.

Soybean (*Glycine max* (L.)) is one of the most important legume crops being introduced in the CHK (Central Highlands of Kenya) expected to increase yields. However, low levels of soil N (nitrogen) and other plant nutrients and soil acidity are seen as the major causes impairing goal achievement. To evaluate the influence of manure, lime, P (phosphorus) fertilizer and their combination on N uptake and soybean performance, an experiment was conducted in Embu ATC (Agricultural Training College) comprising 9 treatments, arranged in a Randomized Complete Block Design with 4 replicates in plots of 4 m × 4.5 m. The study included manure (0, 5 and 10 t/ha), lime (0 and 2 t/ha) and P fertilizer (0, 30 and 60 kg P/ha). The treatments significantly influenced N uptake and soybean yields. Both parameters responded well to application of manure both alone or combined to lime and TSP (triple super phosphate). From these it was concluded that organic and inorganic resources have potential to enhance N uptake and soybean and other crops yields in CHK.

Kibunja C. N., Mwaura F. B., Mugendi D. N., Gicheru P. T., Wamuongo J. W. and Bationo A. (2012). Strategies for maintenance and improvement of soil productivity under continuous maize and beans cropping system in the Sub-humid highlands of Kenya: Case study of the long term trial at Kabete. In Bationo, A.; Waswa, B.; Kihara, J.; Adolwa, I.; Vanluawe, B. and Saidou K. (Eds). *Lessons learned from Long-term soil fertility management experiments in Africa. Springer pp. 60-83*

Inappropriate soil management practices are cited as the main causes of soil fertility decline of cultivated lands in sub-Saharan Africa (SSA). Small-scale farmers are faced with daunting challenges and limited opportunities for maintaining the productivity of their land due to low accessibility and affordability of agricultural inputs. In Kenya, a series of fertilizer trials conducted throughout the country in the 1990s, showed that nitrogen (N) and phosphorus (P) were deficient in 57% and 26% of the sites covered. The effect of continued cultivation with application of mineral and organic fertilizers on soil quality and crop yields was studied in a long-term field experiment a Kabete, in the highlands of Kenya, which was started in 1976. The area is sub-humid with an average bimodal rainfall of 980 mm and two cropping seasons per year. The treatments included: control (no-input); fertilizer nitrogen (N) and phosphorus (P) at 60 kg N/ha and 26 kg P/ha and 120 kg N/ha and 52 kg P/ha; farmyard manure (FYM) at 5 and 10 t/ha and farmyard manure (5 t/ha) combined with 60 kg N and 26 kg P/

ha. For each treatment, crop residues were retained (+) or removed (-) in half of the plots. Maize and beans were planted during the long and short rain seasons, respectively. This paper presents a review of experimental results derived from the long-term experimental site at Kabete, Kenya over a period of 30 years. Results indicate that application of all inputs significantly (P=0.05) improved maize yields over the control but there was no significant differences among the treatments. Cumulative use of FYM gave better yields than NP fertilizers but the combined use of FYM and inorganic fertilizers was the most economically and promising strategy for sustained soil crop yields. A general decline in soil bio-physical properties was observed over time. Soil acidification, decline in soil organic carbon and nitrogen has been noted over time. Use of inorganic fertilizers without addition of FYM or crop residues led to loss of soil biodiversity. None of the strategies used have maintained carbon stocks at the initial level. Integrated use of farmyard manure and chemical fertilizers, combined with liming to reduce soil acidification and use of deep rooted rotational crops should be recommended to sustain soil productivity under continuous cultivation.

Kihanda, F. M., Muriithi, C. and Mwangi M. (2012). Management of Acid soils in Central Kenya highlands for improved productivity. *East Africa Agricultural and Forestry Journal*. Vol. 79(2) 113-117

Aluminium saturation decreased to zero in the plots that had received lime. There was a large increase in soil exchangeable Ca when lime was applied. The Ando-humic Nitisols within the highlands of Central Kenya are characterised by low soil pH, low exchangeable bases and high percent Aluminium saturation resulting in low maize yields. An experiment was conducted to determine the effect of NP fertilizers (0 or 50 kg N & P_20_5/ha), K (0 or 50 kg K_20/ha) agricultural lime (L) at 0 or 1.0 t/ha and farmyard manure (FYM) at 0 or 5.0 t/ha on maize yield and soil chemical characteristics over a period of eight years. The treatments were arranged in a Randomized Complete Block Design replicated two times. There was no significant increase in maize yield due to K application. Lime increased the maize grain yield by 156% where as the application of either FYM or NP fertilizer resulted in a similar increase in maize grain (90%). The highest maize grain yield of 4.5 t/ha was obtained by a combination of NP, lime and FYM. The highest (1.4%) loss in organic C was observed in plots that had not received any NP fertilizer and FYM. Agricultural lime increased the soil pH from 4.4 to above 5.5 irrespective of the NP or FYM.

Mutegi E. M., Kung'u J. B., Mucheru-Muna M., Pieter P., Mugendi D. N. (2012). Complementary effects of organic and mineral fertilizers on maize production in the smallholder farms of Meru South District, Kenya. Agricultural Sciences Vol.3, No.2, 221-229 (2012) doi:10.4236/as.2012.32026

Low soil fertility is a major constraint to maize production in the small holder farms of Meru South District. This is mainly attributed to the mining of nutrients due to cropping without ex- ternal addition of adequate nutrients. Mineral fertilizers are expensive hence un affordable by most small holder farmers. The use of organic matter to increase and maintain soil fertility is being considered as a solution to help the low- income small holder farmers. A study was con- ducted in Mucwa location, Meru South District to determine the levels of complementarity between organic and mineral N amendments on maize yields and their influence on soil chemical properties. The experiment was set in a complete randomized block design (CRBD) with three replicates. The treatments were compared with the response obtained from control. The general soil fertility parameters changed slightly with Calcium, Magnesium and Potassium increasing in all treatments. The organic Carbon and total Nitrogen was higher in treatments that received sole organic N sources than in sole mineral N and a combination of organic and mineral N sources. The highest maize grain yield of 4.8 t/ha and 4.2 t/ha were realized from sole application of calliandra during the 2005 Short rains and 2006 Long rains cropping seasons. Generally the maize grain yields were lower in treatments with mineral N alone compared to the treatments with organics. Treatments with sole calliandra and sole tithonia had the highest benefit cost ratio (BCR), followed closely by manure treatment. More so, integration of organic and mineral N sources resulted to higher net benefit and BCR than the application of the re- commended rate of mineral fertilizers. Results obtained indicated that the use of either organic or combined organic/mineral N soil amendment appear to be superior to using mineral amendment sources alone.

Mutegi E. M., Kung'u J. B., Mucheru-Muna M., Mugendi D. N. (2012). Consequences of organic-mineral N soil fertility amendments on nitrogen uptake and maize grain yield in the smallholder farms of Meru South district, Kenya. Sky Journal of Soil Science and Environmental Management Vol. 1(1), pp. 9 - 14, November, 2012; Available online http://www.skyjournals.org/SJSSEM

The central highlands of Kenya is generally densely populated and declining land productivity with reduced crop yields has been a major problem facing the smallholder farmers in the region. Land sizes are small and this promotes continuous cropping with limited scope for crop rotation and inadequate soil fertility replenishment.

Efficient use of soil N amendments in maize (*Zea mays* L.) production is necessary to maximize producer's economic returns and maintain soil and water quality. An experiment was carried out on the humic nitisols in Mucwa location, Meru South District, with the objective of determining maize grain yields and N uptake under different soil N amendments. The experiment was set in randomized complete block design (RCBD) with three replicates. The results reveal that maize grain yields in the organics and/or mineral N soil amendments was higher than the yields obtained where the recommended mineral fertilizers were used alone. The nitrogen (N) concentration in different parts of the maize crop varied, with the grain having the highest, followed by the stover during the 2005 short rain season. Sole application of calliandra recorded the highest N uptake (170.8 kg N/ha) while the control gave the lowest (49.31 kg N/ha). It is therefore concluded that differences in nutrient release by the organic-mineral N soil amendments can alter net rate of nutrient uptake during crop growth and therefore assist in synchronization of nutrient release and uptake by the growing crop.

Ndung'u-Magiroi K. W. (2012). Effect of Inorganic Fertilizers and Commercial Phosphate Solubilising Biofertilizers on Microbiol Diversity, Soybean and Maize Production in three Agroecological Zones of Kenya. PhD thesis, Chepkoilel University College; Eldoret, Kenya

Crop productivity in many small holder farms in Kenya is de declining due to various constraints including soil fertility decline, especially nitrogen (N) and phosphorus (P) and high fertilizer prices, thereby necessitating the use of minimal fertilizers in nutrient poor soils. After application, P fertilizers are rendered inaccessible due to chemical reactions in soil that fix P into the soil colloids, therefore only a small portion is available for plant uptake. There many rhizospheric microorganisms that solubilise fixed P, making it available for plant uptake. To improve P uptake in crops a number of companies have produced commercial biofertilizers with P solubilising potential in soils. In this study, ten commercial P solubilising (PS) biofertilizers were evaluated under greenhouse conditions in two soils with contrasting properties. Only effective products from the green house study (with>30% increase in biomass above un-inoculated control) were tested in farmers' fields in three counties (Bondo, Meru South and Bungoma). The greenhouse trials showed two effective products in maize growth (Myco Apply Soluble Maxx and Myco Tea). The pot trial further showed the need for supplementation of the biofertilizers with external P. After confirmation in the field with co-inoculation with 1/2 the recommended rate of TSP (13 kg P/ha), none of the biofertilizers were effective in promoting maize production. In soybeans, among the ten biofertilizers, tested under green house conditions, only four (Myco Apply Soluble Maxx, Myco tea, Subtilex and Myco ApplyMaxx) had significant biomass increases above the un-inoculated controls. The product effectiveness was higher when co-inoculated with effective rhizobial inoculants (Legumefix and 1495MAR) than when inoculated alone or in combination with arburscular mycorrhizae fungi (AMF) biofertilizer. In the field, only one PS biofertilizer (Myco Apply Soluble Maxx) was found to be promising in improving soybean grain yields in all the mandate regions. The efficacy of Myco apply soluble Maxx was influenced by soil properties. In acidic (pH<5) and moderately acidic (pH 5 - 5.5) soils and in soils with low (< 5 mg P/kg soil) to moderately low (5-9 mg P/kg soil) available P, supplementation with 1/2 the recommended rate of DAP was necessary, However, in soils with neutral pH (pH 7) and adequate to high available P (10-19 mg P/kg soil), duo inoculation of Myco Apply Soluble Maxx and Legumefix, Gave the highest soybean yields, which were comparable to tripartite application of DAP, Legumefix and Myco Apply SolubleMaxx. There are several microbial biofertilizers that are available in the market, but from this study, it was shown that most of these biofertilizers are not effective in improving crop yields under the conditions tested in this study. Since the Kenya Plant Health Inspectorate Service (KEPHIS) and the Kenya Bureau of Standards (KEBs) are charged with responsibility of ensuring quality biological materials and fertilizers respectively, Vigorous testing of the biofertilizers in the country is necessary to ensure that the farmers are protected from ineffective materials, hence ensuring food security.

Nyankanga R. O., Wekesa F. S., Masinde D. N., and Mugisha J. (2012). Effect of inorganic and organic fertilizers on the performance and profitability of grain Amaranth (*Amaranthus caudatus L*), *Journal of Agricultural Science* Vol.4, No. 1

Protein malnutrition is a major cause of morbidity and mortality in developing countries where the cost and availability of animal protein remain prohibitive. Grain amaranth (*Amaranthus caudatus L)* has the potential to substitute expensive animal protein. Its production and consumption is however low in Kenya. Nitrogen is a key limiting element in grain amaranth production. This study investigated the effects of different rates of inorganic nitrogen and cattle manure on the growth and yield of grain amaranth over a period of two years. Inorganic fertilizer at the rate of 100 kg N/ha significantly delayed flowering. Grain yield showed a linear response to inorganic and organic N application. Regression analysis projected the optimum inorganic fertilizer and manure application rates of 87.5 kg N/ha and 9 t/ha respectively with yield of 1.84 t/ha. The highest profitability was achieved at the optimum manure and fertilizer rates. The projected manure and inorganic fertilizer rates may however not be affordable by the small-scale farmers. Thus a follow-up study to test the combined effect of inorganic and organic fertilizers is recommended.

Opala P. A., Okalebo J. R., and Othieno C. O. (2012). Effects of Organic and Inorganic Materials on Soil Acidity and Phosphorus Availability in a Soil Incubation Study. International Scholarly Research Network

ISRN Agronomy; Volume 2012, Article ID 597216, 10 pages; doi:10.5402/2012/597216

We tested the effects of two organic materials (OMs) of varying chemical characteristics that is, farmyard manure (FYM) and*Tithonia diversifolia* (tithonia), when applied alone or in combination with three inorganic P sources, that is, triple superphosphate (TSP), Minjingu phosphate rock (MPR), and Busumbu phosphate rock (BPR) on soil pH, exchangeable acidity, exchangeable Al, and P availability in an incubation study. FYM and tithonia increased the soil pH and reduced the exchangeable acidity and Al in the short term, but the inorganic P sources did not significantly affect these parameters. The effectiveness of the inorganic P sources in increasing P availability followed the order, TSP >MPR> BPR, while among the OMs, FYM was more effective than tithonia. There was no evidence of synergism in terms of increased available P when organic and inorganic P sources were combined. The combination of OMs with inorganic P fertilizers may, however, have other benefits associated with integrated soil fertility management.

Otinga A. N. (2012). Partial substitution of phosphorous fertilizer by farmyard manure and its localized application increases agronomic efficiency and profitability of maize production. PhD Thesis, Chapter three, Katholieke Universiteit Leuven

As in the previous studies, higher proportions of FYM in the substitutions significantly increased yields and enhanced APE. Agronomic P use efficiency largely depended on the seasons and relative fertility of the soils and related fertility of the soils but increased with increase in % P applied as FYM. Similarly, both soil pH and Olsen P, FYM treatments had significantly lower values as compared to the sole TSP but this was attributed to the sampling time and high solubility of the TSP rather than the quality of the FYM. During the 2009 SRs, localising FYM in 25% of area in the planting rows increased maize grain yields by 23, 17 and 66% for Sega, Bokoli, and Angurai, respectively relative to broadcast and tripled at APE at Angurai meaning that the profitability of this technology would largely depend on the site soil fertility characteristics and the ability of the material to provide other nutrients as well. While substitution of TSP by FYM increased profitability of maize in the short term, it would be worthwhile to study these over a long period of time. Similarly, the fact that concentrating FYM at 25% of the planting rows increased maize yields relative to broadcast at Angurai would warrant an investigation to see long effects could last.

Ogech, J., Nderitu, J. H., Ariga, S. E., Olubayo, F. (2012). Effect of soil fertility on crop nutrient content, bean stem maggot infestation and yield of common beans in Kisii and Kabete of Kenya. *East African Agriculture Forestry Journal* Vol.

Field studies were conducted for two seasons at Kenya Agricultural Research Institute, Kisii station and at the University of Nairobi Kabete Campus field Station to determine the effect of application of farm yard manure at the rate of 5 and 10 t/ha, Triple superphosphate at the rate of 25 and 50 kg/ha (phosphorus) and at 35 and 75 kg/ha for nitrogen (calcium nitrate and ammonium nitrate) on crop nutrient, bean stem maggot infestation and yield of common beans. Three common bean (*Phaseolus vulgaris L.*) varieties cv. EXL52, G 8047 and GLP2 were used. Bean stem maggot counts, shoot dry weight, adventitious root development, grain yield, levels of N, P, K and polyphenol were determined. Bean stem maggot count was high in the long than in the short rains and was significantly lower in EXL 52 than the other varieties. Plant loss due to wilting caused by bean fly in the affected plants in G 8047 (2.7 and 1.8%) and in EXL 52 (3.4 and 1.2%) was significantly lower than GLP2 (4.8 and 1.35) during the short and long rains at Kisii and Kabete respectively. Farmyard manure application at the rate of 10 t/ha significantly lowered bean stem maggots count per plant by (17%) and wilted plant loss by 17% but did not increase adventitious root development, growth measured as root dry weight and grain yield relative to control during the rains at Kisii. In Contrast, phosphorus (TSP) fertilizer application increased bean stem maggot counts (33%), shoot dry weight (26%) and grain yield (250%) but did not increase adventitious root development or lower plant loss associated with bean stem maggots. Nitrogen fertilizer (Ammonium sulphate, 75 kg/ha) significantly increased adventitious root development and plant loss but had no effect on growth and grain yield. Overall, fertilizer application did not have significant effect in the levels of N, P, K and polyphenol in the bean plants.

Herman M. C., Lal R. (2011). Inorganic Fertilizer vs. cattle manure as nitrogen sources for maize (*Zea Mays* L.) in Kakamega, Kenya. The Journal of Undergraduate Research at Ohio State. JUROS Science and Technology Vol. 2 *JUROS Vol. 2*. Pp. 14-22.

Despite worldwide efforts, food security has not improved inSub-Saharan Africa (SSA) since 2000 when the United Nationspublished its Millennium Development Goals. Inconsistent andinefficient soil management by farmers is

a major contributingfactor. Maize (Zea Mays L.) is a staple foods Kenya, but neither fertilizer nor manure are economically available to farmers insufficient quantities. The objective of this study was to comparean inorganic fertilizer with an equivalent dry-weight rate of N fromcattle manure for maize production in Western Kenya using sixmaize plots at four farm sites.Results from this study conducted in 2007 showed that inorganicfertilizer produced grain yields 68% higher than that from manure.However, yields were low. Analysis of maize leaves at initial silkingstage showed that many nutrients were below the critical levels.Further estimates showed that up to twice the amount of N applied to the field is exiting the field via maize grain and stover, thereby creating a negative nutrient budget. For these reasons, it can beconcluded that the recommended N rate of 50 kg/ha is not enoughto either sustain crop yields or restore the degraded soil systems.

Kamau, M., Blanchart E., Chibole L., Jean-luc Chotte, Kibunja, C. N. and Lesucer, D. (2011). Effects of organic and inorganic fertilization on soil bacterial and fungal microbial diversity in Kabete long term trial Kenya. *Biol Fertil soils; Springer*, 47: 315-321

The effect of crop manure and inorganic fertilizer on composition of microbial communities of central highland soils of Kenya is poorly known. For this reason we have carried a 32 year old long term trial in Kabete Kenya. These soils were treated with organic (maize stover (MS) at 10 t/ha farmyard manure FYM at 10 t/ha) and inorganic fertilizer 120 kg N + 52.8 kg P (N2P2), N2P2 + MS, N2P2 + FYM, a control and a fallow for over 30 years. We examined 16rRNA gene and 28S rRNA gene fingerprints of bacterial and fungal diversity by PCR amplification and denaturing gradient gel electrophoresis separation respectively. The PCR bacterial community structure and diversity were negatively affected by N2P2 and were more closely related to the bacterial structure on the soils without any addition (control) than that with a combination of inorganic and organic or inorganic fertilizers alone the effect on fungal diversity by N2P2 with organic and N2P2 alone was different than the effect on bacterial diversity since the fungal diversity was similar to that of the N2P2 + FYM and N2P2 +MS -treated. However soils treated with organic inputs clustered away from soils amended with inorganic inputs. Organic inputs had a positive effect on both bacterial and fungal diversity with or without chemical fertilizers. Result from this study suggested that total diversity of fungal and bacterial communities was practised closely related to agro- ecosystem management practices and may practically explain the yield difference observed between the different treatments.

Muturi J. J., Mbugi J. P., Mueke J. M., Lagerlöf J., Mungátu J. K., Nyamasyo G. and Gikungu M. (2011). Effect of integrated soil fertility management interventions on the abundance and diversity of soil Collembola in Embu and Taita districts, Kenya. Tropical and Subtropical Agro-ecosystems, 13 (2011): 35 - 42 35

The study aimed at identifying soil fertility management practices that promote the Collembola population, diversity and survival in the soil. Soil samples were randomly collected from on farm plots amended with: 1-Mavuno ((Ma)- is a compound fertilizer containing 26% Potassium, 10% Nitrogen, 10% Calcium, 4% Sulphur, 4% Magnesium and trace elements like Zinc, Copper, Boron, Molybdenum and Manganese)), 2-Manure (Mn), 3-*Trichoderna* (Tr) inoculant (is a soil and compost-borne antagonistic fungus used as biological control agent against plant fungal diseases), 4-Farmers practice ((FP) where Tripple Super Phosphate (T.S.P.) and Calcium Ammonium Nitrate (C.A.N.) fertilizers are applied in the soil in mixed form), 5-Tripple Super Phosphate (T.S.P.), 6-Calcium Ammonium Nitrate (C.A.N.). These treatments were compared with 7-Control (Co) (where soil fertility management interventions where not applied). Soil Collembola were extracted using dynamic behavioural modified Berlese funnel and identified to the genus level. Occurrence of Collembola was significantly affected by soil fertility amendments in both Taita and Embu study sites ($P<0.05$). Twenty two genera of soil dwelling Collembola were recorded, with control and organic manure treated plots recording high diversity with a Shannon 1.86 in Embu and a Shannon 2.09 in Taita, respectively. There was significant difference ($P<0.05$) of seasonality on soil Collembola occurrence at both Embu and Taita. Application of cow manure and addition of *Trichoderma* inoculants promoted the soil Collembola. The study has demonstrated that application of organic amendments encouraged the soil Collembola while inorganic fertilizers negatively impacted on these soil organisms.

Nyambati, R. O. (2011). Integrated use of plant residues and urea on maize performance and striga management in Western Kenya. PhD Thesis, Moi University, Eldoret, Kenya

Low soil fertility is a fundamental biophysical cause of the declining food production among small-holder households in Sub-Saharan Africa. The purpose of the study was to develop technologies that will improve soil fertility, and enhance maize production and Striga management. The hypothesis is that cropping systems that use combination of organic resources and mineral fertilizers will lead to improved crop productivity. This was achieved through implementation of three experiments at two sites namely Nyabeda and Bukura in Western Kenya. Firstly, an incubation study with litterbags was conducted to assess decomposition rates and N release

patterns of Calliandra (*Calliandra calothyrsus*) fresh leaves and maize Stover under different environmental and soil conditions. Relative decomposition rates were0.47 g/day and 0.38 g/day for maize Stover and Calliandra at Nyabeda, while at Bukura, decomposition constants were 0.35 g/day and 0.38 g/day for Calliandra and maize Stover, respectively. By the end of 12 weeks, Nyabeda had 67% (50 kg N) released into the soil compared to 62% (46 kg N) at Bukura. Maize Stover depressed N release for up to 8 and 12 weeks at Nyabeda and Bukura, respectively. Secondly, a study to asses the effect of combined application of plant residues and urea on maize yields under different soil conditions was conducted Calliandra applied at an equivalent of 15 kg N/ha in combination with urea at the rate of 60 kg N/ha gave the highest grain yield (4.6 t/ha) at Bukura site, while maize Stover applied at the rate of 30 kg N/ha in combination with urea at 45 kg N/ha gave the highest grain yield (3.0 t/ha) at Nyabeda site. Thirdly, a study on the effect of different combinations of Calliandra and maize Stover residues and urea on Striga infestation was conducted. Calliandra applied at 45 kg N/ha plus urea at 30 kg N/ha and maize Stover applied at 45 kg N/ha plus urea applied at equivalency of 30 kg N/ha suppressed Striga. An economic evaluation was conducted to compare the financial benefits of Calliandra or maize Stover applied alone or in combination with urea on maize productivity. Calliandra at an equivalency of 30 kg N/ha plus urea at 45 kg N/ha gave the highest mean net benefits of 17,990 Kshs/ha at Bukura, while at Nyabeda, maize Stover at 45 kg N/ha plus urea at 30 kg N/ha gave the highest benefits of 4,970 Kshs/ha. Soil fertility management options evaluated in this study provide a range of technological options to farmers at different levels of resource endowment for improving maize productivity and Striga management. Ultimately these technologies will lead to improved food security, poverty reduction, and promote environmental conservation in Western Kenya.

Okalebo, J. R., Othieno C., Kipkoech, A., M., Magiroi, K., and Ms. Osundwa, M. Up-scaling the use of soil fertility replenishment practices for smallholder farmers of Western Kenya. Technical report, World Phosphate Institute (IMPHOS), 3 Rue Abdelkader Al Mazini, BP, 15963, CASABLANCA, MOROCCO pp 24-65

Agronomic studies show that DAP does not perform better alone but increases yields when applied together with lime. In the three experimental sites, for long times now, DAP has been thought to be holding the key to the solution of the perennial problem of food shortage in the area, if only farmers could adapt this fertilization. However, it is emerging that the fertilizer could not be performing as well as it is thought to or compared to when the major project of fertilizer may not be performing as well as it is thought to or compared to when the major project of fertilizer use recommendation (FURP) recommended this fertilizer. In the current experiment, DAP + lime+ CAN performed better in both grain and Stover yield. Technology and information diffusion may take time but farmers are expected to start testing technologies especially the MPR and combination of fertilizers in the coming session in October 2011 and April 2011. According to the adoption theory, a more rapid communication of information about a new idea leads to an earlier creation of knowledge leading to a shift in the awareness curve. Supplying the individual with additional information and decision support can shorten the time of decision-making or adoption. Thus, with available information, it is apparent that technologies will not only depend on whether the farmers have received the information but also on the availabilities of the technologies. In the experiment, DAP + lime or MPR + CAN performed better in both grain and Stover yields. Economic results showed that supplying the individual with additional information and decision support can shorten the time of decision-making and adoption. Thus, with available information, it is apparent that adoption of technologies will not only depend on whether the farmers have received the information but also on the availability of technologies. Sustained growth in agricultural productivity cannot be achieved unless farmers increase the rate of fertilizer use. Fertilizer policies should emphasis provision of directs subsidies to farmers and develops a network of agro-dealers across rural areas to stock appropriate fertilizers. National research and extended programmes should emphasis economic use of fertilizer as the basis for recommending fertilizer rates rather than the agronomic performance.

Achieng, J. O, Ouma, G, Odhiambo, G, Muyekho, F. (2010). Effect of *Tithonia diversfolia* (Hemsley) and inorganic fertilizers on maize yields on Alfisols and Ultisols of Western Kenya. *Agriculture and Biology Journal of North America* Vol. 1 (5) pp 740-747

Smallholder maize (*Zea mays L.)* farmers cannot cope with the high and ever increasing prices of fertilizers, resulting in continuous low grain yield, chronic food shortage and insecurity. Cheaper, Sustainable alternatives of improving soil fertility are being sought. The influence of *Tithonia Diversifolia* (Hemsley) *A.* Gray and fertilizer application on maize yield was studied on N and P deficient Alfisols and Ultisols in western Kenya. An on-farm trial, consisting of six treatments: farmer's practice, N (60 kg/ha), NP (60 kg/ha of each), NPK (60 kg/ha of each N and P; K 40 kg /ha), tithonia+30 kg N/ha, and optimal fertilizer (N, 200; P, 60; K, 120; Mg, 20; B, 5 kg/ha), arranged in a Randomized Complete Block Design, with five replications in each soil type was set-up during wet and dry seasons of 2006. During the wet season, Alfisols gave about 80% more grain yield compared to Ultisols. Treatment comparison within Alfisols indicated that Tithonia had a 102% yield advantage over farmer's practice; but optimal fertilizer, NPK, NP and N had yield advantage of 56%, 6%, 4% and 4%, respectively, over Tithonia. Apart from optimal treatment, all other fertilizer treatments were not significantly different ($P<0.05$) on grain yield. Within Ultisols, Tithonia had a 96% grain yield advantage over farmer's practice; treatments optimal fertilizer,

NPK, NP and N had yield advantage of 76%, 25%, 10% and 7%, respectively, over Tithonia. Again NP and N were not significantly different (P‹0.05) from Tithonia on grain yield. During the dry season, Ultisols gave 17% more grain yield than Alfisols. Comparison within Alfisols indicated that Tithonia had a yield advantage of 30%, 30%, and 13% over N, NP and NPK; respectively. However, optimal treatment had a 4% yield advantage over Tithonia. Within Ultisols, Tithonia gave higher yields compared to N, NP, NPK, and optimal fertilizer in the tune of 36%, 18%, 7%, and 7%, respectively. This study concludes that use of Tithonia not only enhances productivity on acidic soils, but also has a higher cost benefit compared to commercial fertilizers. However, there is need to devise methods of biomass accumulation and safe storage to enable farmers access sufficient amounts for application at sowing time.

Achieng J.O, Ouma G, Odhiambo G. and Muyekho F. (2010). Effect of farmyard manure and inorganic fertilizers on maize production on alfisols and utisols in Kakamega, Western Kenya, *Agriculture and Biology Journal of North America* pp: 430-439.

Soil acidity is one property associated with decline of most crop productivity. Alfisols and Ultisols are some of the acidic soils predominant in western Kenya. An experiment was conducted in both soils to find out the effect of farmyard manure (FYM) and inorganic fertilizers on maize yield on farmers' fields during wet and dry seasons of 2006. The experiment, laid out in a randomized complete block design (RCBD), had five replications in each soil type. The treatments were: farmer's practice, N (60 kg/ha), NP (60 kg/ha of each), NPK (60 kg/ha of each N and P; K 40 kg/ha), FYM + 30 kg N/ha, and optimal fertilizer (N, 200; P, 60; K, 120; Mg, 20; B, 5 kg/ha). During wet season, all treatments in Alfisols gave nearly double grain yield compared to Ultisols. In both soils, during the same season, except for optimal fertilizer, FYM was not significantly (P≤0.05) different from other inorganic fertilizer treatments on plant population, height, cob number, stover, grain yield and 100-seed weight. FYM had a 108% and 103% grain yield advantage over farmer's treatment in Alfisols and Ultisols, respectively. During dry season, plant population, number of cobs and grain yield were higher in Ultisols compared to Alfisols. In each soil type, FYM plus 30 kg N/ha provided maize grain yield equivalent to that of N, NP and NPK treatments. FYM had a 4% grain yield advantage over optimal and NPK treatments on Ultisols during dry season. We conclude that larger amount of fertilizers or liming is needed on Ultisols to enhance their productivity to the level of Alfisols and that due to the fact that smallholder farmers are not likely to afford large amount of fertilizer and liming, use of FYM is their best bet for maize production on both Alfisols and Ultisols as there is no significant yield advantage from N, NP or NPK over FYM. Ultisols appear to be more responsive to FYM during dry season probably due to prevailing higher temperatures and relatively dry soil which enhances faster mineralization of organic matter to available plant nutrients. Addition of N fertilizer failed to increase yield in Ultisols, probably due to decline in soil pH and consequently inefficient utilization of applied resources.

Achieng J. O., Ouma G., Odhiambo G. and Muyekho F. (2010). Effect of *Tithonia diversifolia* and inorganic fertilizers on maize yield on Alfisols and Utisols of Western Kenya. *In: Ouda et al. (Eds) Proceedings of the 12th KARI Biennial Scientific Conference*, 8-12, November, 2010, pp 258-266

Smallholder maize (*Zea mays*) farmers cannot cope with the high and ever increasing prices of fertilizers, resulting in continuous low grain yield, chronic food shortage and insecurity. The influence of Tithonia diversfolia (Hemsley) A. gray and fertilizer application on maize yield was studied on N and P-deficient Alfisols and Ultisols in Western Kenya. An on-farm trial consisting of six treatments: farmer's practice, N (60 kg/ha), NP (60 kg/ha of each), NPK (60 kg/ha of each N and P; K 40 kg/ha), Tithonia + 30 kg N/ha, and optimal fertilizer (N, 200; P, 60; K, 120; Mg, 20; B, 5 kg/ha), arranged in a Randomized Complete Block Design, with five replications in each soil type was set-up during the wet and dry seasons of 2006. During the wet and dry seasons, Alfisols gave about 80% more grain yield compared to Ultisols. Treatment comparison within Alfisols indicated that Tithonia had a 102% yield advantage over the farmer's practice; but optimal fertilizer, NPK, NP and N had a yield advantage of 56%, 6%, 4% and 4% respectively, over Tithonia. Apart from optimal treatment, all others were not significantly different (P<0.05) on grain yield. Within Ultisols, Tithonia had a 96% grain yield advantage over the farmers practice; optimal fertilizer, NPK, NP and N treatments had yield advantage of 76%, 25%, 10%, and 7% respectively over Tithonia. Again NP and N were not significantly different (p<0.05) from Tithonia on grain yield. During the dry season, Utisols gave 17% more yield than Alfisols. Comparison within Alfisols indicated that Tithonia had a yield advantage of 30%, 30% and 13% over N, NP and NPK, respectively. However, optimal treatment had a 4% yield advantage over Tithonia. Within Utisols, Tithonia gave higher yields compared to N, NP, NPK, and other optimal fertilizer in the tune of 36%, 18%, 7% and 7%, respectively. This study concludes that the use of Tithonia not only enhances productivity on acidic soils, but also has a higher cost benefit compared to chemical fertilizers. However, there is need to devise methods of biomass accumulation and safe storage to enable farmers access sufficient amounts for application at sowing time.

Ademba, J. S., Esilaba, A.O., Ngari, S. M. (2010). Evaluation of organic and inorganic amendments on nutrient uptake phosphorus use efficiency and yield of maize in Kisii region. *Proceedings KARI Kisii Conference transforming agriculture for improved livelihoods through agricultural product value chains*, pp 8-12

Soil Phosphorus, nitrogen and striga hermonthica are the major constrains to maize production in Nyanza province of Kenya. The yields are typical of low input systems ranging below 1.0 t/ha against a potential of 5.0 t/ha per season. A field trial was conducted at Bototo in Kisii central in Nyanza province of Kenya during the long and short rain seasons in 2007. The aim was to determine the effect of Phosphatic fertilizers and manure on nutrient uptake, nutrients use efficiency, maize yield and soil nutrient levels at harvest. A randomized complete block design (RCBD) was used with the farmers as Blocks. Maize H614 was sown at a spacing of 0.75m x 0.60m. Treatment were top dressed with CAN fertilizer at a uniform rate of 30 kg/ha, DAP, MRP, and TSP fertilizers were applied at a rate of 60 kg/ha P_2O_5 and Farmyard Manure at 10 t/ha one rate of P (60 kg/ha P_2O_5 was applied on all the phosphorus fertilizers and a no-P in acid soils. complete chemical analysis was done in all the plots. There was significant ($p<0.01$) crop growth vigour response to the fertilizers and manure due to treatments at Bototo. Plants that received manure and fertilizers treatment were more vigorous in growth than those in the control plots. There was a significant ($p<0.1$) grain yield response to phosphate fertilizers and manure treatments. Total grain yield response was significantly ($p<0.01$) higher in the phosphate fertilizers and manure treatments. Harvest index responded significantly ($p <0.1$) increased due to manure and fertilizers. Nutrient uptake and removal by the crop significantly ($p<0.1$) increased due to fertilizers application with a corresponding reduction in the total soil N, P, K Ca and Mg. Phosphate fertilizers and manure application significantly ($p<0.01$) increased available soil P. There was significant ($P<0.01$) agronomic phosphorus use efficiency (APUE) response to fertilizers and manure treatment. Physiological P use efficiency (PPUE) responded significantly ($p<0.01$) to fertilizers and manure treatments. Phosphate fertilizers and manure applications are essential to improve maize yields and nutrient P use efficiency.

Kathuli P., Musyoki, Nguluu S. N., Omari F., Matambii S. M. and Mutunga R. (2010). Effect of Fertilizer and Manure Application on Growth and Area Adaptability of Three Common Aloe Species a Semi-Arid Eastern Kenya. *In: Ouda et al (Eds) Proceedings of the 12th KARI biennial scientific 8-12, November conference*; pp: 1043-1049

Semi-arid lands have limited sustainable cash crops that can survive the dry climatic conditions and provide a stable source of income to the people in the region. Aloes, which grow wildly in this region controls a large world market valued at $20 billion and are a source of natural products that are used in cosmetic and pharmaceuticals industries worldwide. In order to commercialize this crop in dry lands of eastern Kenya, studies were conducted to investigate adaptability, response to fertilizer and/or manure application and growth of three commonly occurring aloe varieties in the semi-arid lands. The 3 aloes were tested for response to 9 fertilizer and or/treatments (Nil fertilizer or manure, 20 Kg P_2O_5 /ha, 10 kg P_2O_5 /ha, 4 t FYM/ha, 2 t FYM/ha,10 kg P_2O_5/ha + 2 t FYM/ha, 20 kg P_2O_5/ha, + 4 t FYM/ha, 10 kg P_2O_5 + 4 t FYM/ha) and their environmental adaptability in the randomized complete block design in a split plot arrangement at Kambi ya mawe in Makueni district from 2007-2009.The results revealed that, Aloe vera *(Secundifolia Engler)* and Aloe vera *(Barbadensis* Miller) had a significantly ($P\leq0.05$) better survival proportion of 96% and 92% after first and 93% and 79.5% at the end of the second year of growth respectively. Leaf area index (LAI) which is a measure of the aloe growth, was significantly ($P\leq0.05$) higher in Aloe vera (*Secundifolia Engler*) and Aloe vera *(Turkanesis Christian*) than Aloe vera *(barbadensis Miller*). After the 2 years of study, the 3 aloes species did not respond significantly ($P\leq 0.05$) to fertilizer and /or manure application. Participating farmers were empowered on aloe agronomy and processing. It was recommended that, *A. secundifolia* engler was most adaptable for growing in the semi-arid lands followed by A. Vera *(Barbadensis*) and can be grown up to 2 years without fertilizer or manure application in very low fertile soils. However, more data is required to show how long the aloes can be grown without soil fertility improvements.

Kibunja, C. N., Mwaura F. B., Mugenda D. N., Kitonyo E. M., Sirma, M. P. (2010). Crop N uptake and fertilizer N use efficiency under a continuous maize bean cropping system in the semi-humid highlands of Kenya. *Proceedings KARI Conference on Transforming Agriculture for improved livelihoods through agricultural product value chains*, pp 8-12

Poor and in appropriate management practices are cited as the main cause of soil fertility decline of cultivated lands. Management of Nitrogen under continuous cultivation is an integral component of efficient crop productivity and land sustainability. Nitrogen is easily lost from the soil through crop removal leaching and soil erosion leading to environmental degradation. Crop nitrogen N uptake and fertilizer use efficiency were monitored over a two year period in a long term maize bean experiment at Kabete Kenya using the 15N isotope technique. Treatments included control (no-input) fertilizer N and phosphorus (P) at 60 kg N and 26 kg P/ha respectively, farmyard manure at 5 t/ha and farmyard manure at 5 t/ha combined with 60 kg N with 15 N fertilizers at an enrichment of 10% atom excess (a.e). Soils were sampled at 0-20, 20-50, 50-100, 100-200 and 200-300 cm deeps, three times for every season for mineral N utilization was low at 40-55% depending on treatment and rainfall distribution but was higher than reported for other tropical regions. Split application of fertilizer recommended for medium to

high rainfall areas to improve fertilizer N efficiency higher mineral N contend at the end of the season increased down the profile (9% of the applied N) compared to Tithonia (0.6% of the applied N. This was attributed to the washing down of the nitrate N from the top soil accumulating in the lower layers of the soil profile. However there was no significant difference in N content down the soil between the Tithonia treatment and the control. It could be conclude that there was no nitrate leaching in the Tithonia treatment. Nitrogen recovery by the maize crop was higher in the urea treatment (76% of the applied N) as compared to the Tithonia treatment (55% of the applied N). This was also true for the residual mineral N in the soil at the end of the season which was about 7.6% of the applied N in the urea treatment and 5.2% in the Tithonia treatment. From this study it was therefore evident that although there was lower N recovery by maize supplied with Tithonia green biomass compared to maize supplied with urea, more nitrogen is being lost (through leaching) from the soil plan system in the urea applied plots than in Tithonia applied plots. However a greater percentage of 27.8% of the Tithonia applied N could not be accounted for and might have been emerged in the soil organic matter unlike urea application N greater percentage (9%) could be accounted for.

Mwangi, T. J. and Ghasem N. (2010). Improving and sustaining soil fertility by use of farmyard manure and inorganic fertilizer for economical maize production in West Pokot, Kenya. *World Journal of Agricultural Sciences* Vol. 6(3) pp 313-321

Low soil fertility is a major constraint in maize production on smallholder farms in West Pokot district of Kenya. The situation prevails despite the fact that farmyard manure (FYM), which can be used as supplement to inorganic fertilizers or as an alternative cheap source of nutrients is readily available. A study was carried out for five years at Cheptuya village, West Pokot district of Kenya to determine the effect of manure and its combination with inorganic fertilizers on soil chemical properties and yield of maize. Farmyard manure was used either alone or in combination with inorganic fertilizers as follows: control (zero fertilizer), 5 t FYM/ha, 10 t FYM/ha, 5 t FYM + 30 kg P_2O_5 & 40 kg N/ha, 30 kg P_2O_5+ 40 kg N/ha, 60 kg P_2O_5 + 80 kg N/ha and farmers practice. The treatments were laid in a randomized complete block design in eight farms for five years between 1996 and 2000. Each farm served as a replicate. Results showed that the change in topsoil organic carbon, available potassium, calcium and manganese due to treatments in the first four years starting from 1996 to 1999 was not significant (P = 0.05). Combined analysis of maize yield data over five years (1996 to 2000) showed no significant difference between the 60 kg P_2O_5+ 80 kg N/ha (recommended inorganic fertilizer rate) and 5 t FYM + 30 kg P_2O_5 & 40 kg N/ha treatments whose maize yields were 5.5 and 4.9 t/ha G1, respectively. The yield of maize from the 10 t FYM/ha treatment increased from 2.2 t/ha in 1996 to 5.4 t/ha in the year 2000. The economical treatments in 1998 that would also be expected to improve soil fertility were: 60 kg P_2O_5 + 80 kg N/ha, 5 t FYM + 30 kg P_2O_5 & 40 kg N/ha and 10 t FYM/ha whose benefit cost ratios were 3.8, 3.2 and 2.4, respectively. These three options were recommended for dissemination in other areas in West Pokot with similar agro-ecological zones and social economic circumstances for improving soil fertility and sustaining maize yields.

Mwangi, T. J. (2010). Improving and Sustaining Soil Fertility by Use of Farmyard Manure and Inorganic Fertilizers for Economical Maize Production in West Pokot, Kenya. *Agricultural Sciences* 6 (3):313-32.

Low soil fertility is a major constraint in maize production on smallholder farms in West Pokot district of Kenya. The situation prevails despite the fact that farmyard manure (FYM), which can be used as supplement to inorganic fertilizers or as an alternative cheap source of nutrients is readily available. A study was carried out for five years at Cheptuya village, West Pokot district of Kenya to determine the effect of manure and its combination with inorganic fertilizers on soil chemical properties and yield of maize. Farmyard manure was used either alone or in combination with inorganic fertilizers as follows: control (zero fertilizer), 5 t FYM/ha, 10 t FYM /ha, 5 t FYM + 30 kg P_2O_5 and 40 kg N/ha, 30 kg P_2O_5 + 40 kg N/ha, 60 kg P_2O_5 + 80 kg N/ha and farmers practice. The treatments were laid in randomized complete block design in eight farms for five years between 1996 to 1999 was not significant (p=0.05). Combined analysis of maize yield data over five years (1996-2000) showed no significant difference in the 60 kg P_2O_5 + 80 kg N/ha (recommended inorganic fertilizer rate) and 5 tons FYM + 30 kg P_2O_5 & 40 kg N/ha treatments whose maize yields were 5.5 and 4.9 t/ha respectively. The yield of maize from 0 t FYM/ha treatment increased from 2.2 t/ha in 1996 to 5.4 t/ha in 2000. The economical treatments in 1998 that would also be expected to improve soil fertility were 60 kg P_2O_5 + 80 kg N/ha, 5 t FYM + 30 kg P_2O_5 and 40 kg N/ha and 10 t FYM/ha whose benefit cost ratios were 3.8, 3.2 and 2.4, respectively. These three options were recommended for dissemination in other areas in West Pokot with similar agro-ecological zones and social economic circumstances for improving soil fertility and sustaining maize yields.

Ng'etich, O. K. (2010). Enhanced growth and yield of African nightshade (*Solanum scabrum* mill.) and spider plant (*Cleome gynandra* L.) through sole and integrated nutrient management. MSc. Thesis, Egerton University, Njoro, Kenya pp: 15-113

African leafy vegetables provide adequate amounts of crude fibre, carotene (a precursor of vitamin A), vitamin C riboflavin, folic acid and mineral salts. Most of the African vegetables have been domesticated and cultivated but information on their sustainable fertility requirement are scanty. The soil fertility in the region has declined over time in most smallholder farms. However, few farmers can afford the inorganic fertilizers while the use of manure alone may be limited by its slow nutrient release. Among the options available for increasing the production is integrating the use of inorganic nitrogen fertilizer with farm yard manure (FYM). The objective of the study was to evaluate the effects of integrated application of farmyard manure and nitrogen fertilizer levels on growth and yield of African nightshade (*Solanum scabrum* Mill*)* and spider plant (*Cleome gynandra* L.) Field trials were conducted at Horticulture Research and teaching Field, Egerton University Njoro, Kenya from April to July (trial 1), and August to November, 2009 (trial 2). The experiment was carried out in split-plot arranged in randomized complete block design, replicated thrice. The main plot treatments were farmyard manure (FYM) levels at the rates of 0, 7.5, 11.3 and15 t/ha and the sub-plots treatments were nitrogen levels at the rates of 0,100,150 and 200 kg N/ha. Standard cultural practices were undertaken to maintain the plants from planting to end data collection. Parameters studied included growth and yield aspects. Data collected was subject to Analysis of Variance (ANOVA) and mean separation performed using Duncan Multiple Range Test (DMRT) at 0.05 level of significance. The results showed that, 7.5 t/ha of FYM and 150 kg N/ha of CAN increased fresh yield of African nightshade by 62% while 11.3 t/ha of FYM and 150 kg N/ha of CAN fertilizer rates enhanced the spider plants fresh yield by 64% compared to the control. The higher treatment combination significantly increased African nightshade plant height by 64% number of branches by 34% leaf area by 59% leaf area index by 89% number of leaves by 77% and above ground biomass by 62%. While in spider plant, the number of leaves was increased by 63%, branches number by 67%, internodes length by 70% and leaf area index by 85% compared to the control. Chlorophyll and stomatal conductance showed an increasing trend with increase treatment levels. The study recommends that application of 7.5 t/ha of FYM and 150 kg N/ha of CAN and 11.3 t/ha of FYM and 150 kg N/ha of CAN fertilizer rates for better productivity of African nightshade and spider plants respectively. The research provides valuable information to farmers and if well utilized, can enhance the productivity of African nightshade and spider plant.

Njeru C. M. (2010). Effects of selected fertility improving practices on productivity of maize-legume cropping system on low or high fertility soils in western Kenya. MSc. Thesis, Moi University, Eldoret, Kenya pp: 35-111

Multipurpose grain legumes, such as *Lablab purpureus* L. have potential to replenish soil fertility through nitrogen additions, phosphorus recycling and to supplement human and livestock nutrition in Western Kenya. Moreover, low cost and low risk strategies such as seed priming and modest fertilizer additions may directly improve legume grain and biomass production, and residual contributions from biomass retention to a subsequently established maize-bean intercrop. This study investigated the effect of seed priming and phosphorus application on lablab productivity and residual effects of legume biomass retention, boma compost and inorganic fertilizers on productivity of maize/bean intercrop at two sites; a low soil fertility site (Kapkarer) and a high soil fertility site (Koibem) in Nandi south district of Western Kenya. Short rain 2008 season field experiments were conducted using a split plot design with three replications per site, with main plot as phosphorus rates (0 kg P/ha, 30 kg P/ha) and sub plot comprising legume seeds treatment (with seed priming, without seed priming). LR 2009 season experiments consisted a split plot design with three replications per site, with main plot comprising legume biomass management (removed, retained), sub plot comprising fertilizer application (no fertilizer input, 15 kg P inorganic + 1.5 t/ha boma compost) and sub sub-plot comprising bean varieties (root rot tolerant KK8, root rot susceptible GLP2), intercropped with maize variety Hybrid 614D. Phosphorus application increased lablab grain yield by 11% in the low fertility site compared to a 20% increment in the high soil fertility site. Phosphorus also increased nodulation at low fertility site, but had no effect at high fertility site. Seed priming resulted to non-significant increases of between 2 to 9% in biomass production and grain yields at low soil fertility site, with no significant interactions between seed priming and phosphorus application on either grain yield or nodulation at either site. LR 2009 biomass retention significantly ($p<0.05$) improved maize yields by 8% in low fertility site but had no effects at high fertility site. Although there was no maize and bean grain yield responses to fertilizer application in low fertility site, significant ($p<0.05$) maize and bean yield response was obtained in the high fertility site. Averaged across biomass management and fertilizer levels, KK8 bean variety yielded over 300% grain yield increase compared to GLP2 bean variety at the low and high fertility sites. These results illustrate the potential for seed priming and application of modest organic/inorganic phosphorus fertilizer rates at improving lablab and maize-bean productivity under heterogeneous smallholder farming conditions of Western Kenya

Njeru C. M., Okalebo J. R., Ojiem J. O., Othieno, L. J. and Medvecky B. (2010). The response of maize-bean intercrops to fertilizer application in low and high fertility areas of Nandi South District, Kenya. *East African Agricultural and Forestry Journal* Vol. 76 pp. 183-191

Soil fertility management is key to improving the productivity of smallholder farming system in western Kenya under continuous maize and bean cultivation. Management strategies combining high value legume biomass residue, boma compost and inorganic fertilizer on productivity of maize and improve vigour of a bean intercrop. This study was conducted to assess the effects of organic and inorganic fertiliser on productivity of a maize bean intercrop in two sites with different soil fertility. Field experiments were conducted in a split split plot design with three replications per site. 4D. Biomass retention resulted into a slight improvement ($P<0.05$) in maize yields in the low fertility site but had no effect on maize grain yields at high fertility site. Although there was no maize or bean grain yield response to fertilizer application in the low fertility site, there were maize and bean yield responses in the high fertility site ($P < 0.05$). Considering bean establishment under biomass retention and organic/inorganic fertilizer application, KK8 bean variety resulted to over 300% grain yield increase compared to susceptible GLP2 bean variety in both low and high fertility sites. Intercropping maize with beans had no effect on maize grain yield. These results show the potential and challenges for improving productivity in low and high fertility environments by combining organic and inorganic fertilizer sources with disease tolerant bean germplasm.

Njeru P. N. M., Lekasi J. K., Nandokha T., Mutea K., Kayaire J., Kungu N., Thairu P., Wakaba P., Olendo S., and Njunge J. (2010). The effect of application of Phosphorous (P) rates and intercropping of multi-purpose tree species on maize production in Central Kenya. Kenya Agricultural Research Institute-Muguga Annual report; pp. 59-62

One of the advantages of mixed farming is the opportunity to convert by-products and wastages from one activity into inputs for another. In an intensive mixed farming system, crop residues are frequently used as livestock feed while the manure and urine produced are used as fertilizers and soil fertility improvers to produce crops and fodder. Zero grazing has become a popular enterprise in central Kenya due to small and fragmented pieces of land, consequently, high fodder demand to feed the zero grazing units. *Calliandra calothyrsus*, a leguminous fodder tree is a species that can be grown on-farm, used as a barrier species in contour hedges, and substitute for purchased dairy meal to improve the basal fodder diet of Napier (*Pennisetum purpurem*). An on-station experiment was established in short rains of the year 2010 which demonstrated the potential of *Calliandra calothyrus* and lecucena diversifolia pruning as soil fertility improvement strategy. The project design is a partially balanced incomplete block design (PBIBD) with six incomplete blocks per replicate, each replicated 4 times. Each incomplete block contains six treatments. Maize grain yields results indicate that there is no significant different ($P<0.01$) between fertilizer P application at the rate of 30 Kg P_20_5 t/ha and 40 kg P_20_5 t/ha. Therefore, there is an observation that it would be very economical to use 30 Kg P_20_5 t/ha as a recommendation to smallholder farmers in Central Kenya. Therefore, there is no concrete conclusion can be reported from this project since this is its first season. Clear recommendations and conclusions will be drawn from next annual report 2011.

Nyabinda N. O. (2010). Effects of cane crop residues, farmyard manure and inorganic P on growth and yield of smallholders' seedcane in western Kenya. Msc. Thesis; Moi University; Eldoret, Kenya

In most African countries, low inherent soil fertility in highly weathered and leached soils largely accounts for the decline in sugarcane yields. Decline in soil organic matter with cropping is a major factor affecting the sustainability of cropping systems. This scenario of nutrient depletion is reflected in food deficits, especially in sub-Saharan Africa. Efforts to replenish the fertility of the degraded soils include among others: application of both organic and inorganic resources. The objective of this study was to monitor and compare effects of crop residues (trash and filter mud) and organic manures (Farm yard manure-FYM) on their own or in combination with inorganic phosphorous (P) on growth and yield of smallholder seed cane. The research was carried out at the Kenya Sugar Research Foundation (KESREF), Kibos, situated to the north-eastern area of Kisumu city. The research was done on two portions of land; the soil texture class of the upper land (Field 10) was sandy loam while lower land (Field 13) was sandy clay loam, classified as eutric Cambisols and eutric Vertisols respectively (FAO/UNESCO classification, 1988). Statistical analysis was done using SAS procedure. The soils in the two sites were characterized by low pH of 5.54 (Field 10) and 5.73 (Field 13), available P was below the critical value of 10 mgP/kg, having the values of 1.21 (Field 10) and 2.60 (Field 13). The low C: N ratio of 19.1 and 14.1 respectively, in the two fields suggested presence of organic matter in these soils. Each plot unit measured 10 m long by 7.2 m wide. The eight treatments of different organic materials with or without P on sugarcane variety N14 were arranged in a randomized complete block design (RCBD), and replicated three times. The results showed insignificant increase in soil pH ($p<0.06$) due to the application of organic materials. Application of organic materials with and/or without P gave a significant ($p<0.001$) increase in soil carbon with a maximum mean increase in carbon value of 16.83% in field 10 and 14.12% in field 13. Germination % increased significantly ($P<0.001$) by 27% in field 10 and ($P<0.05$) by 30.6% in Field 13, above the control. Filter mud at 10 t/ha and FYM 5 t/ha plus 4 kg P/ha gave

significant increase in the tiller density at the end 48 WAP in both fields compared to control and application of sugarcane trash at the rate of 2.5 tons/ha. The shortest stalks were noted in plots supplied with trash 2.5 t/ha, while the tallest in plots treated with 10 t/ha FYM in both fields. Mean stalk height ranged 126.2 cm to 153.4 cm in field 10 and from 125.3 cm to 149.4 cm in field 13. The application of organic materials with or without P gave significant increase in girth ($p<0.024$ in field 10) and ($p<0.001$ in field 13) of seedcane stalks. Use of FYM 10 t/ha gave the highest population of seedcane stalks in field 10 (282 plants/ha), which was 64% above the control (172 plants/ha), second lowest in the trend was 2.5 t/ha with 207 plants per plot. Application of 10 t/ha Filter mud in Field 13 gave the highest number of seedcane stalks of 254 plants/ha, which was 45.7% above the control. Mean stalk population was highly significant among the treatments in both field 10 ($p<0.001$) and field 13 ($p=0.002$). The highest yield of 88 t/ha was obtained in field 10 with application of FYM 10 t/ha, which was 84% above the control, followed by filter mud (in both field 10 and 13) at the same rate, recorded 83 t/ha each, which was 46% above the control. Economic analysis revealed that investing in FYM at the rate of 10 t/ha gave the highest returns of Kshs 100,833.30/ha above that of the control, followed by Filter mud at the same rate gave Ksh 88,333.30/ha above the control. It would be economical to use FYM plus SSP than trash plus SSP.

Odundo S. N., Ojiem O.J., Okalebo J.R., Othieno C.O., Lauren J.G., Medvecky B. A. (2010). Effects of phosphorus on survival, phosphorus accumulation and yield of cowpea (*vigna unguiculata*) varieties across a soil fertility gradient in Western Kenya. Kenya Agricultural Research Institute, Kakamega. Annual report.

Declining soil fertility and poor genetic potential of cowpea germplasm have resulted in decreased yield of the crop in smallholder farms in western Kenya. This is because of limited availability of Phosphorus (p) in the western Kenya soils resulting from inadequate use of fertilizers and P fixation, and susceptibility of the local farmer varieties to major pest and diseases. Due to limited nutrient recycling in these small holder farms use of external sources of P alongside improved cowpea varieties, tolerant to major pest and diseases could improve cowpea yields. Local and improved cowpea varieties were screened to investigate their adaptability, yield and biomass P accumulation across a soil fertility gradient. Experiments were conducted in Nandi south District, western Kenya, during long and short rains seasons 2009. Three local cowpea varieties (enzegu, khaki and Ilanda) and five improved varieties (ICV1, 1CV12, CB46, iT92K-282-2 and 1TD83D-442) were screened at four contrasting sites: Kapkerer, Kiptaruswo, Bonjoge and Koibem representing, low medium-low, medium high, and high soil fertility levels, respectively. The design was RCBD with three replications in factorial arrangement of treatments. P was applied at three levels of 0, 15 and 30 kg p/ha using triple supper phosphate. Data was collected on plant count at 2 weeks and 12 weeks after emergence, total above dry ground matter (DM) and grain yield. Varieties emerged were significant (<0.05) different across sites. Mean survival rate was best in Kapkerer (80%) and worst in Bojonge (39%) There were no significant ($P<0.05$) DM response to application of P averaged over varieties, the mean DM accumulation was 72kg/ha under no P application and 221kg/ha at 30kg P/ha in Bojonge. Similarly at Koibem mean DM accumulation without P application was 360 kg/ha and 417 kg/ha at 30kg P/ha. Application of P had significant (<0.05) influence on cowpea grain yield. In Bojonge site, variety CB46 had the highest grain yield of 434 kg/ha, which was significantly different from CV6 (206 kg/ha) and IT90K-284-2 (217kg/ha). In Koibem, however, ICV12 had the highest grain yield of 342 kg/ha, which was significantly different from Khaki (127 kg/ha) and IT83D-442 (128 kg/ha). The results of this study show that the cowpea varieties screened had differential adaptation to test site environmental conditions. While productivity is influenced by soil fertility status, application of P is essential for enhancing both DM accumulation and grain yield.

Ojiem, J. (2010). Niche-based assessment of contributions of legumes to the nitrogen economy of western Kenya smallholder farms. *Proceedings of the 1st Kenya Agricultural Research Institute Mini conference*. pp: 56-60

Nitrogen (N) deficiency is a major constraint to the productivity of the African smallholder farming systems. Grain, green manure and forage legumes have the potential to improve the soil N fertility of smallholder farming systems through biological N_2- fixation. The N_2- fixation of bean (*Phaseolus vulgaris*), soybean (*Glycine max*), ground nut (*Arachis hypogaea*), Lima bean (*Phaseolus lunatus*), Lablab (*Lablab purpureus*), velvet bean (*Mucuna pruriens*), crotalaria (*Crotalaria ochroleuca*), jackbean (*Canavalia ensiformis*), desmodium (*Desmodium uncinatum*), Stylo (*Stylosanthes guianesnsis*) and siratro (*Macroptilum atropupureum*) was assessed using the ^{15}N natural abundance methods. The experiments were conducted in three agro-ecological zones (AEZ) in western Kenya, representing high rainfall (AEZ1), medium rainfall (AEZ2) and low rainfall (AEZ 3). Experimental fields were classified into high, medium and low fertility classes, to assess the influence of soil fertility on N_2- fixation performance. The legumes were planted with triple super phosphate (TSP) at 30 kg P/ha, with an extra soybean plot planted without TSP, to assess response to P, and no artificial inoculation was done. Legume grain yield, shoot N accumulation, %N derived from N_2-fixation, N_2 - fixation and net N inputs significantly ($P<0.01$) decreased with rainfall and soil fertility. Mean grain yield ranged from 0.86 Mg/ha, in AEZ2 to 0.30 Mg/ha, in AEZ 3 and from 0.78 Mg/ha, in the high fertility field, to 0.48 Mg/ha, in the low fertility field. Shoot N accumulation ranged from a maximum of 486 kg N/ha in AEZ2, to a minimum of 10 kg N/ha in AEZ3. The species fixed 23-90% of their N requirements in AEZ1, 25-90% in AEZ2 and 7-77% in AEZ3. Mean N_2 fixation by green manure legumes ranged from 232 kg/ha (crotalaria) in AEZ1 to 29 kg/ha

(jackbean) in AEZ3. For the forage legumes, mean N_2- fixation ranged from 97 kg N/ha for desmodium in AEZ 2 to 39 kg N/ha for siratro in AEZ 3, while for the grain legumes, the range was from 172 kg N/ha for lablab in AEZ 1 to 3 kg N/ha for soybean without P (soybean-P) in AEZ3. Lablab and groundnut showed consistently greater N_2- fixation and net N inputs across agro-ecological and soil fertility gradients. The use of maize as a reference crop resulted in lower N_2-fixation values than when broad-leaved weed plants were used. The results demonstrate differential contributions of the green manure, forage and grain legume species to soil fertility improvement in different biophysical niches in smallholder farming systems and suggest that appropriate selection is needed to match species with the niches and farmers' needs.

Thiuta, M., Lesueur, D. and Herrman, L. (2010). Evaluation and scaling up new chemical and biological commercial products for improving and improving and sustaining crop yields in selected agro-ecological zones in sub-Saharan Africa. ILRI Compro-Technical report; EAIR Assembly, pp.1-15, Addis Ababa, Ethiopia.

The screening provided a chance to identify promising inoculants to be further tested in the farmers' fields. The sites identified served the purpose of subjecting the inoculants to diverse but possible scenarios any new strain may encounter in various parts of our farming communities. The major obstacle was the poor rain season experienced in most parts of the country which impacted negatively on nodulation, growth and grain production. Considering all the data collected and laboratory analyses, we can conclude the following: 1) the strains/commercial products produced elsewhere are able to nodulate both non promiscuous Nyala and the promiscuous TGx varieties and form effective nodules and nitrogen fixation. 2) When introduced to areas with high populations of native rhizobia capable of nodulating soybean infectivity will depend on the competitiveness of the individual strains contained in the product. It thus follows to say that before introduction of any product in an area it is advisable to check on the presence of native rhizobia and their competitiveness. 3) In an environment with little or no native rhizobia capable of nodulating soy bean and form effective symbiosis. 4) emphasis must be put on the need to ensure that apart from introducing soybean inoculation other important components are provided in adequate amounts for example phosphorous. 5) The experience with HiStick is also an important lesson; it contains the same strains as Vault IvI but differs in formulation. This implies that for the kind of farmers we have the formulation should be given due consideration. It is easier to teach the farmers to use single product but if you have to mix several components as is with vault may not be ideal handling also presents additional challenges. Finally with the results and lessons so far, we do have products that have shown high potential to impact positively the production of soybean in various agro-ecological zones and soil types represented in this study by the mandate areas. Once all data is processed then it can be said with certainty that certain products have tested and proven to work in these areas.

Thuranira, D. M. (2010) Effects of soil fertility management and *Trichoderma asperellum* on severity of wilt disease of passion fruits. Msc Thesis, Jomo Kenyatta University of Agriculture & Technology (JKUAT), Kenya

Passion fruit is the third most important export fruit crop In Kenya, after mangoes and avocadoes. Plant diseases are the main constrains to passion fruit production resulting in 40 to 100% yield loss. Passion fruit wilt diseases caused by *Fusarium Oxysporum f*. sp *passiflorae* is of economic importance in Kenya. Management of this disease is important in Kenya. Management of this disease is difficult because the pathogen persists in the soil for many years. Chemical controls are expensive and in most cases not effective. The most economical control method is the use of tolerant rootstocks, such as yellow passion fruit, which however succumbs to the disease in some cases. The study was conducted to investigate effects of soil fertility management and application of *Trichoderma asperellum* on control of passion fruit wilt disease. In the first experiment, soils managed under organic, integrated and virgin systems were collected from farmers' fields and used to set up a bioassay in a green house using the purple passion fruits seedlings. The soils were inoculated with a field isolate of *Fusaruim Oxysporum f.sp. Passiflorae* (FOP) at 2.25*10^4 colony -forming units (cfu)/g. Spilt plot design with three replicates was used. Microbial population of the antagonists Trichoderma spp fluorescent pseudomonads and actinomycetes were determined by serial dilution two months after transplanting and repeated once per month for eight months. Second experiment was done four weeks after the first experiment. In this experiment, the soil was inoculated with *T. asperellum* at 5*10^7 CFU/ml and three weeks later with FoP at 2, 25*10^4 CFU/g. split-split plot design with three replicates was used. Disease severity, in both experiments, was assessed by length of vascular discoloration and chlorosis at the end of experiment. Data was analysed using analysis of Variance (ANOVA) and treatments were separated using Student-Newsman-keuls test. In the first experiment, disease severity was not significantly different (P<=0.05) between organic and integrated managed soils but significantly lower (P<=0.055) population of antagonist than virgin soils. Organic matter improved efficacy of *T. asperellum*. These results proposed an integrated and sustainable approach towards management of wilt disease of passion fruits by using bio-control agent *T. asperellum* and addition of organic matter.

Ademba, J. S. (2009). Analytical determination of the effects of phosphatic fertilizers and manure on maize yields in acidic soils in Kisii and Rachuonyo Districts, Msc Thesis, Egerton University Nakuru, Kenya

Maize Production in sub-Saharan Africa remains low and the yields are on the decline. This has been attributed to a variety of factors which include soil nutrient depletion and Striga infestation. Soil Phosphorus, nitrogen and Striga (*hermonthica*) are the major constraints to maize production in Nyanza Province of Kenya. The yields are typical of low input systems ranging below 1.0 t/ha against a potential of 5.0 t/ha per season. In an attempt to overcome these constraints, field trials were conducted at two on-farm sites, Bototo in Kisii central district in Nyanza Province of Kenya. The trials were conducted during the long and short rains seasons in 2007. The study investigated the effects of Phosphatic fertilizers and manure on nutrient uptake, nutrient use efficiency, maize yields and soil nutrients contents at harvest in both sites. A Randomised Complete Block Design (RCBD) was used and the farmers served as replicates. Farmers in Bototo Plant H614 variety while those in Kabondo plant H513 maize variety. Plots were top dressed with Calcium Ammonium Nitrate (CAN) fertilizer at a uniform rate of 30 kg N/ha. Di-ammonium Phosphate (DAP), Minjingu Rock Phosphate (MPR) and Triple Super Phosphate (TSP) fertilizers were applied at a rate of 60 kg P_20_5/ha and farmyard manure (FYM) at 10 t/ha. One rate of P (60 kg P_20_5/ha) was applied on all the P sources and a no P treatment (check) plus time only treatment was included in determining the effects due to the applied P in the acidic soils. Complete soil chemical analysis was done in all the plots. To assess the effects of phosphorus fertilizers and manure and estimate the nutrient content and uptake of major nutrients. Plant and soil samples were analysed using standard methods. There were significant ($P \leq 0.01$) crop growth vigour response to the fertilizers and manure treatments at both sites. There were significant ($P \leq 0.01$) grain yield, total dry matter yield and harvest index response to the fertilizers and manure treatments on both sites. Phosphate fertilizers and manure treatments had significant ($P \leq 0.01$) effects on Striga emergence at both sites. Striga emergence correlated weakly with phosphate fertilizers and manure treatments and strongly with grain yield at both sites. Nutrient uptake and removal by the crop significantly ($P \leq 0.01$) increased due to fertilizers and manure applications, with a corresponding reduction in the total soil N, P, K ,Ca, and Mg. Phosphate fertilizers and manure application significantly ($P \leq 0.01$) increased available soil phosphorus, agronomic phosphorus use efficiency (APUE) and physiological phosphorus use efficiency (PPUE) in both sites. The Results indicate that phosphate fertilizers and manure application are essential to improve maize yield, nutrient phosphorus use efficiency and the applied nitrogen reduced the impacts of Striga hermonthica damage to maize yields.

Bashir J. and Kiwia A. M. (2009). Agronomic and financial benefits of phosphorus and Nitrogen sources in western Kenya. *Experimental Agriculture Journal*. Vol. 45, 241-260. Cambridge university press, United Kingdom

A better understanding of the agronomic and economic benefits of integrating organic and inorganic fertilizers is essential for their wide-scale dissemination and adoption of smallholder farming systems in developing countries. Field studies were conducted in 10 cropping seasons (1996-2000) on a Kandiudalfic Eutrudox soil to compare the effects of minjingu phosphate rock and triple superphosphate (TSP) on the yield of *Zea mays*, in the combination with three nitrogen sources: urea, Tithonia diversifolia and Sesbania sesban leafy biomass. Urea and Tithonia were applied to provide 60 kg N/ha. Phosphorous (P) from either MPR or TSP was added either once at 250 kg P/ha at the beginning of the experiment or annually at 50 kg P/ha for five years, the two rates representing two P recapitalization strategies. From the second year, potassium (K) was added to half of each plot to correct the deficiency that emerged. Over the 10 cropping seasons, the agronomic and economic benefits of the two P recapitalization strategies were similar and were not influenced by the P sources used. With N and K application both P sources resulted in a two-fold maize grain yield increase over the control with no P application that averaged 1.1 t/ha. Comparing the N sources, although urea and Tithonia had similar net benefits when P was applied, the total cost associated with Tithonia was inconsiderably higher. Without P application, sesbania fallow was the most financially attractive option. Sesbania fallows as an N source were also at least to increases in the price of fertilizers and the cost of labour although the financial benefits of this system remained low in the absence of P and K application.

Haggai N. O. (2009). Dynamics of Nematode Communities as Influenced by Soil Fertility Management Practices and Bio-control Agents. Msc. Thesis University of Nairobi, Kenya

Two field experiments were conducted to investigate the effect of soil fertility management practices and bio-control agents on the dynamics of nematode communities in Kakamega forest and the neighbouring farmlands. Efficacy of a bio-control agent, *Bacillus subtilus* was tested alongside *Rhizobium leguminosarum biovar* phaseoli strain USDA 2674 for nodul formation in common bean (*Phaseolus vulgaris L.var Rosecoco*). Three *bacillus subtilis* strains (K158 k194 and K263). Singularly or in combination with *Rhizobium leguminosarum* biovar phaseoli were tested in beans and soil fertility management practices which included inorganic N: P: K (75:26:46) kg/ha farm yard manure (5 t/ha) PRE-PAC (800 kg P/ha and 80 kg N/ha were investigated in maize. The experiments were established on four farms representing age sequences since conversion from forest of 1-10, 10-20, 20-40 and>40 years. *Bacillus subtilis* strain K194 in combination with Rhizobium treatment on beans and PRE-PAC on maize reduced the populations of root-knot nematodes leading to an increase in bean yields from 150 to 560

kg/ha. Diversity index analysis showed that application of PRE-PAC reduced nomatode numbers compared to farmyard manure and inorganic fertilizers. Inoculating beans with *Rhizobium Leguminosarum biovar* phaseoli strains USDA 2674 enhanced nodulation and biomass production. Continued land conversion leads to loss of soil fertility and land degradation that ultimately results in loss of nematode biodiversity. Use of PRE-PAC resulted in modification of soil fauna environment that led to reduction in nematode numbers. For instance, the population of *Pratylenchus sp.* was reduced by over 30%. On the other hand, use of inorganic fertilizers released N that promoted multiplication of nematodes as observed in this study where *Pratylenchus sp.* population increased by over 40%.This study further demonstrated that *Bacillus spp* is a viable component of integrated nematode management packages. Potential *Bacillus subtilis* strains as bio control agent for root-knot nematode. *Imeloidogyne spp*. as well as growth promoting agent in beans was demonstrated in the field. Strain K194 gave very consistent trends over three seasons where the population of *Meloidogyne sp* was reduced by over 60%. Success of growing *Bacillus sp.* and *Rhizobium spp* in one medium for production of a bio-inoculant was demonstrated and has been packaged. Suitability of the nematode diversity as bioindicators of land use change/intensification gradient was demonstrated. As nematode populations change during the growth of a crop, it is desirable to standardize sampling on a stage of crop growth; this is often the seedbed or immediately after harvest. Nematode populations increased from planting time, peaking at bean flowering then reduced at harvesting time. High nematode populations were observed in the long rains than the short rains in plots planted with maize. This information indicates that priority ought to be given to plant parasitic nematodes in the long rains when designing pest management programmes in cereals. The significant interactions among soil fertility management practices, time of nematodes sampling and farm age cluster suggest that the populations of soil nematodes is influenced by fertility level, time of sampling and land conversion periods. It is recommended that, soil P and N levels be addressed as direct influence on plant parasitic nematodes. Use of organics where available should be recommended to the farmers.

Kiiya, W. W. (2009). Use of legumes and lime to improve soil fertility and control sheep sorrel (*Rumex acetosella L*) weeds in potatoes (*Solanum tuberosum L*) in Timboroa, Kenya. PhD Thesis, Egerton University, Njoro, Kenya

Low soil pH and infertility exacerbated by continuous cultivation without adequate replenishment of mined nutrients, coupled with total harvest of crop residue as livestock feeds, have lead to the spread of weeds in the North Rift. This has resulted in low potato yields average 7t as opposed to the potential of 30 t ha-1 or more. A focus farm survey, four field experiments and a green house experiment were undertaken at Timboroa from long rains 2002 to short rains 2004 to determine the influence of households and farm characteristics on soil fertility, weed types and their distribution, to screen and identify suitable legumes for growing in the region for use as green manure/smother crops in the control of weeds with special emphasis of sheep sorrel weed. In the screen experiment, lupine (*Lupinus albus l.*) and purple vetch (*vicia benghalensis* L.) gave significantly ($p<0.5$) higher ground cover and biomass than other legumes and were and were identified as the best for the region. Soil incorporation for lupine and garden pea (*Pisum sativam*) significantly ($P<0.05$) reduced sheep sorrel weed biomass by 18.0% and 9 respectively while application of 120 kg N/ha together with in cooperation of lupine reduced sheep sorrel weed density equivalent to hand weeding twice. Potato yields increased with N application only up to 60 kg N/ha but continued increasing in limed plots suggesting availability of more nutrients such as P and Ca with reduced soil acidity. The lack of significant potato yield increase beyond 60 kg N/ha when only N was applied was attributed to more potato vegetative growth at the expense of tuber production. Liming alone significantly ($P < 0.05$) reduced sheep sorrel weed density established that wild radish (*Rhaphanus rahanistrum L*) weed density and biomass increased with liming, suggesting that the weed should not be allowed to form seed if lime was to be adopted as a strategy for controlling sheep sorrel weed.

Lelei, D. K. (2009). Effects of soil fertility management practices on soil aggregation, carbon, and nitrogen dynamics in a long-term experiment at Kabete. Msc. Thesis, University of Nairobi, Kenya

Poor resource farmers cultivate steep slopes without soil conservation measures and apply insufficient plant nutrients thus degrading the soils. Integrated soil fertility management using organic and inorganic sources of nutrients is one of the approaches being advocated to farmers as a way of improving soil health and increasing production. This study was conducted to determine the effects of long-term use of inorganic fertilizer (NPK); inorganic fertilizer (NPK) with manure (F+M); inorganic fertilizer (NPK) with residue (F+R); residue and manure application on soil aggregates, organic carbon and nitrogen and macro fauna in a humic Nitisol soil under annual maize-bean crop rotation. Macro fauna (soil invertebrates) and soil samples were collected from the 31 year- old long-term experiment and assessed for stable aggregate size distribution, total soil organic C and N contents. The diversity, abundance and biomass of soil macro fauna (termites and earthworms) were also determined. The results of the study showed a significant increase in lafge ($p=0.01$) and small macro-aggregates ($p=0.002$) in the 0-15cm and 15-30cm depths under inorganic fertilizer (NPK) combined with manure (F+M) treatment. Also, significant increase ($p=0.03$) in mean weight diameter (MWD) of soil aggregates, soil organic carbon in small macro-aggregates ($p=0.005$) an micro-aggregates ($p=0.044$) in soil that received inorganic fertilizer (NPK) with manure (F+M) compared to control. IN terms of biodiversity, use of inorganic fertilizer (NPK) and inorganic

fertilizer (NPK) combined with manure led to increase in earthworm biomass which was positively correlated with large macro-aggregates (r =0.397, p=0.017), silt and clay (r=0.385,p=0.020), C in small macro-aggregates (r=0.474,p=0.003) and micro-aggregates (r=0.493,p=0.002). Long-term use of combined inorganic fertilizer (NPK) with manure improved the stability of the macro-aggregates and increased mean weight diameter (MWD) in both 0-15 cm and 15-30cm compared to all other treatments. Thus integration of fertilizers and animal manures would result in build up of soil organic matter in the long-term, thus contributing to C sequestration.

Marenya P. P. and Barrett C. B. (2009) state-conditional fertilizer yield response on Western Kenyan farms. American Journal of Agricultural Economics 91(4) (November 2009): 991–1006

Fertilizer interventions have attained prominence in rural poverty reduction programs in Africa. Using data from maize plots operated by small farmers in western Kenya, we find a von Liebig-type relationship between soil organic matter (SOM) and maize yield response to nitrogen application. Low SOM commonly limits the yield response to mineral fertilizer application. Although fertilizer is, on average, profitable in our sample, on roughly one-third of the plots degraded soils limit the marginalproductivity of fertilizer such that it becomes unprofitable at prevailing prices. Moreover, because poorer farmers most commonly cultivate soils deficient in SOM, fertilizer interventions might be less pro-poor than is widely assumed and may instead reinforce ex ante income inequality.

Mugwe, J. N., Mugendi, D. N., Kungu J. and Mucheru-Muna, M. (2009). Maize yields response to application of organic and inorganic input under on- station and on -farm experiments in central Kenya. *Experimental Agriculture, Cambridge University*, Vol. 45, pp.47-59

This study investigated the feasibility of using sole organic or a combination of organic with inorganic fertilizer to improve maize production in on-station and on farm experiments in central Kenyan. The on station experiment combined application of Calliandra (*Calliandra calothyrus*), Leucaena (*Leucaena trichandria*) and Tithonia (*Tithonia diversifolia*) at 30 kg N/ha plus inorganic fertilizer (30 kg N/ha) consistently gave significantly higher maize grain yields than the recommended rate of inorganic fertilizer (60 kg N/ha) sole application of Calliandra, Leucaena and Tithonia also increased maize yields more than the recommended rate of inorganic fertilizer in the nonfarm experiment. These organic resources could therefore be used to supplement inorganic fertilizer as a whole or in part. There was yield between on-station and on-farm trials with on station yields having on average 65% greater yields than the on-farm yields. There is therefore potential for increasing yields at the farm by closing the yield gap.

Mugwe, J. N., Mugendi, D. N., Mucheru-muna, M., Odee, D. and Mairura, F. (2009). Effect of selected organic materials and inorganic fertilizer on the soil fertility of a humic Nitisol in the central highlands of Kenya. *British society of soil science* Vol. 25:434-440

The effect of soil fertility of applying particular organic resource to humic Nitisols in central highlands of Kenya was studied. The organic resources (*Calliandra calothyrus, leucaena trichandria Tithonia diversifolia Mucuna pruriens crotalaria ochroleuca* and cattle manure) were either applied solely or along with organic fertilizer in a cropping trial using maize as the experimental crop. After 4 years of continuous cultivation and manuring, soil fertility varied among treatments. Cattle manure proved to be the most effective and improve soil fertility by increasing pH, cations (Ca, K and Mg) and C. Calliandra, Leucaena, Tithonia and herbaceous legumes generally reduced soil pH, C and N but increased Ca, K, Mg. Cattle manure is therefore an important resource of maintaining soil organic matter (SOM) in the area and in other similar areas with arable livestock systems. Reduction of soil C and N by the high quality organic materials suggest that their role in maintaining SOM in the long term is limited in this area. A sound nutrient management system should strive to make a balance between maximizing crop production and sustaining soil quality.

Muriuki J. P. (2009). An evaluation of organic and inorganic inputs for soil nutrient replenishment in Mukuuni and Murugi, Central Kenya. Msc. Thesis; Kenyatta University, Nairobi, Kenya

Declining land productivity due to declining soil fertility has led to decrease in contribution of agricultural sector to Gross Domestic Product (GDP) of nations in sub-Saharan Africa. Due to the high cost and poor supplies, most farmers are not able to afford sufficient amounts of mineral fertilizers to replenish soil fertility. Cost effective soil nutrient replenishment technologies involving organic and inorganic inputs have been developed and tested. However, few studies have been carried out to evaluate these inputs under farmer management. This study, designed to evaluate the performance of these inputs under farmer management, was carried out in two sites, Mukuuni and Murugi in Meru south district of central Kenya. The two sites were selected because research managed trial sites had been set up in the study area in 2003 by scientist from Kenyatta University, KARI and

KEFRI with the various combinations of organic and inorganic inputs for soil fertility improvement. Farmers were exposed to the technologies through field days and village training workshops before the commencement of the study. The study involved 132 farmers, 73 Mukuuni and 59 in Murugi. Farmers tested pure organic inputs (Tithonia, manure and calliandra), Mineral fertilizers, and combination of Organic and inorganic inputs. Costs and benefits from the selected technologies were evaluated for two seasons; short rains (SR) 2005 and long rains (LR) 2006. Net benefits, benefit cost ratio and returns to labour were used as the main economic tools in data analysis. Comparison of farmers' perception and choices of technologies with economic cost and benefits was done through correlation analysis. All biophysical data was subjected to analysis of variance (ANOVA) and means separated at $p<0.05$; while significance in correlation was done using spearman's correlation coefficient at $p<0.05$. Labour cost comprised over 60% of the total variable cost when organic inputs were used solely or in combination with mineral fertilizers. Tithonia plus manure plus mineral fertilizer had the highest mean total variable cost of KSh. 24,819/ha and KSh. 26,631/ha in Mukuuni and Murugi, respectively, over the two seasons. Returns to labour were highest for mineral fertilizer in both study sites (5.1 and 4.1 in Mukuuni and Murugi, respectively). Tithonia plus manure plus mineral fertilizer had the lowest mean return to labour of 2.9 and 2.8 in Mukuuni and Murugi, respectively. Tithonia plus mineral fertilizer had the highest mean net benefits of KSh. 29,464/ha in Mukuuni and KSh.23650/ha in Murugi. Males differed with females significantly in their perception of some input combinations on perceived costs and benefits. These differences were attributed to differences in access and control of resources at the household level. A positive relationship was found between farmers ranking of technologies based on perceived costs and benefits and ranking based on the calculated costs and benefits. This indicates that economic costs and benefits is a tool that can be used to predict how farmers are likely to rate technologies introduced to them. It also implies that farmers ranking can be used to set priorities in the promotion of these technologies to other farmers. Similarly, ranks of technologies based on calculated economic returns. This implies that economic returns can be used to predict technologies that are more likely to be preferred by farmers. Majority of the farmers (71% in Mukuuni and 54.1% in Murugi) chose technologies combining organic and inorganic inputs for further trial. Manure and Tithonia were the preferred organic inputs mainly due to local availability and multiple benefits perceived, though labour requirements were high.

Muthoni R.G. (2009). Groundnut growth and yield response to fertilizer application. Msc Thesis university of Nairobi

Groundnut is an important food, feed and cash crop in Eastern Africa but in Kenya it has a yield gap of 2.5 t/ha and this is attributed to low soil fertility, diseases, poor seed quality and poor husbandry practices. Soil exhaustion being ranked as the major groundnut production constraint in Sub Saharan Africa and particularly in Western Kenya it was necessary to evaluate the response of growing high yielding and disease tolerant (groundnut rosette virus disease) varieties with the use of various fertilizer types and rates. This would ensure increased productivity for the smallholder farmers who predominantly produce the crop at a profitable production regime. On-station experiments (fertilizer types and rates) were conducted in two sites, which included Kenya' Agricultural Research Institute (KARl) site at Alupe in Busia district and Ministry of Agriculture's Agricultural Training Centre (ATC) site at Siaya district during the long rain (March - July 2007). The on-farm data collection was done through a survey conducted on the farmer's fields at Siaya and Busia districts. The objectives of fertilizer types experiment were (i) to determine the effect of basal application of nitrogen and phosphorous (20 kg/ha) from different fertilizer types on improved groundnut varieties growth and yield (ii) to evaluate varietal yield performance across two major groundnut regions in Western Kenya and (iii) to evaluate the effect of fertilizer types on groundnut rosette viral disease. The fertilizer types treatments included calcium ammonium nitrate (CAN), di-ammoniurn phosphate (DAP), single super phosphate (SSP), triple super phosphate (TSP), Mavuno, Farmyard Manure and a control (without fertilizer). The objectives of fertilizer rates experiment were (i) to evaluate the response of improved groundnut growth and yield to varying Mavuno fertilizer rates, (ii) evaluate varietal performance across two major groundnut growing regions and (iii) evaluate the effect of Mavuno fertilizer rates on groundnut rosette virus disease. The fertilizer used was Mavuno selected on the basis of having all the recommended nutrients for groundnut growth and since it is locally blend at Athi-River Mining Company likely to be available to farmers at the time of planting. The Mavuno fertilizer rate experiment had five treatments levels which were 0 kg/ha, 25 kg/ha , 50 kg/ha , 100 kg/ha , and 200 kg/ha. The improved groundnut varieties included two Spanish types (small seeded lCG 12991 and medium seeded lCGV SM 99568) and Virginia type (large seeded lCGV SM 90704). The experimental design was a randomized complete block design laid out as a split plot with three replications, varieties was the main plot and fertilizer types / rates was the sub plots. Data collected included days to emergence, days to flowering, and days to maturity; plant height at maturity, number of leaves per plant at flowering, number of branches per plant at maturity, dry matter per plant at flowering, leaf area index per plant at flowering, number of nodules per plant at flowering, groundnut rosette virus disease incidence, number of pods per plant at maturity, number of pops at maturity, one hundred seed weight and kernel yield. An on-farm survey was carried out in September 2007 at Siaya District (Yala Division) and Busia District (Matayos Division) with an objective of evaluating the extent of

fertilizer use on ground nut farmers' fields and its effect on groundnut yield. The survey targeted two categories of farmers i.e. contracted farmers by Leldet Seed Company and non-contracted farmers. Ninety contracted farmers were interviewed and out of these only thirty one had mature groundnuts in their field for data collection while fifty non contracted farmers were interviewed with only forty seven farmers having mature groundnuts for data collection. The on-farm data collection was achieved by use of a structured questionnaire and by collecting plant samples from the groundnut fields. The crop sampling was done by randomly uprooting 100 plants from mature groundnut fields and the various parameters recorded i.e. spacing, pod fresh mass, number of plants per every three meters in three quadrants to acquire germination. percentage, no of pops and rosette incidence scoring. The pod samples were then sun dried for 10 days to achieve 10% moisture content and they were shelled to record the kernel weight (translated to yield per ha) and 100 seed mass. All the data obtained from the on-station experiments was subjected to analysis of variance (ANOV A) using Genstat statistical package and means separated using Least Significant Difference (LSD) at 5% probability level. The on station experiments results indicated that fertilizer types, site and varieties significantly affected groundnut growth and yield while the fertilizer rates, site and variety significantly affected groundnut growth but had no effect on the yield. Site and variety significantly influenced days to flowering and maturity with Alupe resulting in early flowering and maturity in comparison to Siaya. In terms of plant growth and yield Siaya performed better in comparison to Alupe. SSP, TSP, FYM and Mavuno fertilizer treatments resulted in the tallest plant height, highest number of branches, highest number of leaves, highest number of nodules, highest leaf area index, highest hundred seed mass and the highest yield in comparison to the control treatment,. At Alupe 100 kg halresulted in the highest plant growth while at Siaya 25 kg/ha , 50 kg/ha and 200 kg/ha fertilizer rates effects were comparable and they resulted in the highest plant growth and yield. ICGV SM 90704 had the lowest disease incidence, highest plant growth and the best yield followed closely by ICG 12991 and lowest was observed from ICGV SM 99568 for all the treatments and sites. The results should be adopted with a caution that the experiment was conducted in only one season and a repeat of the same in other seasons may result to different observations. The survey results showed that most farmers preferred using fertilizer on cash crops or other food crops i.e. maize since the return on fertilizer cost from groundnut was low. Groundnut yield from farmers was very low i.e. an average of 700 kg/ha as compared to Kenya's adopted yield of 3 t/ha reasons being that farmers have poor access to improved seed, highly priced inputs and poor market structure. It was observed that ICGV SM 90704 was a superior variety compared to other varieties that farmers grew because it resulted in the highest kernel yield as compared to other varieties and it had the lowest rosette incidence.

Ngome F. A. (2009). Effects of organic and inorganic phosphorus sources on nitrogen fixation by field grown common bean on an Alfisol and an Ultisol in Kakamega, Kenya. International Journal of Biological and Chemical Sciences 3(2): 168-177; ISSN 1991-8631; Available online at http://www.ajol.info

A field study was carried out in 2005 in Kakamega to quantify the effects of organic and inorganic sources of phosphorus on nitrogen fixation of common bean by the ^{15}N Natural Abundance method. Field experiments were conducted on two different soil groups (Alfisol and Ultisol) in 20 farmers' fields. Six treatments: control with no input, inorganic phosphorus, inorganic nitrogen, inorganic phosphorus plus nitrogen, seed priming with phosphorus and farmyard manure. These treatments were replicated three times in a randomized complete block design. Maize was used as a non-fixing reference plant for ^{15}N analysis. The results showed that the total nitrogen accumulation by common bean ranged from 5 to 20 kg/ha in the Alfisol and from 8 to 26 kg/ha in the Ultisol and treatments in the Ultisol accumulated 20% more biomass compared to treatments in the Alfisol. Further, the rate of nitrogen fixation was 50% to 54% Ndfa for the inorganic phosphorus sources and 40% to 51% Ndfa for the organic phosphorus source. Seed priming with phosphorus, inorganic nitrogen and the control obtained less than 40% Ndfa for nitrogen fixation. These results illustrate that phosphorus sources could differentially enhance nitrogen fixation by common bean in different soil groups in smallholder farming systems in Kakamega.

Njeru P. N. M., Lekasi J. K., Muthamia Z. K., Njihia S., Nadhkha T., Kaiyare J., Kungu N., Thairu P. (2009). The effects of integrated pest and soil fertility management strategies on maize crop yields in central Kenya. Annual report; Kenya Agricultural Research Institute (KARI)-Muguga pp. 73-76

One of the advantages of mixed farming is the opportunity to convert by-products and wastes from one activity into inputs for another. In an intensive mixed farming system, crop residues are frequently used as livestock feed while the manure and urine produced are used as fertilizers and soil improvers to produce crops and fodder. Zero grazing has become a popular enterprise in central Kenya to small and fragmented pieces of land, consequently, high fodder demand to feed the zero grazing units. Calliandra calothyrsus, a leguminous fodder tree is a species that can be grown on-farm, used as a barrier species contour hedges, and substitute for purchased dairy meal to

improve the basal fodder diet of Napier (*Pennisetum purpureum*). An on-station experiment was established in short rains of the year 2009 to investigate the potential of Calliandra calothyrsus and Leucaena diversifolia pruning as soil fertility improvement strategy. The experiment was set in three blocks under Calliandra calothyrsus where the treatments were replicated three times in a randomized complete block design (RCBD). Maize biomass yield was highest in fields under application of manure (5 t/ha) and manure (5 t/ha) + Calliandra pruning compared to the other applications. The lowest maize biomass yield was recorded in the fields under the fertilizer (80 kg N/ha) application. There is no concrete conclusion that can be reported from this project since this is its first season and maize grain yield data has not been collected for comparison with biomass yield. Clear recommendations and conclusions will be reported in the next annual report 2010.

Nyongesa H.W., Obura R.K., Kitur B. K., Ouma J. P. and Nakhone L. N. (2009). Effect of organic and inorganic nutrient sources on maize yield and yield components in Nandi District, Rift Valley Province, Kenya. *Africa crop Society* Vol.9.pp.55-61.

Some by-products such as pyrethrum marc (pymarc), a product of pyrethrum (*Chrysanthenum cinerariafolium*) is known to have a relatively high nutrient concentration. However, little is known about its potential as nutrient sources for soil fertility and crop yield improvement. In this study, an attempt has been made to compare the effectiveness of pymac and Tithonia (*Tithonia diversifolia*) in improving maize yields in two years of experimental trials. The experiments were conducted at Kosirai, Nandi district, Kenya in 2004 and 2005 during the long rains. Treatments comprised of pymarc (T=0, T2=8 t/ha, T3=26 kg/ha P and T4 = 4tha^{-1} +13 kg/ha P). Hybrid maize (H614) was the cultivar used in the years' trials. Maize stover and grain yields were significantly increased when either Tithonia or pyrmarc was applied as compared to control. As expected, the water soluble P source (T3) exhibited superior yields as compared to both T1and T2 (for Tithonia and pymac). Grain and stover yield for T4 (2.5 t/ha Tithonia + 13 kg/ha P were even more superior to soluble P (T3). This observation was prominently expressed with pymarc where 4 t/ha + 13 kg/ha P was more superior to T3 There was a synergistic effect of pymarc +P integration which could not be attributed to nutritional component. The indirect value may be as a result of its chelation of P fixed as Fe/Al-oxide and/or hydroxides which has been documented in soils with low pH. The chelates may also complex Al^{3+} reducing its toxicity and hence, improved yield with integrated products. The results show that less bulky none-traditional agro-industrial wastes products like pymarc may offer an alternative and effective source material for supply of plant nutrients on long term basis on mineralisation, which can increase nutrients, particularly P in P deficient soils.

Opala, P. A. (2009). Effect of organic and inorganic phosphorus sources on selected soil chemical properties and maize (*Zea mays*) yields in acid soils of Western Kenya. PhD Thesis; Moi University, Eldoret, Kenya

Phosphorous deficiencies and aluminium toxicities which often occur simultaneously in acid soils in western Kenya can be mitigated by the use of P fertilizers and lime. This strategy has, however, not been effective among the smallholder farmers due to its high cost. Other cost-effective strategies therefore need to be explored. This study tested the effect of two organic materials (OMs) of varying chemical characteristics i.e. farmyard manure (FYM) and Tithonia (*Tithonia diversifolia*) on maize yields when applied alone or in combination with three inorganic P sources i.e. triple superphosphate (TSP), Minjingu phosphate rock (MPR) and Busumbu phosphate rock (BPR) at Kakamega (one season) and Bukura (three consecutive seasons). The effects of these P sources on selected soil chemical properties were monitored in laboratory incubation study, greenhouse pot study and field experiment. FYM, Tithonia and MPR increased soil pH and reduced the exchangeable Al in short term. TSP was the most effective treatment in increasing the Olsen P in the soils while BPR was the least effective. There was no evidence of synergism in terms of increased Olsen P when organic and inorganic P sources were combined. None of the treatments significantly affected P sorption by soils at Kakamega. However at Bukura, lime applied in combination with TSP was the most effective treatment in decreasing P sorption followed by FYM applied in combination with TSP. Inorganic P fractions were significantly affected by the treatments but the organic fractions were not. Overcoming P deficiency without elimination/reduction of exchangeable Al did not increase P uptake by maize. Similarly reduction of exchangeable Al without a corresponding application of P failed to increase the P uptake. Once the effect of Al toxicity on plant growth was reduced by application of the OMs or lime, the maize grain yield and P uptake increased with increasing available soil P. Tithonia when applied alone or in combination with inorganic P sources was more effective in increasing maize yields than other treatments at similar P application rates because of its stronger ability to reduce exchangeable Al. Although FYM was more effective than Tithonia in increasing the available soil P, it consistently gave lower maize yields than Tithonia, suggesting that the ability of OM to lower the exchangeable Al in soils is more important in increasing maize yields than its ability to increase soil P availability. MPR was superior to TSP when both were applied with urea at Bukura in all the three seasons because MPR had a depressing effect on exchangeable Al. Despite giving high maize yields, the Tithonia treatments had a very high labour cost. This led to a low benefit cost ratio (BCR) thus casting doubts on the potential for adoption of the Tithonia biomass technology in western Kenya. FYM when applied alone and at 20 kg P/ha was the only treatment that exceeded a BCR of 1 and therefore the most likely

of the tested technologies to be adopted. There is need, therefore, to direct more effort in equipping the farmers in the study area, with knowledge and skills of improved FYM management so as to enhance both its quality and quantity on their farms.

Shisanya, C. A., Mucheru, M. W., Mugendi, D. N. and Kungu, J. B. (2009). Effects of organic nutrient sources on soil mineral nitrogen and maize yields in central Kenya. *Soil and tillage research Elsevier* Vol. 103:239-246

High population pressure in the central highlands of Kenya has led to continuous cultivation of land with minimal additional inputs leading to soil nutrient depletion. Research work has reported positive results from use of manure and biomass from Tithonia Calliandra, Mucuna and Crotalaria for soil fertility replenishment. An experimental field was randomised complete block design with 14 treatments replicated three times. At the beginning and at the end of the experiment soil was sampled at 0-15 cm depth and analysed three times and analysed for pH Ca, Mg, C,N, and P end of the 2000/2001 short rains (SR) season and 2001 long rains (LR) season soil samples were taken at 0-30, 30-100 cm for nitrate and ammonium analysis. All the treatments received an equivalent of 60kg N/ha except herbaceous legume and control treatment received no inputs. Results indicate soil fertility increased slightly in all treatments (except control) over the 2- year study period. Average maize grain yields across the treatments was 1.1, 5.4, 3.5 and 4 mg/ha during the 2000 LR, 2000/2001 SR 2001 and 2000/2001 SR respectively. The reduced yield in 2000 LR and 2001 LR are attributed to poor rainfall distribution during the two seasons on average Tithonia with half recommended rate of inorganic fertilizer recorded the highest (4.8 Mg/ha) maize yield followed by sole Tithonia (4.7 Mg/ha). Highest average concentration (144.8 and 115.5 kg/ha of mineral N was recorded at the 30-100 cm soil depth recorded 2000/2001 SR and LR respectively. The lowest average concentration (52.3 kg/ha) the residual mineral N in the 100- 150 cm soil depth doubled at the end of the LR 2001 compared to what was present and the end of the SR 2000/2001 season in all treatments. This shows that there was present and the end of the SR 2000/2001 season in all treatments. This shows that there is substantial amount of mineral N that is being leached below the rooting maize in this region.

Kosgei, A. J. (2008). Use of phosphorus and pymarc in management of Beanfly (*Ophiommyia* species) on common bean varieties (*Phaseous vulgaris* L.). MSc. Thesis, Egerton University, Njoro, Kenya, 14-96

Common bean (*Phaseolus vulgaris* L.) is the most important legume crop grown in Kenya by small scale farmers providing a cheap source of protein. Despite its importance, current annual bean production is below potential yield due to climatic factors, disease, poor farming practices and insect pests. Beanfly (*ophiomyia* species) is a major pest that can cause up to 100% yield losses especially during dry seasons. The damage is also severe on late planted beans and infertile soils without insecticidal application. Although several management practices have been recommended and a few adopted, most of them have various setbacks. Thus there was need to develop sustainable management practices against beanfly damage. Exploiting the principle of cultural control and use of pymarc (pyrethrum by - product) as a natural insecticide was one of the feasible management practices that were investigated. Two field experiments were conducted for two seasons between October 2004 and January 2006 at Kenya Agricultural Research Institute (KARI) -Njoro with an objective of improving the yield of beans through effective management of beanfly. In the first experiment, phosphorus at three levels: 0, 40, and 80 P_2O_5 Kg/ha, pymarc at the rate of 200 kg/ha and gaucho 350 FS at the rate of 8 ml/kg of beans were evaluated on beanfly population, damage and yield of beans using two bean varieties (Red haricot and Rosecoco). The experimental design was Randomised Complete Block Design (RCBD) in split - Split plot arrangement replicated three times. In experiment two, pymarc dust was evaluated at five rates (50, 100, 150, 200 and 250 kg/ha) and gaucho 350 FS at a rate of 8ml/kg of beans on Rosecoco bean variety. The experimental design was RCBD replicated three times. The results indicated pymarc and gaucho 350 FS treated plots were not significantly different ($P<0.05$). Pymarc enhanced yields during the long rains compared to short rains seasons. Phosphorus application reduced bean fly density and percentage plant mortality compared to control although it did not affect yield significantly. Red haricot was resistant to beanfly with lower plant mortality and higher yields compared to rose coco. Pymarc applications at different rates were not significantly different in controlling beanfly population, damage, percentage plant mortality and grain yield as gaucho 350FS. Thus, application of pymarc has a potential to reduce bean fly infestation and damage and improve bean yields.

Maobe, S. N. (2008). Maize response to Mucuna green manure: Nitrogen effects, maize growth, nitrogen uptake and grain yield. PhD Thesis, University of Nairobi, Kenya

On-farm research and greenhouse experiments were carried out to determine effects of Mucuna green manure application rate on maize growth, nitrogen uptake and grain yield. Mucuna rates evaluated were 0, 30, 60, 120, 240 and 480 kg N/ha corresponding to green manure quantities of 0, 1.5, 3, 5, 12 and 24 tons dry matter per hectare; and inorganic fertilizer, urea at levels of 0, 30, 60 and 120 Kg N/ha. The effects of soil moisture content were: field capacity (-0.01 MPa), intermediate (-0.75 MPa), and wilting point (-1.5 MPa). The experimental design was randomized complete block with four and three replications for field and greenhouse experiments, respectively.

Field treatments were evaluated for 5 seasons. Residual N effects were evaluated for two seasons. Mucuna N only increased maize yield when applied at the rate of 120 kg N/ha. Maize grain yield was comparable at 30, 60 and 120 kg N/ha rates of Mucuna and inorganic fertilizer N. There was no residual effect of N application irrespective of quantity or source. Mucuna decomposition was bi-phasic with an initial rapid phase with half-life of one week followed by a slower phase. Peak available N was at 2 weeks after application. Soil available N was significantly high at Mucuna application rate of 240 kg/N ha but comparable at lower rates than 120 kg N/ha. The greenhouse experiment showed that soil water content significantly influenced the quantity of biomass decomposed; soil available N, plant N uptake and maize growth but biomass rates did not. The economic Mucuna N application rate was 120 kg N/ha and 30 Kg N/ha fertilizer N. Combination of low rates of Mucuna green manure and inorganic fertilizer N may be applied judiciously to improve maize yield.

Mucheru-Muna, M. W. (2008). Exploring nitrogen replenishment options for improving soil productivity in sites with varied soil fertility status in the central highlands of Kenya. PhD thesis, Kenyatta University, Nairobi, Kenya.

Declining land productivity is a major problem facing smallholder farmers in Kenya today. This decline is caused by low soil fertility caused by continuous cultivation without adequate addition of external nutrient. Two experiments were established during the 2004 short rains in two distinct agro-ecological areas (Mucwa and Mukuuni are sub humid and Machang'a is semiarid) in the central highlands of Kenya with an aim of enhancing soil productivity. The 1st experiment evaluated biomass transfer systems in Machang'a and Mucwa (two sites, one with fertile soils and other with less fertile soils). Effects of organic sources (Tithonia, lantana, mucuna, calliandra and manure) and combinations with mineral N fertilizer on maize yield, soil chemical properties, economics returns, soil mineral N, N uptake and fertilizer N equivalencies were determined. The 2nd experiment was an intercrop established in Mukuuni and Machang'a to determine the contribution of legumes (bean, cowpea and groundnut), plant spacing (conventional and MBILI) and P fertilizer on overall productivity of the intercropping system. Data was subjected to ANOVA and means separated using LSD ($p<0.05$). Sole manure, sole Tithonia and sole calliandra generally recorded the highest maize grain yields in Machang'a, Mucwa poor and Mucwa good sires, respectively. Generally the maize grain yields were lower in treatments with fertilizer alone compared to treatments with organics across the three sites in the four seasons due to the poorly distributed rainfall. The maize grain yields were higher in the sole organics compared to the integrations (organic + mineral fertilizer) in Mucwa good and poor sites, however in Machang'a the sole organic had higher yields during the short rain seasons while the integrations recorded higher yields during the long rain seasons. There was a general decline in soil chemical properties over the seasons, even with the seasonal input application in all sites. Manure was superior in terms of improving soil chemical properties, for instance, it recorded an increase in soil pH, magnesium, potassium, calcium and Nitrogen in all sites. The economic returns in all sites were low, with negative net benefits, and benefit cost ratio (BCR), which were in most cases less than one. The bulk of mineral-N found in the soil was in the form of nitrate-N in all sites, however in Machang'a the amount of ammonium-N was relatively high due to the drier condition of the soils in the site. In season when rainfall was distributed, the N uptake was relatively high with most of the mineral N being taken up during 0-12 weeks after planting (WAP). High fertilizer N equivalencies of manure, calliandra, Tithonia and mucuna were reported in all sites, suggesting that the organics have beneficial roles than the addition of soil N. In the intercrop experiment, neither legumes nor maize responded to P application in Mukuuni while legume yield was increased by an average of 40% and maize yields more than doubled with P application in Machang'a. In both sites, legume yields tended to be higher when planted at the conventional intercrop, irrespective of legume species or P application; though not consistently significant in all seasons. Maize yields were significantly higher with conventional spacing when intercropped with groundnut, while in MBILI spacing; highest yields were observed for maize intercropped with beans. Generally net benefits, BCR and return to labour were highest when P fertilizer was not applied in both the MBILI and conventional Intercrops in Machang'a and Mukuuni. In Machang'a there were no economic advantages of MBILI over the conventional intercrop, while in Mukuuni MBILI intercrop had more economic benefits than the conventional intercrop especially in the maize/bean intercrop. The N equivalencies were very low both in the MBILI and conventional intercrops, actually in most cases the N equivalencies were negative. The role of organics was well displayed in the study area, which is prone to poor distributed rainfall; therefore further research should be carried out to explore issues of soil moisture conservation.

Ruto E. J. (2008). Effectiveness of ''PREP-PAC'' on nutrient uptake and yields of seven maize-legume intercrops in ferralsol of western Kenya. MSc. Thesis, Moi University, Eldoret, Kenya

Sub-Saharan Africa (SSA), Kenya included, continues to experience the constraint of food insecurity which largely contributes to overall poverty and poor health of rural population. Western Kenya region contains 40% of the country's population only 15% of the country's land area, with population densities ranging from 500 to 1200 persons per km^2. This has resulted to reduced land sizes to about 0.2 ha per household and continuous cropping of land with no addition of fertilizers. Thus, high rates of soil nutrient depletion (especially N and P), reduced maize yields of less than 1.0 t/ha and mainly intercropped common bean grain yields of 200-500 kg/ha. Towards

achievement of food security, 'PREP-PAC', an integrated nutrient management package was developed as a simple, effective and affordable package that can be adopted by resource poor farmers, especially in western Kenya. PREP-PAC contains 2 kg Minjingu phosphate rock, 0.2 kg Urea, 120 g legume seed, Rhizobium seed inoculant, seed adhesive and lime pellets, which are intended to ameliorate low fertility in 25 m^2 area. PREP-PAC was tested in this study, for its diversity on intercrops on a small scale farm in Nyabeda, Siaya District western Kenya for three consecutive cropping seasons. The soil at the farm was characterized by low pH of 5.35, available P was below the critical value of 10 mg P/kg, having the value of 1.12 mgP/kg and generally low-medium exchangeable cations. The low C:N ratio of 6:1 suggested low organic matter in this soil. The soil class was sandy clay loam and classified as Ferralsol (FAO classification). MBILI (one row of cereal crop alternating with two rows of legume crop) system involving seven legumes, intercropped with maize (Zea mays) was used. The legumes included Soya beans (Glycine max), Bambara nuts (*Voandzeia subterranea*), cowpeas (Vigna Unguiculata) groundnut (*Arachis hypogea*), yellow grams (*Phaseolus aureus*) and Dolichos bean (*Lablab purpureus*). The treatments, with or without PREP-PAC additions, were arranged in a 7*2 factorial, in a randomized complete block design and each treatment replicated four times. The results showed significant increases in soil pH and available P ($p<0.01$) due to PREP-PAC application under MBILI intercropping system, seasons and the interactions among the 3 factors. The PREP-PAC under MBILI intercrops and their interaction with seasons gave significant ($p<0.01$) increase in maize grain yields, with a maximum mean increase in maize grain yield of 2002 kg/ha above the control recorded in 2004 LR. Legume grain yields, ranging from 52 to 866 kg/ha varied with the cropping season, Maize-legume intercrops legume species and PREP-PAC application. The use of PREP-PAC under MBILI system generally increased the physiological P use efficiency (PPUE) in maize and legumes. The overall mean PPUE Was highest in 2003 SR with 26.5 and 6.2 kg increases in grain/kg P uptake for maize and legumes, respectively. Economically, the net change in profit was significantly ($p<0.01$) increased due to PREP-PAC application under MBILI intercropping system, whereby, maize-yellow grams intercrop gave the highest value of 89,706.17 Kshs/ha/yr and maize-bambara nuts the least with 25,236.90 Ksh/ha/yr, above the control. therefore it was concluded that PREP-PAC package under the MBILI intercropping system, can economically be adopted by the resource poor farms in Western Kenya to Improve soil fertility, food security and alleviate poverty. The poorly distributed rainfall affected the physiological P nutrient use efficiencies, maize and legume grain yields in 2004 LR/SR. The observed increase in maize yields, when it was intercropped with the legume crops, yellow grams, cowpeas and beans is thought to be due to increased solubilisation of MPR.

Willis, A. (2008). Performance of watermelon (*Citrullus lanatus* [Thunb] Mansf. & Nakai) cv. Crimcon sweet under integrated nutrient management. Msc. Thesis Egerton University

Low soil fertility in small-hold farms due to depletion of nutrients, mainly soil N and organic matter is one of the major factors contributing to the declining yield of watermelon in Kenya. A focused study was therefore carried out at the Kenya Agricultural Research Institute regional research centre in the semi-arid Marigat of Kenya to investigate the effect of different rates of cattle manure. Tithonia diversifolia, manure, CAN fertilizer and their combinations on performance of watermelon (*Citrullus lanatus* [Thanb] Mansf, & Nakai) cultivar `Crimson Sweet'. Cattle manure was applied at the rates of 0 kg (0 t/ha), 2.4 kg (3 t/ha), 4.8 kg (6 t/ha) and 7.2 kg (9 t/ha), Tithonia diversifolia manure at the rates of 0 kg (0 t/kg ha) 1.2 kg (1.5 t/ha), 2.4 kg (3 t/ha) and 3.6 kg (4.5 t/ha), and CAN fertilizer at the rates of 0 kg (0 kg/ha), 280 g (135 kg/ha), 560 g (270 kg/ha) and 840 g (405 kg/ha) per plot and in all the two and three-way combinations of all rates. The farmers' practice of applying only CAN at 135 Kg/ha was used as the control. The treatments were arranged in a factorial randomized complete block design. The study was conducted in two seasons, July to October 2006 and November 2006 to February 2007, and the data analyzed using SAS. Application of cattle manure, Tithonia manure and CAN, in all cases, either singly or in combinations resulted in significant increase in total and marketable yield, fruit numbers, and average fruit weight compared to the control. Fruit shape and fruit skin colour were not significantly influenced by the treatments. Total soluble solids (0 Brix), and rind (cortex) thickness were also not significantly influenced by the increase in application rates of the manures and CAN fertilizer. The manures and the fertilizer either singly or in combinations, promoted growth and development of the crop in terms of the leaf area index, leaf numbers, and vine length. However, branching (secondary vines) did not respond to treatments. From the studies it was observed that combination of 4.5 t/ha Tithonia manure + 6.0 t/ha cattle manure + 405 kg/ha CAN increased the marketable yield by 132.3 percent (21ton) in season I and 166 percent (34.9 ton) in season II. Therefore the application of organic manures and CAN to the Marigat soils are essential in increasing watermelon yield and can assist towards the achievement of sufficient and sustainable watermelon production.

Baaru, M., Mugendi, D., Bationo, A., Verchot, L., and Waceke, W. (2007). Soil microbial biomass carbon and nitrogen as influenced by organic and inorganic inputs at Kabete, Kenya. *In: Andre Bationo, Boaz Waswa, Job Kihara and Joseph Kimetu (Eds). Advances in integrated soil fertility management in Sub-Sahara Africa: Challenges and opportunities*; pp. 827-832

Soil microbial is the main driving force in the decomposition of organic materials and is frequently used as an early indicator of changes in soil properties resulting from soil management and environment stresses in agricultural ecosystems. This study was designed to assess the effects of organic and inorganic inputs on soil microbial biomass carbon and nitrogen overtime at Kabete, Kenya. Tithonia diversifolia, Cassia *spectabilis*, Calliandra calothyrsus were applied as inorganic resources, and Urea as inorganic source. Soil was sampled at 0-10 cm depth before incorporating the inputs and every two months thereafter and at harvesting in a maize-cropping season. Soil microbial biomass carbon and nitrogen was determined by Fumigation Incubation (FI) method. The results indicated a general increase in soil microbial biomass carbon and nitrogen in the season with the control recording lower values than all the treatments. Microbial biomass carbon, nitrogen and carbon dioxide evolution was affected by both quality of the inputs added and the time of plant growth. Tithonia recorded relatively higher values of microbial biomass carbon, nitrogen and carbon evolution than all other treatments. A significant difference was recorded between the control and the originally treated soils at the of the season for microbial biomass nitrogen and carbon dioxide evolution. Both the microbial biomass C and N showed a significance difference ($P<=0.05$) in the different months of the seasons.

Gichangi, E. M., Karanja, N. K. and Wood, C. W. (2007). Managing Manure Heaps with Agro-Organic Wastes and Cover to Reduce Nitrogen Losses on Smallholder Farms. *Soil Science South Africa*, Springer pp: 611-618, 2007

Livestock manure is a valuable source of plant nutrients for crop production in Central Kenya highlands but its quality in terms of available nitrogen (N) is low due to considerable N losses through ammonia volatization. This study aimed at assessing the potential of agro-organic waste to reduce N losses from manure heaps during the storage period. Three organic amendments selected from laboratory simulation experiment were evaluated under farmers' conditions in Karura, Kiambu district for their ability to N losses from cattle manure heaps. The effect of polyethylene sheet covering of manure heaps on N retention was also determined. There were eight treatments that comprised three agro-organic amendments (maize stover, coffee pulp and sawdust) and the control. Agronomic effectiveness of the treated manure samples and N uptake by maize seedlings were evaluated in a glasshouse experiment. Total N content of manure amended with organic materials ranged from 1.26% to 1.85%. The N in manures with organic amendments at the start and at the end of storage was significantly different ($p\leq0.05$). Cumulative N loss ranged from 1.60 and 6.80 g/kg depending on the type of amendment. Nitrogen lost from non-amended manure was 2.74 g/kg with polyethylene cover and 6.80g/kg without polyethlene cover, which represented 19%and 46% of the initial N respectively. Maize growth improved significantly ($p\leq0.05$) with increasing rates of manure irrespective of the organic treatments except for manure amended with sawdust. Treatments that received the recommended rate of N at 100 kg/Nha had significantly higher ($p\leq0.05$) biomass of (21.55 g/plant) the control which produced only 2.78 g/plant. Nitrogen uptake increased with increasing rates of manure and was higher ($p\leq0.05$) with manure amended with coffee pulp. Covering manure heaps to reduce moisture loss was also beneficial in reducing N losses.

Kathuku A. N., Kimani S. K., Okalebo J. R., Othieno C. O. and Vanlauwe B. (2007). Integrated soil fertility management: Use of NUTMON to quantify Nutrient flows in farming systems in Central Kenya. *In: Andre Bationo, Boaz Waswa, Job Kihara and Joseph Kimetu (eds); Advances in integrated soil fertility management in Sub-Sahara Africa: Challenges and opportunities* pp.283-288 Book; Springer

A study based on Participatory Learning and Action Research (PLAR) to categorize soil fertility management was carried out in three districts of Central Kenya: Kirinyaga, Maragua and Kiambu. The PLAR classified farms according to their economic and soil fertility management status. In each district 20-30 farmers were selected who represented three hundred farmers. The selected farmers had discussions with the facilitators who grouped them into three categories according to their soil fertility management level: good (class 1), Average (class 2) and poor (class3). Three farmers in class 1 and 2 and four in class 3 were selected to represent the groups. Out of the selected representative in each group, two were selected for Nutrient Monitoring (NUTMON) questionnaire assessment and this was done during short rains cropping season. The farmers were visited at their homes and researchers had free discussions with them related to their farming systems and soil fertility management. Farm plans were drawn, fertilizer and manure inputs recorded and cash in and out monitored. Results were analyzed using NUTMON software model. Results showed a general trend of negative nutrient balances particularly in food crop fields. Mineral nutrient inputs (INI) was high in classes 2 and 1 but low in class 3, low negative nutrient balances were recorded in Kiambu district while Maragua district had higher nutrient balances.

Kibunja, C. N. (2007). Impact of long-term application of organic and inorganic nutrient sources in a maize-bean rotation to soil nitrogen dynamics and soil microbial populations and activity. PhD Thesis 2007, University of Nairobi, Kenya

Declining crop productivity is a big challenge to both the smallholder farming community and the researchers in crop production in Kenya. Nitrogen (N) is recognized as one of the most limiting nutrients to agricultural productivity in sub-Saharan Africa. The high cost of mineral fertilizers and the adverse effects of continued fertilization have led to a search for alternative sources of nutrient supply. The effect of land management on soil nitrogen dynamics, microbial diversity and land sustainability in a long-term field experiment situated at the national Agricultural Research Laboratories, Kabete, near Nairobi, forms the subject of this thesis. The trial was established in 1976 to study the effect of continuous use of farmyard manure (FYM), crop residues and chemical fertilizers on crop yields and soil properties in a maize-bean rotation. A study was carried out to assess the effect of land management on soil physio-chemical properties and microbial populations. Soil chemical properties declined over time, while acidity and bulk density increased under continuous cropping with no inputs. The effect of organic and inorganic inputs on soil microbes, number and activities of various groups of microorganisms was monitored for one year in the 0-15 and 15-30 cm soil layers. Use of FYM alone or combined with chemical fertilizers gave significantly higher (P=0.05) numbers of microbes, microbial respiration and soil enzymatic activity than plots with no-input or with chemical fertilizers alone. The topsoil layer had significantly (P=0.05) higher microbial activity than the sub-soil regardless of treatment. Bacteria were more numerous (1 x 105 g/dry soil) than fungi (1 x 103 g/dry soil), which may lead to more SOM mineralization and less retention in this cropping system. To study the dynamics of fertilizer nitrogen (N), labelled 15N fertilizers as calcium ammonium nitrate (10% atom excess) at the rate of 60 kg N/ha/year was applied in 1 x 2 m2 micro-plots and monitored at various depths for a 2-year period. A substantial amount of mineral N (NO_3^--N + NH_4^+-N) was found in the 0-300 cm soil profile (114 mg N/kg soil) at the start of the experiment. Of this, 19.3 mg N/kg soil was held in the plough layer (20 cm). Mineral N within the first 1 m (43 mg N/kg soil) decreased with depth as the crop matured (39 mg N/kg soil), which was attributed to plant uptake and loss through leaching. A bulge of 81 mg N/kg soil was found below 1 m soil depth, which increased as the crop matured (94 mg N kg/soil) probably due to mineralization and further leaching, but was not significantly different between the treatments. The leached N was beyond the reach of annual crops and therefore considered lost to the cropping system. The most prevalent form of inorganic N was NO_3^--N. Data on yields, plant N content and soil N content was used to calculate N balances. Biomass production and crop N yield was higher in treatments with combined inorganic fertilizers and FYM than with inorganic fertilizers alone. The amount of crop N derived from fertilizer (%ndff) was about 13-20% and was higher in fertilized plots than in those with combined organic and inorganic inputs. Fertilizer N utilization ranged from 10-55%, depending on rainfall distribution, which is comparable to other tropical regions. All treatments, except the treatments with combined inorganic and organic inputs (+39 kg N/ha/year), gave a negative N balance (-39.5 to -150 kg N/ha/year), which was highest in the no-input control plots (-150 kg N/ha/year). These results indicated that continuous cropping of annual crops is not sustainable as it leads to substantial loss of N from the soil through leaching and continuous N crop uptake. There is need for interventions in farmer fields to reduce nitrogen leaching, enhance sub-soil N recovery and improve N utilization. Combined use of both inorganic and organic inputs is recommended to maintain productivity, reduce acidity and, sustain soil quality.

Kifuko, M. N., Othieno, C. O, Okalebo, J. R., Kimenye, L. N., Ndung`u, K. W., Kipkoech, A. K. (2007). Effect of combining organic residues with Minjingu phosphate rock on sorption and availability of phosphorus and maize production in acid soils of western Kenya. *Experimental Agriculture* Vol. 43, pp. 51-66

Experiments were conducted in both the greenhouse and the field on highly weathered (Orthic Ferralsol) soils to evaluate the effect of combining on-farm organic residues (chicken manure, farmyard manure, sugar bagasse) with Minjingu phosphate rock (MPR) on soil pH, extractable (available) and sorbed phosphorus (P), and to assess the cost benefit for maize production. The greenhouse study results indicated that, in the first eight weeks of incubation, soil pH increased linearly with increase in MPR rates and decreased thereafter. The available P also increased linearly. Chicken manure and sugar bagasse were most and least effective respectively in reducing P sorption, while there was a significant negative relationship between P absorption maxima and extractable P. The field experiment data showed that the available P values increased significantly above the control in all the treatments where MPR and organic materials were applied separately or combined. Treatment effects on Langmiur sorption maxima (Smax) in the field were variable. An increase in Smax with an increase imnMPR rates was noted. However, there was a positive relationship between Smax and available P (r=0.52 to 0.69), suggesting the diversity of factors affecting the complex nature of P dynamics under field conditions.MPR applied alone in the first season gave a significant residual positive effect on maize grain yield for two additional seasons. The economic analysis revealed that a single application of chicken manure (2t/ha) combined with MPR at 60 kg P/ha gave the highest incremental net benefit equivalent to US$ 657/ha during the three maize cropping seasons.

Kihanda, F. M., Warren G. P., Micheni, A. N. (2007). Effects of manure application on crop yield and soil chemical properties in a long term field trial in semi-arid Kenya. Advances in Integrated soil Fertility Management in Sub-Saharan Africa; challenges and opportunities. Springer 2007 pp 471-484

The sustainability of cereal/legume intercropping was assessed by monitoring trends in cereal or legume grain yield, soil organic carbon (SOC) and soil extractable P (Oslen method) measured over 13 years of field experimentation on a P-deficit soil in semi arid Eastern Kenya. Goat manure was applied (annually for 13 years) at 0-5 and 10 t/ha and trends in grain yields were not identifiable because of season to season variations. SOC and Olsen P increased for the first 7 years of manure application and then remained constant. The residual effect of manure applied for 4 years only lasted for 7 to 8 years when assessed by yield, SOC and P Olsen. Mineral fertilizer provided the same annual rate of N and P as in 5 t/ha manures and initially gave the same yield of manure declining after nine years at about 80%. Therefore manure application could be made intermittently and nutrient requirement topped-up with fertilizer. Grain yield for sorghum with continuous manure were described well by correlation with rainfall and manure input only if data were excluded for seasons with over 500 mm. A comprehensive simulation model should correctly describe crop losses by excess water.

Kihara, J., Kimetu, J. M., Vanlauwe, B., Bationo A.; Waswa B; Mukalama, M. J. (2007). Optimizing crop productivity in legume-cereal rotations through nitrogen and phosphorous management in western Kenya. *In: Andre Bationo, Boaz Waswa, Job Kihara and Joseph Kimetu (Eds). Advances in integrated soil fertility management in Sub-Sahara Africa: Challenges and opportunities* pp.493-501 Book; Springer

Combined application of organic resources and mineral inputs is integral to sustainable soil fertility management but in-situ production of adequate matter is often limited by P availability. An experiment was set up at Nyabeda in Western Kenya aimed at (1) quantifying the contribution of herbaceous and grain legumes to nitrogen supply in a cereal-legume rotation system and (2) quantifying the impact of targeting phosphorus (P) to certain phases of the rotation on overall maize yield. In split to split plot experiment, *mucuna pruriens* was used as the herbaceous legume while soybean was used as the grain legume. Results obtained in the two seasons of the study indicated that either use of mucuna or soybean as previous crop significantly increased maize yield with or without the addition of nitrogen fertilizer. More than 5 t/ha of maize grain yield was realized in season two following the addition of phosphorous fertilizer at both seasons one and two compared to about 3 t/ha of maize grain yields obtained when no p was added. It could be concluded that in this region, the addition of P fertilizer is an integral management option to ensure optimal utilization of the nitrogen fixed by the legume crop. Using P during the legume season may be sufficient to supply P requirements to the succeeding cereal crop. Also, applying P to mucuna or soybean legume crop was not any different from applying it both to the legume and cereal crop indicating that farmers can save labour and cash by applying P only to the legume. The good performance of maize planted after mucuna was an indication that mucuna could be used by the farmers in the region as an N source (Nitrogen Fertilizer Equivalency (NFE)>100 kg N/ha) thus reducing cost of buying N fertilizers. Although soybeans showed a lower NFE of 40 kg N/ha it had higher economic benefits and could thus be more acceptable to farmers. These findings could be confirmed by using more than two cereals and legume rotation cycles.

Kimani, S. K., Esilaba, A.O., Odera, M. M., Kimenya, L., Vanlauwe, B. and Bationo, A. (2007). Effects of organic and mineral sources of nutrients on maize yields in districts of central Kenya. In Bationo *et al* (Eds). *Advances in integrated soil fertility management in sub-Sahara Africa: challenges and opportunities, Springer* 2007 PP 353-357

Trials were set up in three districts in central Kenya to evaluate organic and inorganic and mineral sources of nutrients and their effects on maize yields. The experiment was set up during the long rains 2004 with fifteen different soil fertility management treatments. The treatment included cattle manure, Green manure, maize stover, Tithonia and mineral fertilizer. The test crop was maize (*Zea mays*) intercropped with maize (*Phaseolus vulgaris*). The experiment was RCBD with three replicates. At final harvest at maturity recorded. In general the grain yield data were low (<1 t/ha) in the fertilized, control, in crops intercropped with green manure cover crops and where maize stover alone was applied. In Kirinyaga and Maragwa the highest maize grain field (6.5 t/ha) were obtained when manure was combined with mineral fertilizer. The responses were not as clear in the Kiambu site, possibly due to soil acidity at the site. There were no significant difference (P=0.05) in grain yield between green manure and cover crops 90.4-1.5 t/ha), maize stover (0.3-0.9 t/ha and the unfertilized control (0.4-1 t/ha) across treatments and site during the first season. The work confirms the efficiency of combining mineral sources of nutrients with organic inputs.

Kimani, S. K., Esilaba, A. O., Odera, M. M, Kimenye, L, Vanlauwe, B. and Bationo, A. (2007). Effect of organic and mineral sources of nutrients on maize yields in three districts of central Kenya. ***In: André Bationo, Boaz Waswa, Job Kihara, Joseph Kimetu (Eds). Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities.*** **Springer, ISBN: 13978-4020-5759-5 (HB) 2007 pp 353-357**

Trials were set up in three districts of central Kenya to evaluate organic and mineral sources of nutrients and their effects on maize yield. The experiments were set up during the long rains 2004 with fifteen different soil fertility management treatments. The treatments included cattle manure, green manure, maize stover, Tithonia and mineral fertilizer. The test crop was maize (*Zea mays*), intercropped with beans (*Phaseolus vulgaris*). The experimental design was a Randomized Complete Block with three replicates. At final harvest at maturity, grain yield data were recorded. In general the yields were low (≤ 1 t/ha) in the unfertilized control. In plots intercropped with green manure cover crops and where maize stover alone was applied. In Kirinyaga and Maragwa the highest maize grain yields (6.5 t/ha) were obtained when manure was combined with mineral fertilizer. The responses were not as clear in the Kiambu site, possibly due to soil acidity at the site. There were no significant differences (P=0.05) in grain yields between the green manure cover crops (0.4-1.5 t/ha), maize stover (0.3-0.9 t/ha) and the unfertilized control (0.4-1 t/ha) across treatments and sites during this first season. The work confirms the efficiency of combining mineral sources of nutrients with organic inputs.

Kimetu, J. M, Mugendi, D. N, Bationo, A, Palm, C. A, Mutuo, P. K, Kihara, J, Nandwa, S, Giller, K. (2007). Partial balance of nitrogen in a maize cropping system in humic nitisol of Central Kenya. ***In André Bationo, Boaz Waswa, Job Kihara, Joseph Kimetu (Eds). Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*** **pp 521-530. Springer, ISBN: 13978-4020-5759-5 (HB)**

The application of nitrogen in a soil under agricultural production is subject to several pathways including de-nitrification, leaching and recovery by an annual crop. This is as well greatly influenced by the management practices, nitrogen source and soil conditions. The main objective of this study was to investigate the loss of nitrogen (N) through nitrous oxide (N_2O) emissions and mineral N leaching and uptake by annual crop as influenced by the N source. The study was carried out at Kabete in Central Kenya. Measurements were taken during the second season after two seasons of repeated application of N as urea and Tithonia (*Tithonia diversifolia*) leaves. Results obtained indicated that nitrous oxide (N_2O) emissions at 4 weeks after planting were as high as 12.3 µg N m^{-2}/h for Tithonia treatment and 2.9 µg N m^{-2}/h for urea treatment. Tithonia green biomass treatment was found to emit N_2O at relatively higher rate compared to urea treatment. This was only evident during the fourth week after treatment application. Soil mineral N at the end of the season increased down the profile. This was evident in the three treatments (urea, Tithonia and control) investigated in the study. Urea treatment exhibited significantly higher mineral N content down the soil profile (9% of the applied N) compared to Tithonia (0.6% of the applied N). This was attributed to washing down of the nitrate-N from the top soil accumulating in the lower layers of the soil profile. However, there was no significant difference in N content down the soil profile between Tithonia treatment and the control. It could be concluded that there was no nitrate leaching in the Tithonia treatment. Nitrogen recovery by maize crop was higher in the urea treatment (76% of the applied N) as compared to Tithonia treatment (55.5% of the applied N). This was also true for the residual mineral N in the soil at the end of the season which was about 7.8% of the applied N in the urea treatment and 5.2% in the Tithonia treatment. From this study, it was therefore evident that although there is relatively lower N recovery by maize supplied with Tithonia green biomass compared to maize supplied with urea, more nitrogen is being lost (through leaching) from the soil-plant system in the urea applied plots than in Tithonia plots. However, a greater percentage (37.8%) of the Tithonia-applied N could not be accounted for and might have been entrapped in the soil organic matter unlike urea-applied N whose greater percentage (92%) could be accounted for.

Misiko, M. (2007). Fertile ground, soil fertility management and the African smallholder.

PhD Thesis, Wageningen University, the Netherlands

The focus in this thesis is to form a view of how well soil fertility research performs within the ever shifting smallholder contexts. This study examined application of agro-ecological knowledge for soil fertility management by small holder farmers, with the view to enhancing utility of research among resource-deprived farmers of Western Kenya. A realist methodological approach to the study of soil management was applied. It is shown that soil fertility management operates under the assumption that consequences (soil management) are to be explained not just by contextual states (in this case farmer knowledge) but by ''mechanisms'' of decision making and soil management that need to be uncovered. Knowledge is nothing unless it engages with real soil management processes. Between 2003 and 2005, participatory experimentation, monitoring and evaluation of technologies and concepts were explored. Those experiments involved: (i) cereal -legume rotations; ii) screening new soybean varieties and biomass transfer, and (iv) mineral fertiliser response. Farmers' practices following these experiments were investigated, with particular focus on their underlying justification and livelihood objectives. Participating farmers selected experiment plots to ensure that the soils were representative in terms of type, fertility status and history of cultivation. These farms were

classified as infertile during the participatory soil characterisation. Farmers deliberately selected the infertile plots to ''see if the new technologies worked'', and as part of their wider objective. These experimental plots were researcher designed. Researcher notions of organic resource quality was interpreted and amended by farmers based on existing knowledge, experiences and cultural constructs. For instance, Tithonia was perceived as a ''hot resource'' that could be added to composts to increase the ''speed of cooking''. Amendments to this concept and to new soil fertility management technologies were based on ''ordinary'' applications and reflected perceptions of inconvenience: meaning especially labour constraints, land shortage, uncertain yield and economic returns. Alternative (i.e. not-for-soil-fertility-management) uses of the different technologies were prominent. For example, legume varieties with utility beyond soil fertility management were preferred which resulted in readily observable gains when mineral (P) fertilizer in the successful implementation of the cereal-legume rotation scheme or adoption of new promiscuous soybean varieties. Farmers selected varieties primarily on the basis of yields, rate of growth and appearance. Poor yields when mineral fertilizer was not applied or unsteady crop responses after its use, cost-coinciding with priority expenditures and association with particular technologies such as hybrid maize-complicated the use of fertilizer. Limited understanding of fertilizer functionality, soil nutrients or soil fertility mechanisms is clarified in terms of the context mechanism-outcome paradigm of ''realist'' explanation. The farmer paradigm refers mainly to context and outcomes, which we interpret as a kind of positivism. On the one hand, scientists' focus on mechanisms (to the apparent exclusion of context and outcome) does not match the highly variable local social, physical and economic contexts made more difficult by poor (implementation of) policy. Both farmers and researchers, it is argued, need to enhance their capacity to modify their knowledge sets by engaging in well-designed joint research drawing on the context-mechanism-outcome configuration. Experimentation is seen as one way to expand farmers' knowledge sets on soil fertility and to make mechanisms (e.g. nutrient availability) more visible, so that farmers can engage in soil fertility improvement activity in ways that are both more effective and more meaningful. This thesis also concludes that to increase the utility of research requires a shift from component research at subsystem or whole-farm system level to address broader household objectives. The chances of sustainable application of scientific innovations by smallholders will be greatly enhanced if field research embraces and embeds social science methods of engaging the farmer sustainably as a partner in technology development and not simply as a client.

Mucheru-Muna, M., Mugendi, D., Kung'u J. Mugwe J. and Bationo, A. (2007). Effects of organic and mineral fertilizer inputs on maize yield and soil chemical properties in a maize cropping system in Meru South District, Kenya. *Agroforestry Systems*. 69 (3):189-197. DOI:10.1007/s10457-006-9027-4 · 1.24

Soil Nutrient depletion as a result of continuous cultivation of soils without adequate addition of external inputs is a major challenge in the highlands of Kenya. An experiment was set up in Meru South District, Kenya in 2000 to investigate the effects of different soil-incorporated organic (manure, *Tithonia diversifolia, Calliandra calothyrsus, Leucaena leucocephala*) and mineral fertilizer inputs on maize yield and soil chemical properties over seven seasons. On average , Tithonia treatments (with or without half recommended rate of mineral fertilizer) gave the highest grain yield (5.5 and 5.4 Mg/ha respectively) while the control treatment gave the lowest yield (1.5 Mg/ha) after 2 years of trial contents were improved with the application of organic residues, and manure in particular improved soil calcium content. Results of the economic analysis indicated that on average across the seven seasons, Tithonia with half recommended rate of mineral fertilizer treatment recorded the highest net benefit (USD 787/ha) while the control recorded the lowest (USD272/ha). However, returns to labour or benefit-cost ratios were in most cases not significantly improved when organic materials were used.

Mugwe, J., Mugendi, D. N., Kungu, J. B. and Mucheru-Muna, M. (2007). Effect of plant biomass, manure and inorganic fertiliser on maize yields in the central highlands of Kenya. *African Crop Science Journal*. Vol. 15 (3) pp 111-126

Soil fertility degradation remains the major biophysical cause of declining per capita crop production on smallholder farms in sub-Saharan Africa. Appropriate soil fertility regimes, are therefore, critical for improved crop productivity. This study investigated the feasibility of using sole organics or their combinations with inorganic fertilisers to improve maize (*Zea mays*) production in the highlands of central Kenya. Sole application of *Calliandra calotyrsus*, *Leucaena trichandra, mucuna pruriens, crotalaria pchroleuca, Tithonia diversfolia* and cattle manure at 60 kg N/ha or combined application of the organic materials (30 kg N/ha) plus inorganic fertiliser (30 kg N/ha) gave significantly ($P \leq 0.05$) higher maize grain yields than the recommended rate of inorganic fertiliser (60 kg N/ha). These treatments maintained maize yields at 4 to 6 t/ha. Farmers had their own innovations where they combined resources and generally appreciable yields (3.0 to 5.6 t/ha) were obtained from these innovations. However, there was a maize yield gap between on-station and on-farm trials with on-station yields having on average 65% more yields than the on-farm yields. This was mainly attributed to differences in management practices arising from partial adoption of recommended rates. There is need therefore to develop and implement mechanisms tailored to ensure that farmer's modifications of recommended soil amendments regimes and other agronomic practices are appropriate for enhanced crop productivity. Further studies are needed to establish the optimum mixture of different organic materials.

Mugwe, J. N. (2007). An evaluation of integrated soil fertility management practices in Meru south district, Kenya. PhD Thesis, Kenyatta University, Nairobi, Kenya

Farmers in the Central highlands of Kenya do face problems of low crop yields due to soil fertility decline. This is as a result of continuous cropping, nutrient losses through crop harvests, soil erosion and leaching coupled with inability to replenish the soil through use of external inputs. The situation is aggravated by poor adoption, among farmers, of improved soil fertility management options. This study investigated feasibility of using integrated soil fertility replenishment options. This study investigated feasibility of using integrated soil fertility replenishment technologies (SFRT) involving organics in combination with inorganic fertilizer to improve soil fertility and consequently crop yields in Chuka, Meru South district. The organic materials evaluated comprised of two leguminous trees (*Calliandra calothursus* and *Leucaena trichandra*), two herbaceous legumes (*Mucuna pruriens* and *Crotalaria ochroleuca*), Tithonia diversifolia, a locally available tree shrub, and cattle manure. Effect of these organic materials (sole or combined with organic fertilizer on maize yields and soil properties (pH, macronutrients, inorganic nitrogen) was assessed under both on-station and on-farm experiments. Farmer preferences and farmer's experiences' as well as household and farm characteristics determining decision to adopt or not to adopt SFRT. All biophysical data were subjected to ANOVA and means separated using LSD at a =0.05. Social data were subjected to descriptive statistics and summarised using means, frequencies and percentages. The factors influencing adoption were subjected to multivariate regression analysis. The on-station experiment showed that treatments that had sole application of the organic materials at 60 kg N/ha, and organic materials (30 kg N/ha) plus inorganic fertilizer (30 kg N/ha) gave similar yields ($p<0.05$). However, these treatments recorded higher maize yields than that from sole inorganic fertilizer treatment. They maintained maize yields at 4 to 6 t/ha and should therefore be recommended for use by farmers, who currently get 0.5 to 1.5t/ha from their conventional farming systems. Herbaceous legumes gave the lowest yields among the organic resources, but performed better than the control treatment. At the on-farm trials, maize yields from researcher designed and managed trials were less variable than those from farmer designed and managed trials, which was attributed to differences in management practices among farmers. The organic materials had a positive contribution to soil pH, K, C and N while cattle manure showed superiority in terms of its contribution to soil properties. The amount of soil inorganic N within the plow layer and N-uptake by maize monitored during 2002 LR and 2004 LR seasons showed variation among the treatments, sampling periods, and between seasons. There were high amounts of soil inorganic N at 0-15cm soil depth at the beginning of the season, followed by a decline from around 4 to 8 weeks after planting. This trend was attributed to rapid mineralization of the incorporated organic materials and ''Birch effect'' that was followed by leaching, due to intense rainfall, coupled with uptake of N by the maize crop. Treatments that had Tithonia, Calliandra and Leucaena applied had the highest soil inorganic evident that the effect of external inputs on N uptake was dependent on climatic conditions (especially rainfall) prevailing throughout the growing period. Poor rains during 2004 LR resulted in accumulation of soil inorganic N and restricted N uptake by the maize crop. There was high residual inorganic N at 100-150cm soil depth that was probably due to greater N mineralization compared to plant uptake in the top-soil depth that was probably due to greater N mineralization compared to plant uptake in the top-soil immediately after the onset of the rainy season and subsequent nitrate leaching. This inorganic N observed in the 100-150 cm depth is below the rooting zone of most maize plants and may not be available to the maize crop. The study established that first farmer preferences were SFRT involving manure and Tithonia combined with fertilizer followed by fertilizer alone and was attributed to easy accessibility and probably low opportunity cost of practicing these technologies. Technologies that combined organic and inorganic fertilizer were more popular among farmers and farmers used them on significantly ($p<0.05$) larger plots than with application of either sole organics or inorganic fertilizer. Farmers developed innovations that involved mixing of organic materials, which gave high yields possible due to increased nutrients supply and other benefits associated with organic materials. The main benefits reported were increased crop yields and fodder (*Calliandra* and *Leucaena*) and this could have been a driving force to the adoption of the technologies. The major constraints were high labour demand and inadequate biomass and farmer tried to cope by preparing; and early, applying materials without chopping and planting trees near the crop fields. Five factors were identified to significantly ($p0<0.1$) influence adoption. Age of household head and number of mature cattle negatively influenced adoption. Farm management category, ability to hire labour and number of months in a year households bought food for the family positively influenced adoption. The odds in favour of adoption increase by a factor of 0.9 for households hiring labour, while households buying food for more than three months in a year have an adoption probability of 25%. The implication of these results is that adoption of improved SFRT could be enhanced through targeting of young families were both spouses work on farm fulltime, food insecure households and farmers who lack access to other sources of soil improvement such as those without enough cattle to produce manure. This study has filled an important gap by providing a recommendation on some appropriate technologies for replenishing soil fertility in small holder farms of Meru South District. The role of cattle manure in increasing soil fertility parameters was well demonstrated and due to its easy accessibility in the region, it is likely to remain one of the key resources for managing soil fertility. It is therefore recommended that factors that seem to limit its performance especially on farms such as low quality be addressed. The study also showed how farmers test and manage new soil fertility management innovations to meet their livelihood objectives, and identified factors crucial for enhancing adoption of integrated SFRT. The government therefore needs to strengthen expand and support long-term soil initiatives that aim at enhancing adoption of these technologies. Policies and institutional support should be focussed enhancing

willingness and ability of farm households to adopt the technologies while taking into consideration key factors that were identified to influence adoption in this study. Further research is recommended on the following areas: residual effects on soil of low and high quality organic resources, partitioning of N upon decomposition of these resources, partitioning of N upon decomposition of these resources, tradeoffs of biomass banks on farms and their economic viability, diffusion and potential of up-scaling of integrated soil fertility management technologies in the area.

Mugwe, J., Mugendi, D., Kung`u, J., Mucheru-Muna, M. (2007). Effect of plant biomass, manure and inorganic fertiliser on maize yield in the central highlands of Kenya. *African Crop Science Journal* 2007 Vol. 15 pp. 111-126

Soil fertility degradation remains the major biophysical cause of declining per capita crop production on smallholder farms in sub-Saharan Africa. Appropriate soil fertility regimes, are therefore, critical for improved crop productivity. This study investigated the feasibility of using sole organics or their combinations with inorganic fertilizers to improve maize (*Zea mays*) production in the highlands central Kenya. Sole application of *Calliandra calothyrsus*, *Leucaena trichandra, Mucuna pruriens, Crotalaria ochroleuca, Tithonia diversofolia* and cattle manure at 60 kg N/ha or combined application of the organic materials (30 kg N/ha) plus inorganic fertiliser (30 Kg N/ha) gave significantly ($P \leq 0.05$) higher maize grain yields than the recommended rate of inorganic fertilizer (60 kg N/ha). These treatments maintained maize yields at 4 to 6 t/ha. Farmers had their own innovations where they combined organic resources and generally appreciable yields (3.0 to 5.6 t/ha) were obtained from these innovations. However, there was a maize yield gap between on station and on farm trials with on station yields having on average 65% more yields than the on-farm yields. This was mainly attributed to differences in management practices arising from partial adoption of recommended rates. There is need therefore to develop and implement mechanisms tailored to ensure crop productivity. Further studies are needed to establish the optimum mixture of different organic materials.

Nyongesa, H. W. (2007). Effects of Phosphorus and Organic Nutrient Sources on Improvement of Soil Fertility and Maize (*Zea Mays* L.) Production on Selected Soils in Kenya. PhD. Thesis, Egerton University, Njoro, Kenya

Maize yield in Kenya is low primarily due to decline in soil fertility. Inorganic fertilizers are however, too expensive and cause environmental pollution. Organic manures are low cost therefore, have great potential in increasing yield. The quality, quantity, and placement methods of these diverse materials is however, not known. The supply of organic materials on farms is also insufficient, thus the need to develop other organic resources. Pymarc is a by-product of pyrethrum processing that could be used as a fertilizer. The use of organic manure as P source is limited by the low P content. Supplementation with inorganic P fertilizer is therefore required. A series of pot and field experiments were conducted in 2003 and 2004 to determine NPK release pattern from Pymarc and the optimal mode and rate of application and effect of combining Pymarc or Tithonia with TSP on maize yield and the net benefits. Pot experiment was conducted in 2003 in a greenhouse at Egerton using Phaeozems, Cambisols and Ferrasols. A factorial experiment in a CRD replicated thrice with rates of Pymarc equivalent to 0, 2, 4, 6 and 8 t/ha was tested. Samples were taken at 0, 2, 4, 6, 8, 12 and 16 weeks for NPK analysis. Field experiments were conducted in 2003 and 2004 with Pymarc at Egerton (Phaeozems), Mole (Cambisols), Kosirai (Ferrasols) and Tithonia at Kosirai (Ferrasols) Pymarc at 0, 4, 8, t/ha and Tithonia at 0, 2.5, 5 t/ha were each tested for suitable mode of application as spot versus broadcast in a 2x3 factorial arrangement in a split plot design replicated thrice. Nitrogen released after 112 days of incubation in pot experiment ranged from 142 mg N/kg in Ferrasols to 163 mgN/kg in cambisols and 170 mgN/kg in phaeocems. Phosphorus mineralized from Phaeozems, 6.1 mg N/kg and cambisol, 7.2 mg P/kg was twice the amount of P mineralized from Ferrasols, 3.1 mg P/kg. Potassium mineralized at 112 days of incubation was 101 mg K/kg in Phaezems, 100 mg K/kg in Cambisols and Ferrasols was 45 mg K/kg. Increasing rate of Pymarc application led to increase in the amount of Nitrogen, Phosphorus, and Potassium released. Cambisols had the highest potential mineralized N of 182 m/kg, P of 7.6 mg/kg and K of 101 mg/kg than Phaeozems with N of 163 mg/kg, P of 6.4 mg/kg and K of 99 mg/kg and Ferralsols with N of 148mg/kg, P of 3.6 mg/kg and K of 12 mg/kg. Nitrogen and Potassium released was consistently related to C:N lignin, N, pot: N and Pol + Lig: N ratio: Pymarc significantly increased root biomass. NPK concentration leaf, stover, grain yield, macrofauna fresh biomass, diversity and abundance. Pymarc and Tithonia using the Kosirai experiment had a significantly higher macrofauna fresh biomass, diversity and abundance than Pymarc. Positive and significant correlations were observed between Nitrogen and Lignin, Plant Residue Quality Index (PRQ1) and earthworms; Phosphorus and earthworms, polyphenols and termites, ants and centipedes. Negative correlations were also observed between Nitrogen and Ants; Lignin and Polyphenols and PRQ1 and Earthworms. Phosphorus applied as Pymarc at 4 t/ha or Tithonia at 2.5 t/ha in combination with TSP at 13 kg P/ha had the highest relative grain yield. Tithonia integrated with TSP had the highest relative grain yield increase. The addition of either Pymarc in combination with TSP at Egerton, Molo and Kosirai resulted in added maize yield of 110% 103% and 117% respectively. At Kosirai, Tithonia in combination with TSP resulted in added maize yield of 123% compared to TSP, Pymarc or Tithonia alone. Maximum net benefits were obtained at 11 kg/ha when Pymarc was applied at Egerton, Molo and Kosirai for both spot and broadcast placement methods respectively. The NPK

release pattern is influenced by soil characteristics, amount, and quality litter. Thus the release of nutrients by Pymarc and Tithonia and their effect on maize production makes them suitable for improvement of soil fertility and maize production when applied at 4 t/ha and 2.5 t/ha or integrated with TSP at 13 kg/ha, respectively.

Okalebo, J. R., Othieno, C. O., Woomer, P. L., Karanja, N. K., Semoka, J. R. M., Bekunda, M.A., Muasya, R. M., Bationo A., Mukhwana E. J. (2007). Available technologies to replenish soil fertility in East Africa. In Bationo et al (Eds); *Advances in integrated soil fertility management in Sub-Sahara Africa: challenges and opportunities*. Springer 2007 76 issues 2-3

Low inherent soil fertility in the highly watered and leached soils largely accounts for low and un-sustained crop yields in Africa countries. But in particular the major nutrients nitrogen N and P are commonly deficient in these soils. This scenario of Nutrient depletion of nutrients is reflected on food deficit and hence the food aid received continuously specifically in Sub- Saharan Africa. Substantial efforts have been made in the continent to replenish the fertility of degraded soils in attempts raise crop yield. Towards self sufficiency and export such efforts consist of application of both organic and inorganic resources to improve the organic status of the soil and enhance nutrient uptake by crops provided that soil moisture is adequate. Overall positive crop responses to these materials have been obtained. Thus in East Africa region maize (staple) yields have been raised in one growing season from below 0.5 t/ha without nutrient input to 3-5 t/ha from various nutrient amendments at the smallholder farm levels. However in spite of the crop responses to nutrient input farmers are generally slow to adopt the soil fertility management technologies. In this paper we review the impact of some technologies focussing the use of nutrients resources of different characteristics (qualities) in relation to fertilizers often give immediate crop responses but their use of adoption. Thus inorganic resource or fertilizers farmers who can afford to buy these materials. Organic resources which include crop residue water hyacinth and agro forestry shrubs and trees are widely distributed but they are generally of low quality reflecting the need to apply large quantities to meet crop nutrient demands. Moreover most nutrients will add N mainly to soils .On the other hand phosphate rocks of varying reactivity are found widely in Africa and are refined elsewhere to supply soluble P sores. The recently developed soil fertility management options of East Africa have suggested the efficient use of N and P crops and integrated nutrient management approach. Some people have also felt that the repacking of inputs in small affordable quantities such as the PREP-PAC described I this paper may be an avenue to attract more smallholder farmers to use nutrient inputs. None the less crop response to nutrients input vary widely within and across agro-ecozones (AEZs) suggesting unspecified recommendations. We highlight this observation a case study where by eight soil fertility management options developed independently are being tested side- by -side on farm level. Farmers will be empowered to identify technologies from their own choices that are agronomically effective and economically friendly. This approach of technology testing subsequent adoption is recommended for technology development in future.

Omondi, M. O. (2007). Soil amendment with chickpea residue effects on water retention and availability, and wheat yield. Msc. Thesis; Egerton University, Njoro, Kenya

Soil water retention and availability limit crop yields in many rain-fed areas in Kenya. Lack of suitable fallow management strategy, mono-cropping and wheat-fallow rotations practiced in wheat growing areas deplete soil organic matter which is an essential agent for aggregate stability and in turn water retention and availability in addition to supplying plant nutrients. Incorporating a drought tolerant legume such as chickpea in rotation with wheat offers a possible strategy to improve soil organic matter. It was hypothesised that incorporating chickpea residue into soils under rotation with wheat would improve water retention and availability during the subsequent wheat crop, which, in turn, would improve wheat yield. In this study, the main plot treatments were: chickpea ploughed into the soil at flowering stage, chickpea at maturity with the residue without seeds incorporated into the soil during land preparation for wheat, and fallow land, ploughed but not planted with chickpea. The sub-plot treatments were inorganic fertilizers at three rates 0 kg N/ha, 30 kg N/ha and 60 kg N/ha. The treatments were arranged as split-plots in randomised complete block design with four replicates. Tension infiltrometers were used to measure steady state infiltration rates at two suctions - 15cm and -5cm resulting in estimates of saturated hydraulic conductivity, Ksat. Disturbed soils sampled from the upper 15 cm soil layer were packed to a bulk density of 1.0 Mg m-3 and pressure plate apparatus used to determine water retention at 0, -10, -33, -100, -300, -500, -1000 and -1500 kPa. Total soil organic matter was determined by loss of weight procedure while size fractionation of particulate organic matter was done using wet sieving method. Above ground biomass of wheat at maturity was harvested to determine yield. Soil water retention was significantly influenced by the residue management techniques. The residue management techniques resulted in significant differences in available water capacity. Incorporation of chickpea residues both as green manure and mature residues significantly increased the saturated hydraulic conductivity of the soil studied compared to the untreated soil. Residue management techniques and inorganic N rates did not have significant effects on both above ground wheat biomass and grain yield. Particulate organic matter, liable and non-liable carbon fractions were not significantly affected by both residue management techniques and inorganic N rate. In drier conditions < 500 kPa, mature chickpea residues improved water retention more than the green manure applied plots.

Ramish M. J. (2007). Integrated soil fertility management Technologies: review for scaling up mission. *In: Andre Bationo, Boaz Waswa, Job Kihara and Joseph Kimetu (Eds). Advances in integrated soil fertility management in Sub-Sahara Africa: Challenges and Opportunities* pp. 873-880. Book; Springer

It is recognised that smallholder famers in Sub-Saharan Africa significantly depend on land for their livelihoods. Nevertheless, these livelihoods are constrained by inherent low soil fertility. Over a long time, researchers and farmers have battled to arrest Integrated Soil Fertility Management (ISFM) technologies. Between 2001 and 2004, Tropical Soil Biology and Fertility (TSBF) researchers and local smallholder farmers in western Kenya have been adopting these technologies to local circumstances under the community-based initiative called Strengthening Folk Ecology (FE). This initiative involved participatory demonstration-trials and dialogue as principal methods in the learning and adaptation process. Follow up studies have been undertaken to identify successful cases of this process. Initial results show that although such cases are few and far between, they are promising and benefits need to be scaled up for wider use by farmers in areas beyond the FE sites. Nevertheless, scaling ISFM technologies is complicated. ISFM technologies are knowledge intensive and their adaptations and applications are diverse. This paper provides insights into this problem by discussing selected ISFM technologies with regard to their inherent scalability.

Tabu, I. M., Bationo, A., Obura, R. K. and Masinde, J. K. (2007). Effect of Rock Phosphate, Lime and Green Manure on Growth and Yield of Maize in a Non Productive Niche of a Rhodic Ferralsol in Farmer's Fields. *In André Bationo, Boaz Waswa, Job Kihara, Joseph Kimetu (Eds). Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities* pp 449-456. Springer ISBN: 13978-4020-5759-5 (HB)

Ferralsol and Acrisol soil types important for maize production in Western Kenya have low pH, phosphorus (P) and organic matter plus high levels of Al and Fe oxides that fix P. Minjingu rock phosphate (MRP), lime and green manure (Tithonia) that are cheap and locally available are recommended for use. The low solubility of MRP when directly applied and unavailability of adequate organic materials limits their use. The low solubility of MPR when directly applied and unavailability of adequate organic materials limits their use. An experiment was carried out in farmers' field to determine the interactive effect of combing MRP and Tithonia or lime in a degraded patch of Ferralsol soil in Western Kenya. The treatments: ± MPR ± lime ± Tithonia + Triple superphosphate (TSP) and their combinations were applied to maize in (4 × 5) m2 plots. The field layout was in a completely randomized block design replicated four times. Plant height (eight weeks after emergence) and leaf number showed a significant interactive effect between: TSP × Tithonia ($P \leq 0.0001$), MRP × Tithonia ($P \leq 0.05$) and Tithonia × TSP × Lime ($P \leq 0.005$). Leaf area index (m^2 leaf m^{-2}) similarly was significantly affected by TSP ($P \leq 0.0001$), lime ($P \leq 0.05$), lime × TSP ($P \leq 0.0002$), TSP Tithonia ($P \leq 0.0001$) and lime × Tithonia × TSP ($P \leq 0.05$). The significant treatments also affected were similarly observed in grain yield (t/ha) as TSP (2.5 t/ha), MRP (1.0 t/ha), lime × TSP (2.5 t/ha), TSP × Tithonia (2.9 t/ha) and Tithonia × TSP × lime (2.4). Hence combining TSP or MRP with Tithonia may be used to alleviate multiple problems in the degraded patches of Ferralsols.

Tabu I. M., Batiano A., Obura R. K. and Masinde J. (2007). Effect of rock phosphate, lime and green manure on growth and yield of maize in a non productive niche of a rhodic ferrasol in farmers fields. *In: Andre Bationo, Boaz Waswa, Job Kihara and Joseph Kimetu (Eds). Advances in integrated soil fertility management in Sub-Sahara Africa: Challenges and opportunities* PP 449-456 Book; Springer

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Ashiono, G. B., Ouma, P. J., Gatwiku, S. W. (2006). Farm yard manure as alternative nutrient source in production of cold tolerant sorghum in the dry highlands of Kenya

***Journal of Agronomy* Vol. 5(2), pp. 201-204**

An experiment was conducted over three seasons to determine the effects of different rates of application of farmyard manure and inorganic fertilizer on growth and yield of cold tolerant sorghum variety E1291. The trial was conducted on a sandy loam soil at the Kenya Agricultural Research institute - Lanet, Kenya. Farmyard manure obtained from the centre cattle shed was incorporated into the soil at the time of sowing at 0, 5, 10, 15, 20, 30 and 40 Mg/ha in a Randomized Complete Block Design Replicated three times. Standard inorganic fertilizer was included as a control at the rate of 60kg and 30kg P_2O_5/ha. The Highest grain yield was produced where 5 Mg/ha of farm yard manure was applied during the first year while 40 Mg/ha produced lowest yield among the manure treatments. During the second year, significant ($p<0.05$) higher grain yields were achieved from treatments of 30 and 40 Mg/ha. In the third year, no significant differences ($p<0.05$) were observed among the manure treatments but 30 and 40 Mg/ha farm yard manure produced highest yields. Manures produced higher yields in all years than the recommended inorganic fertilizer. After three seasons of evaluation, 10 Mg/ha of farm yard manure produced similar grain yields to the standard control while 30 and 40 Mg/ha farmyard manure consistently produced highest yields. These yield differences were not significantly different from treatments with 15 Mg/ha of farm yard manure.

Gichangi, E. M, Karanja, N. K, Wood, C. W. (2006). Composting cattle manure from zero grazing system with Agro-organic wastes to minimize nitrogen losses in smallholder farmers in Kenya. *Tropical and Sub-tropical Agro-Ecosystems* Vol. 6 pp 57-64

Livestock manure is a valuable source of plant nutrients for crop production in the Central Kenyan highlands but its quality in terms of available nitrogen (N) is low due to considerable N losses through ammonia volatilization. This study aimed at assessing the potential of agro-organic wastes to reduce N losses from manure heaps during the storage period. Three organic amendments selected from a laboratory simulation experiment were evaluated under farmers' conditions in Karura, Kiambu District for their ability to reduce N losses from cattle manure heaps. The effect of a polyethylene sheet covering of manure heaps on N retention was also determined. There were eight treatments that comprised three agro-organic amendments (maize stover, coffee pulp and sawdust) and the control, with or without a polyethylene cover. Agronomic effectiveness of the "treated" manure samples and N uptake by maize seedlings was evaluated in a glasshouse experiment. Total N content of manure amended with organic materials ranged from 1.26 to 1.85%. The N in manures with organic amendments at the start and at the end of storage was significantly different ($p \leq 0.05$). Cumulative N loss ranged from 1.60 to 6.80 g/kg depending on the type of amendment. Nitrogen lost from non-amended manure was 2.74 g/kg with polyethylene cover and 6.80 g/kg without the polyethylene cover, which represented 19 and 46% of the initial N respectively. Maize growth improved significantly ($p \leq 0.05$) with increasing rates of manure irrespective of the organic treatments except for manure amended with sawdust. Treatments that received the recommended rate of N at 100 kg N/ha had significantly higher ($p \leq 0.05$) biomass (21.55 g/plant) than the control which produced only 2.78 g/plant. Nitrogen uptake increased with increasing rates of manure and was higher ($p \leq 0.05$) with manure amended with coffee pulp. Covering manure heaps to reduce moisture loss was also beneficial in reducing N losses.

Kimuyu, D. M. (2006). Comparative study on the growth and yield of NERICA cultivated with organic and inorganic fertilizers: participatory on farm at Marakwet District in Kenya. *Journal of development in sustainable agriculture*, Vol. 4:106-117; University of Tsukuba, Japan

A participatory field study was conducted in Tunyo division Marakwet district Kenya to investigate where there would be a significant response of new rice for Africa NERICA) cultivars 1 and 4 farmyard manure and chemical fertilizers. Seeds were directly sown in 2m X 5m plots at a depth of 2-3 and a spacing of 30 x 1.5 cm. The treatment included chemical fertilizer, organic fertilizer (farm yard manure) and control (no fertilizer) in the chemical fertilizer treatment 2.5 g N/m-2 was applied as compound fertilizer N P K (20:12:12) as basal fertilizer at planting and 2.5 g N/m using area (46:0:0) as top dressing at panicle initiation stage. In the organic fertilizer treatment 10.6 N/m from farm yard manure (N 0.53%, P 0.62%, K 1.35%) obtained from cattle droppings was applied at planting. The experiment was conducted in two farmers' fields using split plot design with two replicates. Day on days to seed emergence panicle initiation heading flowering and maturity were collected. Plant height and tiller number data were recorded during vegetable growth stage. At harvest panicle number panicle length, grain number per panicle, weight in 1000 grains and paddy yield were measured. Growth pattern, fertilizer response and post harvest qualities of NEIRCA 1 as having excellent response to fertilizer good growth vigour as evaluated NERICA 4 was significantly higher than that of NERICA 1 irresponsive of treatment. Farmers evaluated NERICA 1 as having excellent tillering ability, excellent response to fertilizers good growth vigour as measured by height and yield, excellent threshability and aroma berry good milling quality and good eating qualities. Farmers also succeeded NERICA 4 as having excellent tillering ability, excellent response to fertilizer, excellent growth vigour excellent yield, excellent threshability and taste, very good milling properties and good eating qualities. NARICA

4 performed as well as or better than NERICA 1 in most attributes evaluated in this research. NERICA 1 was preferred for its aroma while NERICA 4 earned the overall performance for cultivation owing to its superior yield. This research showed that the participation of farmers in yield research strengthens the research- extension- farmer linkage, which could be expected to lead to faster technology and uptake of new farming practices in Kenya.

Laghat, J. K., Wangia, S. M. and Njehia, B. K. (2006). Evaluation of Rotuba Bio- Agric manure, farm based organic residues and inorganic fertilizers in depleted soils of Nort Rift, Kenya. A technical report; KARI, Kitale; Advances in Integrated soil Fertility Management in Sub- Sahara Africa -challenges and opportunities, pp 63-66

Increasing the rate of Rotuba bio-agric manure above the manufacture's rate did not improve maize yields. Farm yard manure performed both manure and maize Stover under this season. High maize yields in Rotuba treatments were realized when top-dressing was done using CAN as compared to the recommended Rotuba top dress. Generally combining Rotuba with inorganic fertilizers at planting gave higher maize yields and improved its relative agronomic effectiveness in comparison to when Rotuba was applied alone. This implies that, to improve the efficiency of Rotuba, addition of inorganic fertilizer both at planting and top dressing is strongly recommended.

Mwangi, T. R., Onyango, M., M., Barkutwo, J. (2006). Use of rock phosphate and organic resources to rejuvenate soils under continuous maize production, Annual report KARI-Kitale 2006 PP 82-87

The DAP/CAN, MPR/CAN and MPR/CAN (60 kg P_2O_5 + 30 kg N) + 5 t FYM/ha were the best options for soils at the on-station sites. The Mavuno/CAN (30 kg P_2O_5 + 30 kg N) + 5 t FYM, SSP/CAN and 10 t FYM/ha were the best treatments for soil at Itigo sites. Similarly, Mavuno/CAN and Mavuno/CAN (30 kg P_2O_5 + 30 kg N) + 5 t FYM/ha were the most economic treatments in Kimuri sites. The experiment should be conducted over a long period of at least five years in order to document soil chemical changes due to treatments and its effect on maize yields.

Savini I., Smithsonnancy, P. C., Karanja, K. N. and Yamasaki, H. (2006). Influence of *Tithonia diversifolia* and triple super phosphate on dissolution and effectiveness of phosphate Rock in acidic soil. Plant Ntr. Soil Sci. 2006 169:593-604; WILLY-VCH verg GNBH & CO. KGAa WEINHEM

Incubation and a pot experiment were conducted to evaluate the dissolution and agronomic effectiveness of a less reactive phosphate rock Busumbu soft ore 9BPR, in an Oxisol in Kenya Resin (anion and anion + cation) - extractable P and sequentially extracted P with 0.5 M $NaHCO_3$ 0.1M NaOH and 1M HCL were analysed. Dissolution was determined from the increase in anion resin (AER) -$NaHCO_3$- and NaOH -extracted P in soil amended with PR compared with the control soil. Where P was applied resin P significantly increased above the no-P treatment, Busumbu-PR solubility was low and did not increase significantly in 16 weeks. Anion + cation ACER - extractable P was generally greater than AER-P. The difference was greater for PR than for triple superphosphate (TSP). The ACER extraction may be a better estimate of plant P availability particularly when poorly soluble P sources are used. Addition of P fertilizers alone or in combination with Tithonia diversifolia TSP, BPR, TSP + Tithonia and NPR + Tithonia increased the concentration of liable inorganic P pools ($NaHCO_3^-$ and NaOH-P) cumulative evolved CO_2 was significantly correlated with cumulative N mineralized from Tithonia (r0.51-P<.05) remained where Tithonia was incorporated at all sampling times. However when PH was increased NH_4^+ declined with a corresponding rise in NO_3^-. Tithonia significantly depressed soil exchangeable acidity relative to control with time. A significant increase ($p< 0.05$) was observed for P applied. The variations in yield and P uptake due to source and rate of application were statistically significant. At any given rate highest yields were obtained with Tithonia did not enhance the effectiveness of the PR. The poor dissolution and plant P uptake of BPR may be related to the high Fe content in the PR material.

Powon, M. P., Aguyoh J. N. and Mwai, A. V. (2006). Growth and tuber yield of potato (*Solanum turberosum* L.) under different levels of phosphorus and farm yard manure. *Agricultura Tropica et Subtropica* Vol. 39(3) pp 189-193

Low soil fertility is a major constraint to potato production in most Parts of Kenya. To enhance growth and yield of potato field research was carried on potato (Asante variety) for 2 seasons at NARC – Kitale and on farm Psigirio in 2002 and 2003. The experimental design was Randomized Complete Block (RCB), with three replications. Nine treatments of phosphorus rates (0, 52.2 and 100.4 kg/ha and farmyard manure 0, 10 and 20 t/ha) either singly or in combination were used. Data were recorded on tuber dry weight, shoot dry weight and total yield of potatoes. Phosphorus and FYM had a significant ($p< 0.05$) influence on tuber dry weight, shoot dry weight and total yield depending on the season and year. A combination of P at 100.4 kg/ha and FYM at 20 t/ha resulted in an increase of 82% tuber dry weight and 62% of fresh tuber yield compared to the control. Tuber number and shoot dry weight were also affected by the application of P and FYM. Potato yield can therefore be improved through application of phosphorus and farm yard manure

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Ayaga, G. and Brookes, P. C. (2005). Increasing fertilizer phosphorus use efficiency through organic matter cycling for enhanced maize production in Kenya. Proceedings of the 21st Soil Science Society of East Africa, Conference 1st -5th Dec. 2003. Eldoret, Kenya pp 345-362.

Phosphorus has been identified as a major bottleneck to improve crop production in soils with high P-retention capacities. These soils occupy large areas of the productive lands in Kenya and the highlands of East Africa. Several management options have been suggested to provide solutions to the P nutrition limitation. However, their applicability under smallholder systems has not been evaluated. Similarly the transformation of the applied fertilizer P to soil under the various management options has remained unclear. The aim of this experiment was to evaluate impact of some of the available management options on yield in soils having high P-retention capacities. The fate of the applied P-fertilizer under some management options is also traced and measured through P-fractionation scheme and the option that ensures adequate availability of applied P for crop uptake is recommended for use by the smallholders. Two approaches were adopted. Firstly, to attempt to saturate the P-fixing sites in the soils by applying a large annual application of P (75 kg P/ha), which should serve for several seasons. Secondly, to attempt to keep the fertilizer P in biological forms supplying fertilizer P and manure in combination i.e. promote the cycling of P through the soil microbial biomass and associated metabolites and so help increase plant availability. These treatments were investigated under field conditions on smallholder farms in Kenya; one, considered a 'high P fixing' soil at Malava (Kakamega District) and the other considered a 'low P fixing' soil at Mau Summit (Nakuru District). The following treatments were applied in 1997 and 1998: Nil, 25 kg super phosphate P/ha, FYM at 1.9 t/ha dry matter, FYM + 25 kg P/ha in combination and 75 kg superphosphate P/ha all in four replicates in a randomized complete block design. All treatments received 100 kg N/ha as basal application. Maize was the test crop. There was no significant correlation in either year at both sites between soil P, measured as $NaHCO_3$ -extractable P, resin P or NaOH -extractable P and maize yield. However, the different soil fractions were closely correlated with each other. There was a significant positive relationship ($P<0.05$) between biomass P and crop yield, again at both sites and in both years. The treatment FYM + P gave the best yield and the largest biomass P. The results indicate that combined use of organic and inorganic fertilizer inputs in these low input systems may promote better biological cycling, enhanced availability and consequently improved plant uptake of soil and fertiliser P. The results also indicate that biomass P measurements may provide a better indicator of soil P availability in these soils than the more conventional chemical extractants. However both findings require further evaluation.

Kibunja, C. N, Mugendi, D. N, Mwaura, F. B, Kitonyo, E. M, Salema, M. P. (2005). Fate of applied nitrogen in a long-term maize-bean cropping system in Kenya. Proceedings of the 21st Annual Conference 1st -5th Dec. 2003. Eldoret, Kenya. pp 363-370.

Low soil fertility has been recognized as one of the major bio-physical constraints affecting agriculture in Sub-Saharan Africa. Nitrogen in particular is the most limiting element in crop production leading to low and declining yields as a result of continuous crop harvest removal, leaching and soil erosion. One way of reversing this situation is by returning nutrients to the soil through use of chemical and organic fertilizers. Another way is to improve the recovery of applied fertilizer N by crops, reduce losses of N and encourage the build-up of soil organic N, which, contribute to long-term, soil fertility. The long-term field experiment at NARL, Kabete, was used to study the partitioning of fertilizer N applied to annual crops. The treatments were: chemical fertilizers NP at 60 kg N and 26 kg P/ha with or without stover; combinations of NP (60 kg N and 26 kg P/ha) and manure (5 t/ha) with or without stover incorporation. The main objectives were to monitor the movement of N down the soil profile and to quantify the uptake of labelled fertilizer N by maize and bean crops over a period of four seasons. Maize was planted during the long rains while beans were planted during the short rains. Labelled 15N fertilizer (10%

atom excess) as calcium ammonium nitrate at 60 kg/ha was applied to the maize at the 7th leaf stage. Soils were collected at the depths of 0-20, 20-50, 50-100, 100-200 and 200-300 cm three times per season and analyzed for mineral N (NH4-N + NO3-N) and total N. Dry matter yields, plant N uptake and 15N recovery was determined at the end of each season. Results showed that the 20 cm plough layer had a substantial amount of pre-season mineral N (10-25 mg N/kg soil) that decreased as the crop matured. A bulge of mineral N (40-60 mg N/kg soil) occurred at depths below 100 cm. Combined use of organic and inorganic fertilizers gave the highest grain yields while the N content in the grain, stover and roots was highest in the plots supplied with chemical fertilizers. The fractions of N in the grain derived from labelled fertilizer N (ndff %) was low in the range of 11-15%. The stover contained 12-19% while the roots took up 11-18%. Only about 10% was found in the top 20 cm soil layer at the end of the season while the rest (>40%) was unaccounted for. The fertilizer use efficiency for all treatments was low (20-32%). This cropping system is not sustainable as it leads to a substantial loss of mineral N through leaching. Rotation of annual crops with deep-rooted short fallows is a promising way of capturing sub-soil N.

Kimani, S. K, Macharia J. M, Odera, M. M, Kathuku, A. N, Kaiyare, J, Wakaba, P. (2005). Economic evaluation of organic and mineral sources for replenishing soil fertility. KARI-Muguga South, Kenya, Annual Report 2005 pp 118-126

In order to make low-external input technologies sustainable, there is need to evaluate their economic and social trade-offs under different agro-ecosystems, and their adaptability to different smallholder farming systems. It has been established that small-scale, resource poor farmers use organic fertilizer materials extensively. Little work has been done on costs and benefits associated with adoption of such technologies. A study was carried out to verify economic viability of low-external input technologies such as Farm Yard Manure, composts, green manure cover crops and maize stovers. The study was conducted in 2004 in Kiambu, Marangwa and Kirinyaga districts of central Kenya. Partial Budgeting Analysis Model was used to determine Net Present Values (NPV) from different technologies based on an agronomic trial conducted in 2003. NPVs displayed present worth of benefits and costs streams from investing in different technologies. From Relative Agronomic Evaluation (RAE), it was clear that application of increasing levels of any input, there was an increment in yield indicating that soils were lacking in that particular nutrient being applied. In both sites, as the levels of inorganic N increases, yields increased dramatically up to application of 40-60 kg N/ha. Beyond this level, little increments were recorded. From partial budgets, it has been observed that treatments that gave the highest yields were not necessarily the most economical ones. The study found manure at 5 t/ha plus 60 kg N/ha more economical than the other technologies in Marangwa and Kirinyaga, while in Kiambu manure at 5 t/ha plus 20 kg N/ha was found to be the most economical.

Mangale, N., Mzingirwa, A. M. and Katama C. K. (2005). Verification of the effect of different soil amendments on the soil chemical and physical properties, weed density and diversity on farm. KARI-Mtwapa, Kenya, Annual Report pp 14-16

Most of the soils in the coastal region are sandy, low in organic matter and have a low inherent fertility and water holding capacity. A study was carried out in Mtwapa, where eight different soil fertility replenishment sources were used and four different weedings were tested. The study carried out between 2003 and 2004 aimed at determining the effects of application of different manures on soil physical and chemical properties and weed species density and diversity. The results showed that the area was deficient in Nitrogen (N), extractable phosphorus (P), potassium (K), Magnesium (Mg), Zinc (Zn) and Copper (Cu) and organic carbon. Combining the farmyard manure with inorganic fertilizers resulted in the highest maize grain yield. Combining poultry manure and goat manure increased maize grain yield over the control but slightly less than using goat and poultry manure singly. Application of inorganic fertilizer and farmyard manure singly increased maize grain yield over the control but slightly less than the other treatments. Weeding twice resulted in the highest maize grain yield, confirming previous findings that the practice is necessary for one to realize high yields. Due to imposition of weeding regimes onto the manure and inorganic fertilizer treatments, maize grain yields were much lower. Thus organic and inorganic combination accompanied by weeding twice has the potential for high maize grain yields in the coastal region.

Mavuthu, A. K. (2005). Effects of coppicing and non-coppicing improved fallow specie son soil inorganic nitrogen and *Striga hermonthica* in western Kenya. Msc. Thesis, Moi University

Striga (*hermonthica*) weed in the inherently infertile soils of lake Victoria Basin has become a real threat and the largest biological barrier to the production of staple food crops in western Kenya. The use of short duration improved fallows with non-coppicing leguminous trees and shrubs have been found to improve soil fertility, control striga weed and increase crop yields. The objective of this study was to assess the efficacy of coppicing improved fallow species in controlling striga compared to non-coppicing ones that require re-establishment in every planting season. A study was conducted in western Kenya in 2001 to assess striga emergence following

field trials with three coppicing tree species, Gliricidia (*Gliricidia sepium*), Leucaena (*Leucaena trichandra*) and Calliandra (*Calliandra calothyrsus*) and three non-coppicing tree/shrub species, Sesbania sesban-sesbania, Mucuna (*Mucuna pruriens*) and Tephrosa (*Tephrosa vogelli*) that were established in March 2000. Other treatments included: natural fallow-NF, continuous cropping without fertilizer-CC-F, and continuous cropping with fertilizer-CC+F. All plots were split into two, with one half receiving nitrogen (N), at 60 kg N/ha and the other at 0 kg N/ha. Soil inorganic N content was significantly higher ($p<0.001$) in the coppicing fallows (48.8 kg N/ha for +N and 43.2 kg N/ha for -N sub-plots) than in the non-coppicing fallows (37.3 kg N/ha for +N and 33.7 kg N/ha for -N sub-plots). Inorganic N content in the controls was 29.8 kg N/ha for +N and 26.1 kg N/ha for -N sub-plots. At the start of long rainy season of 2001, initial striga seed count in the soil following maize crop was determined and ranged from 42 to 188 seeds/kg of soil. In the long rainy seasons of 2001 and 2002, striga density (emergent shoots m-2) was determined and compared. After the long rainy season of 2002, percentage decline of Striga density in comparison to the density in 2001, was calculated and found to be highest in the coppicing fallows (68.6% for +N and 60.2% for -N sub-plots), intermediate in the non-coppicing fallows (60.8% for +N and 53.1% for -N sub plots), and lowest in the controls, (47.7% for +N and 45.7% for -N sub-plots).Treatments that had the highest inorganic N content caused the greatest decline of striga density. Maize grain yield in the long rainy season of 2002 was in the decreasing order: 6.5 t/ha for the +N and 5.1 t/ha for the -N coppicing fallows, 5.9 t/ha for the +N and 4.9 t/ha for the -N non-coppicing fallows. The yield was least in the control treatments (3.0 for +N and 2.2 for -N sub-plots). The results of this study suggest that improved fallows of coppicing species are better than those of non-coppicing species in replenishing soil inorganic N, controlling striga weed and improving maize crop yield. Farmers in striga infested areas are recommended to use coppicing improved fallow species as a control measure.

Nafuma, L. S., Maina, M. P. D., Njau, P. N., Karanja, L. S. and Kamwaga, J. N. (2005). Strategic combination of crop residue management, lime, fertilizer and varieties to enhance wheat production on acid soils of Kenya. Annual Report 2005 pp 55-57, Kenya

Poor fertility of acidic soils is due to a combination of mineral toxicities (aluminum and Manganese) and deficiencies (phosphorus, calcium, magnesium and molybdenum). Al toxicity has been singled out as the most important factor, being a major constraint to crop production. Although acid soil problem can be remedied by surface application of lime, this is often not economical or physically feasible. Hence combining the use of acid soil tolerant cultivars with liming is often the most effective strategy for improving crop production on acid soils. The maintenance of high organic matter content in soil also plays an important role in regulating the harmful effects of acid soils to crops. High organic matter content helps to maintain a uniform pH in the soil and forms stable complexes with Al and Mn, thus buffering the availability of these elements to higher plants and preventing toxicity. A study was carried out to investigate a combination of crop residue management, lime, fertilizer and wheat varieties. The main purpose of the study was to identify the best and sustainable combination of crop residue management, lime, fertilizer and varieties that can increase wheat production on acid soils of Kenya. Soil analysis results indicated that the soil at the experimental site was acidic and deficient in Nitrogen (N) and phosphorus (P). Liming of soil did not significantly ($P>0.05$) influence wheat yield and yield components at both recommended and double recommended rates during the first year. Due to lack of rains, application of N and P had no influence on the low organic matter and low fertility soils of Njoro. Improved wheat variety NBW2 showed positive response that could be exploited to overcome the acid soil problem.

Thuita M.N., Okalebo J. R., Othieno C. O., Kipsat M. J., Bationo A., Sanginga N. and Vanlauwe B. (2005). An attempt to enhance solubility and availability of phosphorus from phosphate rocks through incorporation of organics in western Kenya. African Crop Science Conference Proceedings, Vol. 7. pp. 1021-1027

Soil fertility depletion has been identified as the most significant constraint to increased agricultural productivity in Western Kenya. Many years of continuous cultivation without nutrient returns have resulted in the depletion of native soil fertility and subsequent decline in productivity. Soils are widely deficient in nitrogen (N) and phosphorus (P). Phosphate rocks (PRs), though generally insoluble, are thought to have improved solubility and hence increased P availability when incorporated into soils with organic materials. However, the quality and quantity of organic materials influence PRs solubility. An experiment was conducted between March 2004 and January 2005 at Nyabeda, Siaya district western Kenya in which two east African PRs, Minjingu (MPR) and Busumbu (BPR) were compared. Both were applied at a rate of 60 kg P/ha each and a similar rate was used for a standard P source of Triple superphosphate (TSP) for comparison. N was applied at 75 kg / ha. Four local organic materials were tested and incorporated into soils at the rates of 1 and 2 t/ha each. Control with no P or N and farmers' manure treatment were also included. Planting was done using staggered two rows of maize and two legume (soybeans) rows spacing (MBILI intercropping system). Soil sampling was done monthly for the determination of available P and pH to assess P release (solubility) from PRs. The data collected analyses were done using SPSS 12.0 for Windows. Economic analyses related to use of materials were also done. There were

significant differences (p³ 0.05) in the treatments on maize yields. The control was the lowest yielder (<200 kg / ha) while MPR and TSP had the highest yields (>3 t/ha). BPR was not significantly different from farmers manure although they were both positively different from the control. MPR with organics showed comparable yield results, as there were no significant differences between it and TSP on yield. *Lantana camara* and pyrethrum industrial waste were the most promising organic materials and further trials should be done, particularly on unreactive BPR. It is recommended that studies be done in other areas with similar soil conditions and chemical studies to identify the organic acids in these materials and their specific roles in the PR solubilization.

Wandahwa P. and Tabu I. M. (2006). Effect of intercropping and fertilizer type on growth and yield of Soybean. *Agronomy, Journal* (1): 69-73

Studies were conducted at the Kenya Agricultural Research Institute in 2002 to determine the effect of intercropping and fertilizer type on the growth the growth and yield of soybeans. The treatments included cropping system (sole and intercropped soybean with maize), Varieties (no-herbaceous) and fertilizer type (organic and inorganic). The experiment was laid out as split-split plot in a randomized complete block design with three replications. Cropping system formed the main plots, the varieties sub-plots and fertilizer the sub-plots. Results showed a significant variety by cropping system interaction. Non herbaceous variety yielded significantly higher as a sole crop. Inorganic fertilizer significantly depressed the growth and yield of soybean in season II because of the salt effect on plant germination. To improve soybean production, account should be taken of variety of morphological characteristics, cropping system and initial fertilizer type during a particular season.

Ademba, J., Obaga, S., Kidula, N., Tong, I. E. R. N. (2004). Determination of the residual phosphorus and its effects in soils of smallholder mixed farms of Kisii and Rachuonyo Districts. Kenya Agricultural Research Institute-Kisii. Annual Report 2004 pp 22-26, Kenya

A study was carried out in Bototo "B" in Kisii district and Kabondo in Rachuonyo district to study residual phosphorus and its effect in soils of smallholder farm. Soil tests were carried out in the experimental sites prior to nutrient applications. Phosphorus was supplied by Diammonium phosphate (DAP), Rock phosphate (RP) and Triple superphosphate (TSP) applied at 60 kg P_2O_5/ha and farmyard manure at 10 t/ha. Maize was grown as a test crop. The results showed a wide spread phosphorus (P) and Nitrogen (N) deficiencies in Kabondo but in Bototo "B" only P was deficient while all the sites showed acidic soil characteristics. A combination of Diammonium phosphate and farmyard manure gave the highest maize yields.

Ayuke, F. O., Rao, M. R., Swift, M. J. and Opondo-Mbai, M. L. (2004). Effect of organic and inorganic nutrient sources on soil mineral nitrogen and maize yields in western Kenya. In Andre Bationo (Ed.) *Managing nutrient cycles to sustain soil fertility in sub-Saharan Africa. Academy Science Publishers*, Nairobi, pp. 66-76

The effects of organic and inorganic fertilizers on soil mineral N and maize yields were evaluated in a Kandiudalfic Eutrodox soil of western Kenya. Leaf biomass of Tithonia (*Tithonia diversifolia* [Hemseley] A. Grey) and Senna (*Senna spectabilis D.C & H.S. Irwin*) at 5 t/ha dry weight were incorporated into the soil and compared with the response obtained from control without any input and fertilizer at 120 kg N, 150 kg P and 100 kg K/ha from urea and Triple superphosphate (TSP). Soil mineral (inorganic), N, was measured at the beginning of the trial and subsequently at 1,2,3,4 and 12 weeks after applying the treatments. Maize grain and stover yields were estimated at harvest. Total inorganic nitrogen in the soil at the beginning of the season was at a similar level in all treatments. It increased rapidly after applying the materials and at the onset of rains for all treatments probably because of rapid nitrogen mineralisation in all treatments. After four weeks, inorganic nitrogen decreased progressively until the end of the experiment in all the treatments. The highest contribution of mineral N to the soil by the organic residues was noted at four weeks stage and this was significantly higher with Tithonia than Senna. This could be due to rapid N mineralisation by these residues. Senna treatment that had the lowest mineral N during the first weeks of the trial, showed that N mineralisation was slow with the mineral N reaching highest level at the four-week stage. However, it is interesting to note that while soil N under Tithonia was statistically higher than in Senna at four weeks, it was higher under Senna at later stage observations. Thus Tithonia decomposed completely in about four weeks, while Senna was still mineralising at 8 weeks. Fertilizer use increased maize grain yield by 63% over the control. Although Tithonia biomass increased maize grain yield by 38% over the control and did not differ significantly from fertilizer treatment, Senna increased maize yield by only 6% over the no input control. Higher yield with Tithonia than Senna was partly because of higher nutrients added for the same quantity of material applied. The study indicates that high quality residues such as Tithonia can be used as sources of nutrients to improve crop yields.

Buigutt, J. C, Kipkech, F. C. and Moi, T. K. (2004). Potential of using farmyard manure to improve soil fertility in a maize/bean intercrop in the drylands. *Proceedings of the 7th Biennial Scientific Conference* 11-15th November 2002 at KARI Headquarters, Kenya. pp 235-241.

Low soil fertility is a limiting factor in maize and bean production in ASAL areas is a pertinent topic for investigation owing to the importance of the crops as stable food as well as sources of income and employment for the increasing population by immigration from the congested a highlands. The use of readily available and cheaper sources of plant nutrients such as farm yard manure (FYM), under the common practice of intercropping is one way of sustaining agricultural production in the drylands. This study was conducted in LM5 (under irrigation) and LM5 (under rainfed) Agro-ecological zones of Baringo District to determine the potential of use of FYM and bean intercropping to improve soil fertility for higher maize yields. The results showed that the maize pure stand produced the highest yields of 3.2 t/ha under DAP though this were not significantly different with FYM, FYM+CAN and No fertiliser treatments. Under intercrop, the highest maize yields of 2.8 t/ha was obtained under FYM+CAN. Economic analysis showed that the beans pure stand gave the highest net benefits followed by the intercrop and lastly the maize pure stand. Results further showed that low crop yield coupled with low prices renders Katumani maize variety uneconomical to be grown under irrigation and that the higher yielding hybrids (e.g. H513) using FYM+CAN could be more profitable to farmers in both zones.

Bunemann E.K., Smithson, P.C., Jama, B., frossard, E. and Oberson, A. (2004). Maize productivity and nutrient dynamics in maize fallow relations in Western Kenya. *Plant and Soil*

One season fallows with legumes such as crotalaria (*Grahamiana wight & Arn*) and phosphorus (P) fertilization have been suggested to improve crop yield in Sub-Saharan Africa. Assessing the suitability of these measures requires a sound understanding of soil processes especially transformations of P which is often the main limiting nutrient. We compared plant production nitrogen (N) and P balances and selected soil properties during 5.5 years in a field with three crop rotation (continuous maize , maize-crotalaria and maize natural fallow rotations) and at two levels of P fertilization (0 and 50 kg P/ha/yr applied as triple Superphosphate) on a Kandiudalfic Eutrudox in Western Kenya. The maize yield forgone during growth of the crotalaria was compensated by higher post fallow yields but the cumulative total maize yields was not significantly different from continuous maize. In all crop rotations P fertilization doubled total maize yield, increased N removal by maize and remained without effect on amounts of cycled biomass. Crotalaria decreased in the course of the experiment due to P set problems. The highest levels of organic and microbial C, N and P were found in the maize - crotalaria fallow rotation. The increase in organic P was not accompanied by a change in resin-extractable P while H_2SO_4- extractable inorganic P was depleted by up to 38 kg P/ha (1% of total P) in the 0-50 cm layer. Microbial P increased substantially when soil was supplied with C and N rather than P availability. Maize legume fallow rotations resulted in a shift towards organic and microbial nutrients and have to be completed by balanced additions of inorganic fertilizers.

Gachimbi L. N., Maina F., Obanyi S. N., Onduru D. D. and Muchena F. N. (2004). Evaluation of Organic, Inorganic Fertilizers and Tithonia (*Tithonia diversifolia*) on maize performance in Nitisols of Central Kenya: A Farmer Field School approach. Kenya Agricultural Research Institute; Technical report Nairobi, Kenya

At Ngaita FFS, the treatment that should be adopted is use of manure + DAP+CAN which is the farmers practice. However, the use of lime to correct the soil acidity is of immediate action and that explains the favourable response by manure. Use of Tithonia at planting and top-dressing with Tithonia, tea offers another option to use of mineral fertilizers. This is because it may be cheaper than mineral fertilizers. If rains are not adequate, then use of water harvesting techniques should be adopted together with use of manure to retain the water in the soil for longer period. Alternatives such as use of rock phosphate should be explored to provide phosphorus nutrient, which is low or use 250 kg/ha of triple super phosphate during planting time and then top dress with CAN at knee high at 80 kg/ha for maize crop. Integrated Nutrient Management (INM) approach to soil fertility management and maintenance should go a long way in increasing crop yields as well as improving nutrient use efficiency.

Gikonyo E. W. and Smithson P. C. (2004). Effects of farm yard manure, potassium and their combinations on maize yields in the high and medium rainfall areas of Kenya. *In: Andre Bationo (eds); Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa.; Academy Science Publishers (ASP) in association with the Tropical Soil Biology and Fertility Institute of CIAT*; Nairobi Kenya 2004 Volume 98 pp 11-33

A national Fertilizer use Recommendation Project (FURP), conducted trials in 71 sites in 32 districts of Kenya to monitor the effects of potassium (K) and farmyard manure (FYM) on maize yields. The trials were in 36 sites in different agro-ecological zones with widely varying soil characteristics. Out of 36 sites, 8 responded to K, with 4 sites responding positively and an equal number negatively. Maize yield increases due to K ranged between 0.6 to 1.0 t/ha. Farmyard manure significantly increased yields in 13 sites by about 0.46 to 1.3 t/ha (P=0.01-4.58). The yields were significantly improved by a combination of FYM and K in only 4 sites (P=2.5-4.95). Response

to inorganic K was in most cases reduced by manure application probably due to excessive K resulting from the additional K supplied from the manure. Results from one site that received linear K levels from 0 to 75 kg K_2O/ha, indicated that the K response to 50 kg K_2O/ha was almost equalled by 5 t/ha FYM. This suggests a supplemental effect of K by manure, hence no yield benefits of applying K fertilizers and manure combination.

Kimetu, J. M., Mugendi, D. N., Palm, C. A., Mutuo, P. K., Gachengo, C. N., Nandwa, S. and Kungu, J. B. (2004). Nitrogen Fertilizer Values for Different Organic Materials based on Maize Performance at Kabete, Kenya. *In André Bationo (Ed). Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa. Academy Science Publishers (ASP) in association with the Tropical Soil Biology and Fertility Institute of CIAT* pp 207-223 ISBN: 9966-24-075-6

Decline in crop yields has been a major problem facing small holder farming in Kenya and the entire sub-Saharan region. This is attributed mainly to the mining of macronutrients due to cropping without external addition of adequate nutrients. Inorganic fertilizers are expensive hence unaffordable by most small holder farmers. Although organic nutrient sources are available, information about the right proportion of application is scanty. An experiment was set up in 1999 at the National Agricultural Research Laboratories (NARL) at Kabete, with the overall objective of determining nitrogen fertilizer equivalencies based on high quality organic inputs. The specific objectives of the study included determination of the nitrogen fertilizer equivalency values of *Tithonia diversifolia*, *Senna spectabilis* and *Calliandra calothyrsus* and the investigation of nitrogen use efficiency from combined organic and inorganic inputs. The experiment consisted of maize plots to which freshly collected leaves of Tithonia (*Tithonia diversifolia*), *Senna spectabilis* (senna) and Calliandra (*Calliandra calothyrsus*) (all with %N>3) obtained from hedgerows grown ex situ (biomass transfer from outside) and urea (inorganic nitrogen source) were applied. Results obtained indicated that a combination of both organic and inorganic nutrient sources gave higher maize grain yield than when each is applied separately, except for Tithonia whose sole application gave better grain yield than a combination of the same with mineral fertilizer. Maize grain yield production after organic and inorganic application was in the order of tithonia>tithonia+urea=calliandra+urea>urea>senna+urea>calliandra>senna>control. The percentage N recovery was highest in sole application of urea followed by a combination of both urea and Tithonia while sole application of Tithonia biomass had relatively lower percentage N recoveries. In both seasons, the mineral N content was high in sole application of Tithonia than in senna and calliandra treatments. The three organic materials (senna, calliandra and Tithonia) gave fertilizer equivalency values of 68%, 72% and 119% respectively.

Kimetu, J. M., Mugendi, D. N., palm, C. A., Mutuo, P. K., Gachengo, C. N. and Bationo, A. (2004). Nitrogen fertilizer equivalence of organics of differing quality and optimum combination with organic nitrogen source in central Kenya. *Nutrient cycling in agro-ecosystem, Kluwer academic publishers* Vol. 68:127-135

Diligence in crop yield is a major problem facing smallholder farmers in Kenya and the entire Sub -Saharan region. This is attributed mainly to the mining of major nutrients due to continuous cropping without addition of adequate external nutrients. In most cases, inorganic fertilizers are expensive hence unaffordable to most smallholder farmers. Although organic nutrient sources are available, information about their potential use is scanty. A field experiment was set up in the sub humid-highlands of Kenya to establish the chemical fertilizer equivalency values of different organic materials based on their quality. The experiment consisted of maize plots to which freshly collected leaves of Tithonia (*Tithonia diversfolia*) Senna (*Senna spectabilis*) and Calliandra (*Calliandra calothyrus*) (all with % N > 3) obtained for the cumulative above ground biomass yield for three seasons indicated that of both organic and inorganic nutrients source gave higher maize biomass yield than when each was applied separately. Above ground biomass yield production i maize (t/ha) from organic and inorganic fertilization was in the order of Senna + urea (31.2) Tithonia + urea (29.4) Calliandra + urea (29.4) Calliandra + urea (29.3) Tithonia (28.6) Senna (27.9) urea), Calliandra (25.9) and control (22.5). For three cumulative seasons on average the three organic materials (*Calliandra and Tithonia*) gave fertilizer equivalency values can be attributed to the synergetic effects of nutrients supply and improved moisture and soil physical conditions of the mulch. However for sustainable agricultural production combination with mineral fertilizer would be the best option.

Kipkosgei L. K. (2004). Response of African nightshade (*Solanum villosum*) and spider plant (*Cleome gynandra*) to farmyard manure and calcium ammonium nitrate fertilizer and pest infestation in Keiyo district Kenya. MSc. Thesis; University of Nairobi, Kenya

The African Leafy Vegetables (ALVs) are particularly important as adjunct accompaniment to the staple cereal foods such as the East African corn meal (Ugali). In the context of hidden hunger, these local vegetables do play a significant role in food security. Unfortunately exploiting the full potential of these crops has been hampered by lack of interest of policy makers, researchers, extension workers as well as farmers themselves, a situation that has contributed to food insecurity, malnutrition among resource poor farmers. In order to increase productivity and utilization of these ALVs there is need to develop agronomic practices suited for farmers in specific agro-ecological zones. A study was carried out with an objective of determining the effects of various levels of farmyard manure (FYM) and Calcium Ammonium Nitrate (CAN) on vegetative growth, yield and quality (vitamins A &C, nitrates,

iron, calcium, zinc, manganese and potassium) of *solanum villosum* and *Cleome gynandra* in Keiyo district. Effects of prolonged cooking by the Keiyos on the quality of these vegetables were also determined. The study was conducted between the long rains and short rains of the Year 2002. Several insect pests were also identified and the damage they cause to these vegetables assessed. The experimental layout in the field was a RCBD with four replicates. The treatments were set at four levels of farmyard manure (5, 10, 15, 20 t/ha) and four rates of Calcium Ammonium nitrate fertilizer (100, 200, 300, 400 kg/ha). Results revealed that the addition of various rates of farmyard manure and calcium ammonium nitrate that were tested significantly improved vegetative growth and increased leaf and seed yields of both *solanum villosum* and *Cleome gynandra* ($p<0.05$). Both leaf and seed yields obtained from plants grown with farmyard manure were generally higher than those with CAN fertilizer. The incorporation of either farmyard manure or CAN fertilizer increased vitamin A content. The farmyard manures increased vitamin C while the application of CAN fertilizer decreased vitamin C. The application of 300 kg/ha of CAN fertilizer increased the accumulation of nitrates, while the farmyard manure did not. The addition of various rates of FYM and CAN fertilizers did not significantly affect the concentration of zinc, manganese and potassium in both plants ($p<0.05$). The incorporation of either farmyard manure or CAN fertilizer decreased iron content in both vegetables. In all experiments, the farmers' crop in all attributes though better than the controls, was comparable to low fertilizer levels applied. Traditional methods of boiling the ALVs for long significantly reduced vitamin A & C, nitrates, iron, calcium, zinc, manganese and potassium. The two vegetables were found to be attacked by a total of twelve insect pests. These were Cutworms (*Agrotis spp*), black aphids (*Aphids fabae*), cotton aphids (*Aphis gossypi*), Leaf miner (*Lyriomyza spp*), Red spider mites (*Tetranchus spp*), Root-Knots nematodes (*Meloidyne spp*) Flea beetles (*Chrysomelidae spp*), Epilanchna beetles (*phytophagous Lady Birds*), Diamondback moth (*plutella xylostella*) African bollworm (*Hellicoverpa armigera*), Systates weevils (*systates pollinosus*) and flea beetles (*Chrysomelidae spp*). Most pest species were recorded at 8th week after planting. In conclusion the kind and rate of fertilizer applied, the season of growth, plant age, farmers agronomic practices as well as cooking influenced the quality attributes of *Solanum villosum* and *Cleome gynandra*, significantly ($p<0.05$). This investigation shows that *Solanum villosum* and *Cleome gynandra* is liable to attack by a large variety of insect pest species.

Micheni, A., Kihanda, F. and Irungu, J. (2004). Soil Organic Matter (SOM): The Basis for Improved Crop Production in Arid and Semi-Arid Climates of Eastern Kenya. *In André Bationo (Ed). Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa. Academy Science Publishers (ASP) in association with the Tropical Soil Biology and Fertility Institute of CIAT* pp 239-248, ISBN: 9966-24-075-6

Soil organic matter (SOM) plays an important role in maintaining physical, chemical and biological properties of the soil, and therefore the crop productivity. A study was conducted in arid and semi-arid lands (ASALs) of eastern Kenya to assess the influence of SOM on crop productivity after 10 years of application of high quality goat manure. The manure was acquired from a single source where same breeds and flock management were maintained throughout the experimentation period. The manure contained 0.48% P, 2.04% N and 25.62% C, and was annually applied at 0, 5 and 10 tons ha-1 in soils where continuous cultivation was a common practice. The residual effects of manure were monitored after discontinuation of 4 years manure application. Also, inorganic fertilizers to supply phosphorus (P) and nitrogen (N) were applied to compare the potency of long-term SOM maintenance and inorganic fertilizers on crop performance. The observed maize yields were compared with simulated (predicted) values from modelling using the Agricultural Production Systems Simulator (APSIM) model. The results showed that both the application of manure and mineral fertilizers improved crop total dry matter, and discontinuation of annual manure application led to run-down trends in crop yields. A general conclusion made from the study was that, it is worthwhile in terms of crop productivity to maintain SOM through annual application of high quality manure at 5 tons/ha in ASALs where continuous cultivation is practiced.

Muriithi L. M. M. and Irungu, J. W. (2004). Effect of integrated use of inorganic fertilizer and organic manures on bacterial wilt incidence (BWI) and tuber yield in potato production systems on hill slopes of central kenya. *Journal of Mountain Science* Vol 1 No 1 (2004): 81-88. Article ID: 1672-6316 (2004) 01-0081-09

Bacterial wilt (BW) caused by *Ralstonia solanacearum* is one of the most damaging diseases of potato (*Solanum tuberosum L.*) in Kenya and worldwide. In Kenya, potato tuber yield losses due to BW infection are estimated at 50 ~ 100%. Low soil fertility is also one of the most important constraints limiting potato production in central Kenya highlands. Farmers tackle this problem through use of inorganic fertilizers and organic manures, both of which amend the soil environment to influence bacterial wilt development. Un-decomposed organic manures can also introduce the pathogen into a clean field. Between short rains 1999 and 2000, 10 on-farm extension-researcher farmer- designed and farmer-managed trials were done at Kianjuki catchment in Embu District. The objective was to use farmers' participatory research approach and select the most suitable organic and inorganic fertilizer combination(s) with lowest BWI and acceptable usable tuber yields, and also to demonstrate use of some components of integrated disease management methods in reduction of disease incidence and spread. Seven

treatments were proposed, presented to the farmers for discussion and the most relevant four were selected for evaluation. A newly released potato variety 'Asante' was planted during the short rains 1999 and long rains 2000. BWI didn't result in significant differences between treatments but the tuber yields were significantly different in short rains of 1999 and 2000. During short rains 2000, both BWI and tuber yields and unusable tubers differed significantly between treatments. The results confirmed that well decomposed manures or manures from pathogen-free areas can be used in combination with inorganic fertilizers to improve soil fertility and potato tuber yields in smallholder farms without influencing BWI. Use of certified seed tubers in pathogen free field and following recommended field sanitation measures resulted in apparently bacterial wilt free crop. Considering the high cost of inorganic fertilizer and its negative effects on the environment, reduced usage at half the recommended rates combined with half rates of FYM is feasible option friendly to the farmer, soil and environment. The interviewed farmers also ranked the option as the most appropriate combination for soil fertility improvement for potato production in smallholder farms.

Nziguheba, G, Merckx, R, Palm, C. A. and Mutuo, P. K. (2004). Combined use of Tithonia and Inorganic Fertilizers for Improving Maize Production in a Phosphorus Deficient soil in western Kenya. *In André Bationo (Ed). Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa. Academy Science Publishers (ASP) in association with the Tropical Soil Biology and Fertility Institute of CIAT* pp 329-345 ISBN: 9966-24-075-6

The ability of *Tithonia diversifolia*, fertilizers and their combination to improve maize production in a phosphorus (P) deficient ferralsol was compared in western Kenya. Tithonia and fertilizers were applied separately or combined in different proportions to give equal rates of 165 kg N/ha, 15.5 kg P/ha and 155 kg K/ha in two consecutive maize growing seasons, followed by two residual maize crops. Maize grain yields and P recovered in the above-ground biomass were higher in sole Tithonia than sole fertilizer treatments. Maize yields increased with increasing rate of Tithonia in the mixed treatments. When less than 36% of the total P applied in the mixture were supplied by Tithonia, there was no added yield benefit in the combined treatments compared to the sole fertilizer treatments. However, an added value ranging from 18 to 24% increase in yields was observed at higher Tithonia rates. Economic returns were larger from the application of Tithonia alone than the application of sole fertilizers, with larger profit when Tithonia was collected from existing niches than when produced on site. Collecting Tithonia from current niches resulted in larger net returns from all combined treatments than from fertilizers. The results of this study indicated that a high quality organic residue such as Tithonia can increase maize production to a greater extent than fertilizers. The combination of Tithonia and fertilizers can be an alternative to scarce resources and an added benefit can be obtained by maximizing the proportion of Tithonia in the mixture.

Nziguheba, G., Merckx, R., Palm, C. A. and Mutuo, P. (2004). Combined used of Tithonia diversifolia and inorganic fertilizers for improving maize production in a phosphorus deficient soil in western Kenya. *In: Bationo A. (Ed) Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa*. Academy Science Publisher PP: 330-345

The ability of *Tithonia diversifolia*, fertilizers and their combination to improve maize production in phosphorus (P) deficient Ferralsol was compared in western Kenya. Tithonia and fertilizers were applied separately or combined in different proportions to give equal rates of 165 kg N/ha and 155 kg K/ha in two consecutive maize growing seasons, followed by two residual maize crops. Maize grain yields and P recovered in the above-ground biomass were higher in sole Tithonia than sole fertilizer treatments. Maize yields increased with increasing rate of Tithonia in mixed treatments. When less than 36% of the total P applied in the mixture were supplied by Tithonia, there was no added yield benefit in the combined treatments compared to the sole fertilizer treatments. However, an added value ranging from 18 to 24% increase in yields was observed at higher Tithonia rates. Economic returns were larger from the application of sole fertilizers, with larger profit when Tithonia was collected from existing niches than when produced on site. Collecting Tithonia from current niches resulted also in larger net returns from all combined treatments than from fertilizers. The combination of Tithonia and fertilizers can be an alternative to scarce resource and added benefit can be obtained by maximizing the proportion of Tithonia in the mixture.

Okalebo J. R., Palm C. A., Lekasi J. K., Nandwa S. M., Othieno C. O. Waigwa M. and Ndung'u K.W. (2004). Use of organic and inorganic resources to increase maize yields in some Kenya infertile soils: A Five-Year Experience. *In: Andre Bationo (Eds). Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa. Academy Science Publishers* (ASP) pp: 355-372

Use of organic and inorganic resources to increase and sustain agricultural productivity of soils has been practised worldwide over a long period. Positive effects from these materials are known to be the enhanced nutrient inputs to soils and improved soil physical and biological properties. Effects of separate or individual and combined application of organic materials to soils have been studied rather extensively and the results are complex. But

it appears for certain, that the quality and quantity attributes are the driving forces towards basic processes in soils such as nutrient mineralisation and release and the overall effectiveness of added materials on crop yields. However, many studies have considered mainly the immediate or seasonal effects of organics and inorganics on crop yield. Therefore the monitoring of soil process studies in relation to crop growth and yield, as well as considerations on economic benefits arising from the use of theses external resources seem to have been slighted. In this paper we present results of field studies at four on-farm, researcher managed sites that vary widely with climate and soils (Acrisols, Ferralsols and Luvisols). In 1994 first rains, the effectiveness of crop residues (maize stover, groundnut trash and *acacia mearnzill* prunings) on-farm, manures and Minjingu phosphate rock (PR) was tested on maize yields at Ndeiya, Gatuanyaga and Malava sites. The organics above were incorporated into soils individually or in combinations giving a target or economical rate of 60 kg N/ha, while the PR was added at a uniform rate of 40 kg P/ha in various combinations of the organics. Maize yields in that season ranged from 1256 - 3761 kg/ha (at Ndeiya and Malava sites only with adequate rainfall). Although maize yields increase did not attain statistical significance, the high N organics (poultry manure, Acacia *(Acacia mearnzii*) and groundnut trash), with PR combinations, gave overall high yields increase. The study period was too short to monitor residual effects of treatments and solubilisation of PR. But in the Chepkoilel Campus ferrasol (Moi University), maize has been cropped over four consecutive years (1997-2000) in plots receiving annual maize stover, wheat straw and initial superphosphate application of 100 kg Pha^{-1} plus combinations from 20-100 kg N/ha. Maize yields over the entire study period have ranged from 751-6836 kg/ha with significant variations occurring from rainfall variations. Nevertheless, again the combined application of organic and inorganic resources favoured maize production. There are favourable effects of the materials used to improve the soil fertility status of soils. The results suggest an economic potential, to the smallholder farmers, arising from combined use of organic and inorganic resources.

Ojiem J. O., Palm C., Okwuosa E. A. and Mudeheri M. A. (2004). Effect of combining organic and inorganic phosphorous sources on maize grain yield. In: Bationo A (Ed) Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa. AfNet-CIAT, Academy science

The western Kenya soils are typically low in fertility due to continuous cropping with inadequate fertilizer use. A three-year experiment was conducted to investigate the effect of combining organic and inorganic Phosphorus (P) sources on maize grain yield in a P deficient (2ppm) experimental site at the Regional Research Centre, Kakamega, Western Kenya. The design was a randomized Complete Block, replicated three times. Farmyard manure (FYM) and triple super Phosphate (TSP) were combined at the ratios 0:100, 25:75, 50:50 and 100:0 to attain 30 kg P/ha and applied at planting to all plots except the control plot which received no P. To prevent Nitrogen (N) and Potassium (K) deficiencies confounding P responses was toped up to top-dressed in equal splits at 3 and 6 weeks after maize emerges, while K (KCI) was applied at planting. Maize grain yield was determined at 13% moisture content and plotted against organic-inorganic P treatments to determine the response pattern. Non-linear regression analysis was then performed to estimate their effects of organic and inorganic P. Grain yield was significantly higher (p=0.05) with P than without and sole organic P was comparable to sole inorganic P. Grain yield responses best fitted quadratic functions and the regression coefficients estimating organic P, inorganic P and the interaction were significant (p=0.05), indicating real FYM and TSP effects and synergy between them. The results demonstrated grain yield benefits of integrating organic and inorganic P sources.

Okalebo, J. R, Palm, C. A., Lekasi, J. K., Nandwa, S. M., Othieno, C. O., Waigwa, M. and Ndungu, K. (2004). Use of organic and inorganic resources to increase maize yields in some Kenyan infertile soils: A five-Year Experience. *In: André Bationo (Ed). Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa. Academy Science Publishers (ASP) in association with the Tropical Soil Biology and Fertility Institute of CIAT* ISBN: 9966-24-075-6 pp 359-371

Use of organic and inorganic resources to increase and sustain agricultural productivity of soils has been practiced worldwide over a long period of time. Positive effects of from these materials are known to be the enhanced nutrient inputs to soils and improved soil physical and biological properties. Effects of separate or individual and combined applications of organic and inorganic materials to soils have been studied rather extensively and the results are complex. But, it appear for certain, that the quality and quantity attributes are the driving forces towards basic processes and the overall effectiveness of added materials on crop yields. However, many studies have considered mainly the immediate or one seasonal effect of organics and inorganics on crop yield. Therefore the monitoring of soil process studies in relation to crop growth and yield, as well as considerations on economic benefits arising from the use of these external resources seem to have been slighted. In this paper we present results of field studies at four on-farm, researcher managed sites that vary widely with climate and soils (Acrisols, Ferralsols and Luvisols). In 1994 the first rains the effectiveness of crop residues (maize stover, groundnut trash and *acacia mearnzii* prunings) on-farm manures and Minjingu phosphate rock (PR) was tested on maize yields at Ndeiya, Gatuanyaga and Malava sites. The organics above were incorporated into soils individually or in combinations giving a target or economical rate of 60 kg N/ha, while the PR was added at a uniform rate of 40 kg P/ha in various combinations of the organics. Maize yields in that season ranged from 1256-3761 kg/ha (at Ndeiya

and Malava sites only with adequate rainfall). Although maize yield increase did not attain statistical significance, the high N organics (poultry manure, Acacia Mearnzii and groundnut trash), with PR combinations, gave overall high yields increases. The study period was too short to monitor residual effects of treatments and solubilisation of PR. But in the Chepkoilel Campus ferralsol (Moi University), maize has been cropped over four consecutive years (1997 - 2000) in plots receiving annual maize stover, wheat straw and initial superphosphate application of 100 kg P/ha plus combined urea combinations from 20 - 100 kg N/ha. Maize yields over the entire period have ranged from 751 - 6836 kg/ha with significant variations occurring from rainfall variations. Nevertheless, again the combination applications of organic and inorganic resources favoured maize production. There are favourable effects of the materials used to improve the soil fertility status of soils. The results suggest an economic potential, to the smallholder farmers, arising from combined use of organic and inorganic resources.

Sikuku D. N. (2004). Effect of composted farmyard manure and nitrogen fertilizer on the growth and yield of maize (*Zea Mays L.*). Msc. Thesis, University of Nairobi, Kenya

Fertilizer use in Kenya and Africa has been on a declining trend, because of high maize production-input prices relative to output prices. With increased prices of fertilizers there is need for maize production guidelines on alternative fertility management technologies for farmers. Manure is the most effective and affordable material for supplying plant nutrients (Siderus and Muchena, 1977) and its efficient management may be at a cornerstone for sustainable agriculture. Field experiments were conducted at Manor House Agriculture Centre, Kitale ,Kenya to determine the influence of farmyard manure (FYM) alone or in combination with nitrogen (N) fertilizer on soil fertility, maize growth and yield under field conditions. The experiments were laid out in a completely randomized block design with four replications over two seasons during the long rains (April-September 1998) and short rains (October 1998-March 1999). Treatments consisted of non-fertilised (control), 2.5 t FYM/ha + 45kg N/ha, 5 t FYM/ha + 30 kg N/ha, 7.5 t FYM/ha + 15 kg N/ha, composted FYM 10 t/ha dry weight) and recommended inorganic fertilizers (60 kg N/ha and 60 kg P_20_5/ha). The inorganic phosphate fertilizer was applied as di-ammonium phosphate (DAP). Inorganic nitrogen (N) fertilizer was applied as Calcium Ammonium Nitrate (CAN). The FYM was hand broadcasted and incorporated into the experimental plots one week before planting in both seasons. Soil pH and nutrient levels (% C, %N, P, K, Ca, Mg, Mn, Na), maize growth, grain yields and yield components were measured. The results revealed that the residual effect of inorganic fertilizers on soil nutrients was not superior to that of FYM treatments. The effects of the treatments on the yield components were translated into the final grain yield. The average maize on the grain yield was 10.8 and 4.3 t/ha in the first and second seasons, respectively. FYM and N interactions increased yields up to 53% and 41% over the control during the first and second crop seasons, respectively. FYM alone increased yield by 45% and 8% over the control during the first and second seasons, respectively. Approximately equal yields were obtained in maize fertilized with 7.5 t FYM/ha + 15 kg N/ha, 5 t FYM/ha + 30kg N/ha, 60 kg P_20_5 + 60 kg N/ha, 10 t FYM/ha, whereas low yields were observed with 2.5 t FYM/ha +45 kg N/ha and the control. Overall maize yields was 60% lower in season 2 compared to season 1. This work has revealed the usefulness of using FYM as a basal fertilizer in maize growing with equally good results. The slow-nutrient (nitrogen) release from organic manure appears to supply the plant demands throughout the growing period. It can, therefore, be concluded that application of FYM improves crop yield, but may not have much beneficial effect on the fertility status of the soil. The results further reveal that the use of recommended inorganic fertilizer does not lead to an increase in yield comparable to the FYM treatments. An economic study is needed to determine the cost especially labour of FYM use and to help identify types of farming systems within which FYM is likely to be beneficial to the farmer in increasing and sustaining soil fertility.

Kwabiah A. B., Stoskopf N. C., Palm C. A., and Voroney R. P. (2003). Soil P Availability as Affected by the Chemical Composition of Plant Materials: Implications for P-Limiting Agriculture in Tropical Africa. *Agriculture, Ecosystems and Environment*. Canada, Elsevier. 100 (2003) 53-61

Plant materials that can replace costly inorganic fertilizers as phosphorus (P) sources are needed in smallholder farming systems in tropical Africa, where P is often yield-limiting. The objective of this study was to determine the relationship between the biochemical composition (quality) of plant materials, described in terms of total P, total nitrogen (N) lignin (LIG), and soluble phenolics (Pp), and soil P availability (Pav) under laboratory incubation conditions. The materials were ground and added to the soil at a rate equivalent to 10 Mg/ha (DM) and the samples (including a control soil) were kept at 50% field moisture capacity and 25°C. The anion exchange resin method was used to extract solution P periodically. Because P added was not balanced among the treatments, Pav was expressed as a percentage of total P of plant material (i.e. Pav=100*[(Pav amended soil-Pav control soil)/total P added]. Some treatments showed net P release and others showed net P uptake. The pattern of Pav was viewed in three phases (1) an initial rapid P release from the sparingly soluble inorganic P fraction of the plant material, (2) a subsequent phase when P in solution comes from both soluble P and mineralization of plant materials, and (3) a last phase when P in solution is influenced by its equilibrium with P sorption processes. Total P was the best predictor of Pav with r^2 ($P \leq 0.05$) ranging from 0.50 to 0.77. Predictive functions were developed to determine the critical quality levels for net P release and P uptake. The critical quality levels ranged from 2.0 to 2.7 g/kg for P;

156:1 to 252:1 for C/P ratio; and 7:1 to 14:1 for N/P ratio. Among the materials tested, Tithonia diversifolia and croton megalocarpus which contained total P>3.0 g/kg of total dry weight were identified as having the potential to release adequate P to replenish solution P for crop uptake.

Okalebo J. R., Mukhwana E. J., Woomer P. L. and Kimenye L. (2003). Evaluation of soil fertility replenishment technologies in Kenya. Final Technical Report 2003; Moi University, Eldoret, Kenya

Soil analyses results confirmed that the problem of low soil fertility at the selected sites was considerable. The results of compost and farmyard manure (FYM) analysis generally indicate that both amendments were potentially adequate at rates applied. However, optimal rates of fortified compost and FYM need to be evaluated further for each site of district; Crotalaria biomass yield was low in Siaya, Busia and Siritanyi sites since the fallows were intercropped with maize resulting to intense nutrient and light competition. Nevertheless, high biomass yield in Teso and Chwele sites indicated the need to shift from the usual maize-fallow intercrop to fallow legume since the legume has low chances of shading the fallow. High yields of maize were obtained in these crotalaria treatments in Chwele and Teso sites during the second season and high bean yield during the first season. The trials have also shown that the application of PRE-PAC and FURP to the nutrient depleted soils of Western Kenya significantly improves crop yields in the season preceding application. However, for long term crop yield improvement, fertilization with these recommended fertilizers would only be profitable if applied seasonally. Availability and awareness of PRE-PAC in local markets needs also to be improved since most farmers had no access to this technology. More research also needs to be done on the MBILI and lablab technology in order to come up with the best management practices of these two promising technologies.

Okoko, E. N. K, Makini, F, Mureithi, J. G. (2003). Effect of organic and inorganic fertilisers on maize and traditional vegetable yields in Kisii highlands. *East Africa Agriculture and Forestry Journal* 2003 vol.69 (1) pp 89-98

One of the major problems facing resource-poor small-scale farmers producing maize and traditional vegetables in Kenya is a decline in soil fertility. During participatory rural appraisal (PRA) exercises undertaken in Bogetaorio village, Nyamira District Kenya, farmers attributed low yields of maize and traditional vegetables to declining soil fertility as a result of continuous cropping, burning of crop residues and soil erosion. The PRA further showed that farmers in the region applied low quantities of organic and inorganic fertiliser because of their high cost. A study was therefore started during the short rains of 1995 to address the problem of low crop production by improving soil fertility. The objectives of this study to determine: 1) the effect of both organic and inorganic fertilisers on yield of maize and traditional vegetables and 2) low cost fertilisers for recommendation to farmers in the study area. The treatments varied according to test crop and included varying rates of farm yard manure (FYM) combined with inorganic fertiliser. Application of organic/inorganic fertiliser treatment combinations significantly increased soil nutrient status over the experimental period. The level of soil P, Ca, and K increased by over 70%. The fertiliser treatment combinations generally gave higher yields than FYM/compost treatments alone. In 1998, the combination treatment of 10 t/ha compost + 15 kg P_2O_5/ha + 15 kg N/ha gave a maize yield of 7.8 t/ha, which was significantly higher ($P<0.05$) than yields from the other treatments and was within the range of potential maize yield (7.2-9.0 t/ha) in the region. The fertiliser treatment combinations also increased yield of traditional vegetable significantly ($P=0.05$) compared to FYM applied alone. Thus, a combination of organic and reduced rates of inorganic fertilisers may be a promising low cost option to the use of the recommended rate of inorganic fertiliser for maize and vegetable production.

Okoko, E. N. K., Makini, F. and Mureithi, J. G. (2003). Effect of organic fertilizer and inorganic fertilizers on maize and traditional vegetable yields in Kisii highlands. *East African Agriculture Forestry Journal (EAAFJ)*, Vol. 69(1)89-98

One of the major problems facing resource poor small scale farmers production maize and traditional vegetables in Kenya is a decline I soil fertility. During participatory rural appraisal (PRA) exercises undertaken in Bogetaorio village, Nyamira district of Kenya, farmers attributed low yields of maize and traditional vegetables to declining soil fertility as a result of cropping burning of crop residues and soil erosion. The PRA further showed that farmers in the region applied low quantities of organic and inorganic fertilizers because of the high cost. A study was therefore started during the short rains of 1995 to address the problem of low crop production by improving the soil fertility. The objectives of the study were to determine 1) The effect of both inorganic and organic fertilizers on yield of maize and traditional vegetables and 2) Low cost fertilizers to recommend to farmers in the study area. The treatments varied according to test crops and included varying rates of farmyard manure (FYM) combined with inorganic fertilizers .Application of inorganic/organic fertilizer treatment combinations significantly increased soil; nutrient status over the experimental period. The level of soil P, Ca , and K increased by over 70%.The fertilizer treatment combinations generally gave similar yields to the recommended rate of inorganic P and N fertilizers and gave higher yields than FYM/ compost treatments alone. In 1998 the combination treatments of

10 t/ha compost + 15 kg P_2O_5/ha + 15 N/ha gave maize yield of 7.8 which was significantly higher (P<0.05) than yields from the other treatments and was within the range of potential maize yield (7.2-9) t/ha) in the region. The fertilizer treatment combinations also increased yield of traditional vegetables significantly (P= 0.05) compared to FYM applied alone. Thus, a combination of organic and reduced rates of inorganic fertilizers may be a promising rate low cost option to the use of the recommended rate of inorganic fertilizer for maize and vegetable production.

Onyuka, E. A. (2003). Effects of Nitrogen and Phosphorus on Maize (*Zea mays* L.) performance in Phosphorus-Deficient and Striga (*Striga spp.*) infested soils of Siaya District in Western Kenya. Msc. Thesis; Egerton University, Kenya

Soil nitrogen and phosphorus deficiency, and *Striga hermonthica* infestation are major constraints to maize production in western Kenya. The yields are typical of low input systems ranging below 1.0 t/ ha against a potential of 5.0 t/ha per season. In an attempt to overcome these constraints, field trials were conducted at three on- farm sites; Aboke, Nyagondo and Ukwala in Siaya District of Western Kenya during the long and short rains of 1999. The study investigated the effects of nitrogen and phosphorus on striga infestation, Nutrient uptake and use efficiency, maize yields and soil nutrient contents at harvest. Two rates of nitrogen (0 and 80 kg N/ha) and five rates of phosphorus (0, 13, 26, 39 and 52 kg P/ha) were combined to give ten treatments, which were allocated to the experimental plots in a Randomized Complete Block Design (RCBD) in a split plot arrangement. The treatments were replicated three times per site. Nitrogen was placed on the main plots and phosphorus on the sub plots. There were significant (p=0.05) grain yield responses to N and P rates at all the sites. Total dry matter significantly increased due to N at Aboke and Nyagondo and P at Ukwala. Harvest index responded significantly (P=0.05) to P rates at all the sites. Nitrogen and phosphorus rates had no significant (p=0.05) effect on striga emergence at all the sites. Striga emergence correlated weakly with N and P rates, and strongly with grain yield at all sites. Nutrient uptake and removal by the crop significantly (P=0.05) increased due to fertilizer N and P application, with a corresponding reduction in the total soil N, P, K, Ca and Mg. Phosphorus application significantly (P=0.05) increased available soil P content at all the sites. Fertilizer P use efficiency increased with N while it declined with increase in P rates at all the sites. Fertilizer N and P application are essential to improve maize yields, nutrient P use efficiency and to reduce the impact of *Striga hermonthica* damage to maize yields.

Rutunga, V., Gachene, C. K. K., Karanja, N. K., Palm, C. A. (2003). Grain maize yield improvement using *Tephrosia vogelii* and *Tithonia diversifolia* biomass at Maseno, Kenya. *Tropical and subtropical agro-ecosystems* UNESCO ROSTA Vol. 2 pp.1-11

This study aimed at assessing the response of maize crop to application of *Tephrosia vogelii* and *Tithonia diversifolia* biomass obtained six month-old fallows. The biomass were chopped into 5cm long pieces and incorporated in the soil one week before planting maize. The natural fallow biomass was used as a control. These organic inputs were supplied with 20 kg P/ha to attain P recommended rates. Shrub above ground and litter fall biomass incorporation significantly (p=0.05) increased maize yield. Plots where above ground biomass was removed produced lower maize yield compared to those where the above ground biomass was retained. Addition of 20 kg P/ha to soil together with the biomass increased maize yield by 40%. P in form of organic materials was insufficient to meet plan nutrition requirement. Residual effect of the biomass was low on the second and third subsequent crops. This may be due to the high rate of nutrient release during the biomass decomposition, the high crop nutrient uptake and also the nutrient losses through soil chemical and physical processes.

Waigwa, M. W., Othieno, C. O. and Okabelo, J. R. (2003). Phosphorus availability as affected by the application of phosphate rock combined with organic materials to acid soils in western Kenya. *Experimental Agriculture* Vol.39, pp. 395-407, United Kingdom Cambridge University Press

Most of the Agricultural land in the highlands of western Kenya is depleted of the plant nutrients, particularly phosphorus. This depletion has resulted in a continued decline in crop production in the area. Recent experiments, in which direct application of indigenous phosphate rocks were evaluated, have yielded variable results, depending on the relative reactivity of the rock phosphate tested. The effectiveness of rock phosphate was generally low compared with fertilizers such as triple super phosphate. This is attributed to the relatively low solubility of the rocks as opposed to the readily water soluble phosphorus fertilizers. Phosphate rocks are available locally and are cheaper than triple supper phosphate. If the solubility of these phosphate rocks could be improved, the resource-poor small holder farmers in western Kenya would have an affordable source of phosphorus for their crops. Green house and field experiments were conducted to evaluate the effects of combining different on-farm organic materials with the Minjingu rock phosphate (from Tanzania) on the availability of phosphorus to maize (*Zea mays*) in western Kenya. The green house results indicated that there were significant positive linear relationships between rock phosphate application rates and (i) the Olsen-extractable soil phosphorus in the soil taken four weeks and nine weeks respectively after application of the treatments; (ii) the dry matter yield and (iii) phosphorus uptake. Results of the yield showed that rock phosphate combined with farmyard manure or crop residues (maize stover)

generally increased the Olsen-extractable soil phosphorus, maize yields and phosphorus uptake, particularly in the first season when both the Minjingu rock phosphate and organic materials were applied, but the effectiveness of the materials and their combinations varied between the two sites. Combining Minjingu rock phosphate with the organic materials improved its relative agronomic effectiveness for maize.

Wanjiku, M. (2003). Soil fertility technologies for increased food production in Chuka, Meru South District, Kenya. Msc Thesis, Kenyatta University, Nairobi, Kenya.

The high population pressure in Chuka has led to continuous cultivation with minimal additional of inputs, leading to soil nutrient depletion. Research work has reported positive results from the use of manure a biomass from Tithonia, Calliandra, Leucaena, Mucuna and crotalaria for soil fertility replenishment. In relation to this a multi disciplinary farmer's participatory trial was established in Chuka Division, Meru District, to offer small-scale resource poor farmers feasible soil nutrient replenishment technologies. The experiment was set up in a randomized complete block design with 14 nutrient replenishment treatments (technologies) replicated thrice. At the beginning and at the end of the study soil was sampled at 0-15cm depth and the samples analysed for pH, Ca, Mg, K, C, N and P. At the end of the 2000/2001short rains season and 2001 long rains season soil samples were taken at 0-30, 30-100 and 100-150cm, for nitrate and ammonium analysis. All the treatments received an equivalent of 60 kg N/ha except the herbaceous legume treatments where the amount of N was determined by the amount of the biomass harvested and incorporated and the absolute control treatment that received no inputs. Net benefit and benefit-cost analysis were conducted using farm gate prices. The results indicate that soil fertility increased slightly in all the treatments (except) the control) over the two years of the study period. The average maize grain yield across the treatments was 1.1, 5.4, 3.5 and 4.0 Mg/ha during the 2000 long rains, 2000/2001 short rains, 2001 long rains and 2001/2002 short rains respectively. The poor yields in the 2000 long rains and 2001 long rains seasons were attributed to the poor rainfall received in these two seasons. On average Tithonia with half recommended rate of inorganic fertilizer recorded the highest (4.8 Mg/ha) maize yield followed by sole Tithonia (4.7 Mg/ha).The highest average concentration (144.8 and 115.5 kg N/ha) of mineral N was recorded at the 30-100cm soil depth at the end of both the 2000/2001 short rains and 2001 long rains respectively. The lowest average concentration (67.1 kg N/ha) was recorded in the 100-150cm soil depth during the 2000/2001 short rains while during the 2001 ling rains the 0-30cm depth recorded the lowest concentration (52.3 kg N/ha). The residual mineral N in the 100-150cm soil depth doubled at the end of the long rains 2001 compared to what was present at the end of short rains 2000/2001 season in all the treatments. This shows that there is a sustainable amount of mineral-N that is being leached below the rooting systems of maize. Sole Tithonia was ranked as the best treatment, while, the control was ranked as the poorest treatment by both the farmers and future farmers (students). The treatment ranking by both groups was closely related to the actual maize grain yields attained later at the end of the season. Out of the 171 farmers who attended the 3rd field day, 153 farmers (90%) indicated willingness to take the technologies to their farms. Sole Leucaena and Calliandra were the most cost effective technologies with a benefit/cost ratio (BCR) of 7.3 while sole Tithonia followed closely with a (BCR) throughout the four seasons.

Gachene, C. K. K., Mureithi, J. G., Anyika, F. and Makau, M. (2002). Incorporation of green manure cover crops in maize based cropping system in semi-arid and sub-humid environments of Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp145-151.

A study involved two experiments; the first experiment was at Machakos Farmers Training Centre (semi-arid) while the second was at Kabete Campus Field Station (sub-humid). The aim of the fist experiment was to assess the effect of different residue management practices using green manure cover crop (GMCC) on maize yield. The treatments, which were repeated during the subsequent seasons, were: maize without fertilizer, maize with fertilizer, maize intercropped with Lima bean (Phaseolus lunatus), maize + Sunhemp (*Crotalaria ochroleuca*) and maize + Mucuna (*Mucuna pruriens*). The biomass obtained was either incorporated or left as surface mulch or removed during the subsequent seasons. The second experiment aimed at assessing the effect of short-duration fallows of green manure cover crops on maize yield. The species planted during the fallow period were *Mucuna pruriens*, purple vetch (*Vicia benghalensis*) and *Crotalaria ochroleuca*. Two additional plots were planted with a pure stand of maize, with or without fertiliser. The biomass obtained after the fallow period was incorporated in the soil, removed or left as surface mulch during the subsequent season when all the plots were planted with maize. Biomass accumulation during the first season of the first experiment ranged from 2.8 to 5.9, 5.6 to 18.5 and 11.5 to 20.9 t DM/ha for P. lunatus, C. ochroleuca and *M. pruriens* respectively. Maze grain yields were generally higher in the incorporation followed by mulching. The removal treatment had the lowest yield. However, in seasons of low rainfall, the trend especially for mucuna changed, the mulching treatment gave the highest grain yield (4.01 t/ha) followed by the incorporation treatment (1.90 t/ha) and the removal treatment gave the lowest yield (1.51 t/ha). The increase in yields in the mulched plots was attributed to soil moisture conservation. Biomass accumulation for the short duration fallows ranged from 2.0 to 15.6, 11.2 to 18.0 and 15.6 to 20.0 t DM/ha for

V. benghalensis, C. ochroleuca and M. pruriens, respectively. Maize grain yield after residue incorporation was higher than from maize + fertiliser plots although no fertiliser had been applied in the former plots. Incorporating V. benghalensis and C. ochroleuca more doubled the yields when compared with the control. Yield increments of 16 to 58% compensated loss of yields during green manuring.

Gitari, J. N, Mureithi, J. G, Karumba, S. K. and Mwaniki, K. (2002). Integrated use of legume green manure, cattle manure and inorganic fertiliser for increased for increased maize production in mid altitude areas of central Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 115-120.

The beneficial effects of combining legume green manures with other organic and inorganic nutrient sources were investigated using maize as a test crop. The study was conducted over three cropping seasons at Embu Regional Research Centre situated in the central Kenya highlands in 1998 to 1999. The study evaluated factorial combinations of a) three levels of nitrogen (0, 2.5 and 25 kg/ha) b) two levels of cattle manure (0 and 2.5 t DM/ha) and c) three levels of green manure (none, *Mucuna pruriens* (mucuna) and *Crotalaria ochroleuca* (crotalaria). Dry matter production of the legume green manure in the first season was 8.1 and 6.3 t/ha for mucuna and crotalaria, respectively. Due to unfavourable rainfall, 0.4 and 2.3 t/ha of mucuna and 0.2 and 1.4 t/ha of Crotalaria was produced in the second and third seasons, respectively. In the first and second cropping seasons, differences among the treatments were not conspicuous. This was due to high residual fertility levels in the soil. During the third and final cropping season differences due to the treatments were more significant. All plots with organic as well as inorganic sources of nitrogen registered a higher maize yield than the control. The range in maize yield was 9.3 to 7.0 t/ha.

Gitari, J. N, Mureithi, J. G, Karumba, S. K. and Mwaniki, K. (2002). Legume green manuring for maize production on smallholder farms in the eastern and central Kenya region. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya pp 121-128.

On-farm legume green manuring trials were conducted for four seasons commencing September 1997 at Karurina and Gachoka locations of Embu and Mbeere districts of Eastern Province, Kenya. The main objective of the study was to introduce green manure legumes, velvet bean (*Mucuna pruriens*) and sunnhemp (*Crotalaria ochroleuca*) in smallholder farms for soil fertility improvement. The green manures were used alone or in combination with half the recommended rates of inorganic fertiliser (20 kg N/ha) or animal manure (5.0 t/ha). The results showed that sunnhemp or velvet bean may be grown as an intercrop with maize without adversely affecting maize yields. Highest levels of legume biomass were achieved during the 1997 short rains when 9.6 and 6.7 t/ha were recorded in velvet bean and sunnhemp, respectively. The use of legume green manure as a source of nitrogen increased maize grain yields significantly ($P<0.05$) at the wetter site of Karurina where 6.48 and 6.1 t/ha were obtained during 1998 and 1999 long rains, respectively. In the less wet site of Gachoka, maize yields were 4.72 t/ha in the green manure plots during 1998 long rains compared to 3.11 t/ha in the inorganic N fertilised plots. Similar trends were observed during 1999 cropping seasons. Combined use of green manure and inorganic N was more beneficial during less wet period of 1999 long rains when lower quantities of legume herbage were generated for incorporation into the soil. Participatory farmer evaluation of the treatments revealed that the smallholders ranked legume green manure higher than either mineral fertiliser or animal manure. The farmers noted that green manure usage would cut farm input costs and conserve soil moisture.

Kamidi, M, Gitahi, F, Osore, P, Cheruiyot, D, Okumu, M, Barasa, G. (2002) Effect of green manure legume on the yield of maize and beans in Matunda farm, Trans Nzoia district, North Rift Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 177-181.

Maize and bean yields in Matunda farm, Trans Nzoia District are usually low due to non-use or use of sub-optional amounts of inorganic fertilisers. Though farmers make and use compost, the amounts available are not adequate to cover a large area. A study was carried out to evaluate legume green manure species as a supplement to the expensive inorganic fertilisers on maize and bean grain yields. In 1997, five legume treatments: Mucuna (*Mucuna pruriens*), soybeans (*Glycine max*) dolichos (*Lablab purpureus*), sunnhemp (*Crotalaria ochroleuca*) and cowpeas (*Vigna uniguilata*) were relay planted in a maize crop after bean harvest. The legume species were replicated on six farms in a randomized complete block design. They were incorporated in the field and maize and beans planted at the on-set of rains in 1998 using fertiliser rates of 30 kg P_2O_5/ha and 30 kg N/ha. In August 1998, the legumes were relay cropped in the same plots but with purple vetch replacing cowpeas. This was followed by maize/bean intercrop at the on-set of rains in 1999 using the same amount of fertilisers as in 1998. The combined use of green manure and 30 kg P_2O_5/ha and 30 kg N/ha significantly ($P<0.05$) increased maize yield compared to use of 30 kgP_2O_5/ha and 30 kg N/ha or green manure alone.

Kifuko, M. N. (2002). Effect of combining organic manure with phosphate rock and triple superphosphate o phosphorus absorption and maize performance in acid soils of western Kenya. Msc. Thesis, Moi University, Eldoret, Kenya

Organic materials upon decomposition have been found to reduce phosphorus (P) sorption by soils and increase its availability. However most studies obtained may not be reproducible under field conditions. Therefore the main aim of this study was to assess the P sorption characteristics of one major soil type (ferralsol) and also to reduce P sorption by combining agricultural based organic materials of different qualities with inorganic fertilizers under green house and field conditions. The impact of these conditions on maize performance and overall soil properties was also studied. The study was carried both in station (Uasin Gishu District, Chepkoilel campus, Moi University for both field and incubation studies) and off station (Busia and Siaya district field experiment). In Busia three rates (0, 30, 60 kg P/ha) of Minjingu phosphate rock (MPR) were combin3ed with chicken manure (CM) FYM and sugar bagasse (SB) at 0, 2t/ha each. In Uasin Gishu two sources of P namely, MRP and TSP at 0, 20, 40 kg P/ha each were combined with CM and FYM at 0, 2 t/ha each. In Siaya two rates (0, 60 kg P/ha) of MPR were combined with maize Stover MS and (FYM) at 0, 1and 2t/ha each. The same treatment used in Busia district with an extra treatment of 60 kg P/ha as TSP for comparison were used in incubation studies in all the field experiments, maize was planted as a test crop and soil samples were done at pre-planting, maize vegetative stage (periods of rapid maize nutrient uptake and growth) and after harvest during the first season for site characterisation and analysis of available P, iron oxides and P sorption measurement. In the subsequent seasons meant to monitor the residual of treatment applied during the first season, sampling was done before planting and after harvesting in the incubation studies sampling was done for up to 16 weeks at intervals of 4 weeks. The sorption data was fitted to the Langmuir equation while yield and soil properties data were subjected to analysis of variance to check treatment effects. In both the incubation and the field studies it was found that the sorption capacity if soil increased with increase in the rate of MPR whereas TSP reduced the P sorption throughout the incubation period probably due to its solubility resulting in increased quantity of H_2PO_4 anions that satisfied the sorbing sites in soils. A comparison of the organic materials alone revealed that chicken manure proved superior in terms of reducing the P sorption while sugar bagasse was found to be an inferior material. Poor correlation coefficient between sorption parameters with soil pH Aluminium oxide or iron oxide data in Busia and Uasin Gishu are compared to Siaya soils suggested that they were not dominant factors on sorption capacities of these soils. Combining organic materials with MP*R or TSP significantly (P<0.005) increased the extractable P in both incubation of MRP significant (*<0.005) treatment effect on maize grain yield increases occurred in Busia and Siaya sites in all the second seasons (2001 long rains) and this signified that MPR at 30 kg P/ha with high quality organic materials e.g. CM may help reduce P sorption in highly P depleted sites and increased its availability. In Busia MPR at 30 kg P/ha combined with farmyard manure (2 t/ha) was considered the best in increasing P uptake, P recovery and N use efficiency in Siaya MPR at 60 kg P/ha combined with FYM (2 t/ha) gave the highest P uptake while no significant treatment effects was obtained on maize yield and P uptake in Uasin Gishu. The organic analysis revealed that across the three sites the highest incremental profit of Kshs 51,477 was obtained when TSP was applied at 20 kg P/ha over the two maize cropping seasons in Uasin Gishu which was closely followed by CM (2t/ha) combined with MPR at 60 kg P/ha (51,244) in Busia site over the three cropping seasons. High residue yields reflect the potential of MPR to supply P over a long time and there is need to continue with the experiment for a longer period to determine for how long P from MPR can remain beneficial to the crop. A detailed economic analysis to determine the long term beneficial effect of combining MPR with organic inputs will be necessary.

Kihanda, F. M. and Rimui, C. M. (2002). Use of compost manure enriched with high quality organic residues to improve growth and yield of maize. *Proceedings of the 8th Biennial Scientific Conference* 11-15th November 2002 at KARI Headquarters, Kenya, pp 145-149

A field trial was conducted to test whether composted manure with Tithonia or lantana would improve growth and yield of maize. A field trial consisting of 5 compost types and inorganic N fertiliser N was carried out in a site low in nitrogen (N) using maize (Zea mays var. H513) as a test crop. The compost and the fertiliser were applied at an equivalent rate of 100 kg N/ha. Above-ground maize biomass was taken at 2, 6, 10, 14 and 18 weeks after crop emergence, dried and N content determined. Amongst the composts, the highest dry matter accumulation N uptake and grain yield were observed in farmyard manure composted with Tithonia at 1:1 ratio. At all stages of crop growth inorganic fertiliser treatment gave the highest dry matter and N uptake. Based on the growth and N uptake in the fertiliser treatments it was concluded that N release in all the composts was lower than that required to meet the crop demand.

Kinyua N. D. (2002). Amelioration of the most limiting plant nutrients in the Nitisols of Central Kenyan

highlands, Kiambu District. MSc. Thesis, University of Nairobi, Kenya

Farmers in the Central highlands of Kenya are aware of the consequences of nutrient depletion and practise complex integrated nutrient management strategies such as addition of organic and inorganic fertilizers, soil erosion conservation and agroforestry albeit at a minimal level. These past management practices have resulted in the development of unproductive nutrient deficient patches than are located at a distance from the homestead referred to as "outfields". Farmers are able to distinguish the unproductive patches on yield basis and this was confirmed in the laboratory based soil nutrient analysis. The study site was at Karura catchment scheme in Kiambu District of Kenya. The site is characterized by humic Nitisols. The aim of this study was to identify the most limiting nutrients and the most effective soil fertility management practises hereto referred to as the "Best-Bet" for ameliorating the soil deficient patches so as to increase crop production at on farm level. Two test crops commonly grown in the area were used for this study: Kale (*Brassica oleracea* var acephala) and maize (Zea mays). To achieve this aim, a study was carried out in three stages; greenhouse experiments, on-farm trials and laboratory nutrient analysis of both plants and soils. The results obtained from both crops indicated that there was a positive response to P and N application especially in the unproductive soil patches. Application of Cu and/or other micronutrients (Fe, Mn, Zn, B, Mo and Co) reduced maize productivity especially in the unproductive patches. Addition of copper improved crop yield only when major nutrients were added. Addition of 100 kg K/ha also reduced dry matter and grain yields of maize in both soil categories meaning that K is not a limiting nutrient in the Nitisols currently. Application of micronutrients in combination with nitrogen and phosphorous in both soil categories resulted in the increased dry matter and grain yields. In the unproductive soil patches where N and P were limiting crop productivity, addition of 100 kg N/ha and 44 kg P/ha, and/or the addition of 215 kg DAP/ha combined with 7 tons/ha cow manure would be required to improve nutrient availability, restore soil fertility and result in increased crop productivity. The most limiting nutrients to crop production were found to be N, P and Cu. Plant nutrient deficiency symptoms could be used as rapid indicators of plant nutrient deficiencies. The "Best-Bet" soil fertility practise of applying 215 kg DAP/ha combined with 7-tons/ha of cow manure (farmers practise) was the best soil ameliorative strategy in terms of dry matter and grain yields in both productive and unproductive soil categories in Kiambu District. This confirmed the notion that farmers have the best soil ameliorative strategy but re hampered by internal and external factors e.g. Capital and use of inorganic resources in their endeavour to increase crop production in their fields. Crop harvest removal is a major avenue for nutrient loss in these highlands. There is need to increase the rate of fertilizer and manure application in order to meet the resultant nutrient deficits following harvesting of kale and maize grains. Intensive nutrient balance studies need to be incorporated in future research meant for these highlands.

Kute, C. A. O., Chirchir, P. (2002). Effect of low levels of inorganic fertiliser and organic manure on yields of finger millet in Chobosta, North Rift, Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 47-51.

During a Participatory Rural Appraisal (PRA) exercise conducted in 1994 in Chobosta village, Soy Division of Uasin Gishu District, it was observed that finger millet was retarded in growth and plants had P and N deficiency symptoms. These deficiencies were also confirmed from soil analysis results of samples taken from the farmer's fields. A study was conducted in Chobosta in the lower highland (LH4) to evaluate the effectiveness of low levels of P, N and compost and/or farm yard manure (FYM) and their performance on finger millet performance. Five farmers planted the trial in a randomised complete block design (RCBD) and each farm acted as replicate. The effect of fertiliser rates (12.5 kg P + 12.5 kg N + 2.5 t compost/FYM/ha; 25 kg P + 25 kg N/ha, 5 t compost/FYM/ha and zero or no application as farmer treatment) on millet grain yields were evaluated. A compound inorganic fertiliser of 20:20:0 was used in the trial. Results of the two year study indicate that the use of inorganic fertilisers and combinations of inorganic and organic fertiliser application increased finger millet grain yields to more than a tonne per hectare and reduced P and N deficiency. The farmer evaluation indicated that the combinations of fertilisers and manures were preferred to zero treatment in finger millet production.

Lekasi, J. K., Ng'ang'a, N. and Kabira, J. N. (2002). improving potato quality through potash fertilisation. K ARI, Muguga South, Kenya, Annual Report, 2002

It is generally assumed that soils in Kenya are supplied with adequate potassium for crops growth. Consequently, potassium fertilisation does not form part of fertilisation recommendation unless for very special plants such as ornamentals. This phenomenon has led to some recent observation of pockets of potash deficiencies in some crops. This study was therefore, to investigate the effect of potassium fertilisation on the potato tuber yield quality, storage and processing qualities. The trial was set up in a randomised complete block design (RCBD). The number of plots was 6 rates x 3 sources of K x 2 varieties x 3 replicates giving a total of 108 plots of 5m x 5m. The tubers were planted at a spacing of 30 cm within the rows and 75 cm between the rows. There were two potato varieties used; - Tigoni and Nyayo. Three types of fertiliser were used in the trial in the trial viz: Potassium sulphate, Cattle manure and Di-ammonium phosphate. For potassium sulphate (K_2SO_4) and manure the rates applied were equivalent to 0, 25, 50, 75, 100 and 200 kg K/ha. DAP was applied at 0, 50, 100, 250, 350 and 500 kg DAP/ha. Nutrient uptake

at 1, 2 and 3 (final harvest) months after planting was determined. Total dry matter was also measured. The final harvest was subjected to storage tests, total dry matter, and chipping quality tests. The results indicate that there was a significant response to application of K fertiliser and DAP compared to the control. The highest yields for the three sources of fertiliser were obtained at 50 kg/ha of K as K_2SO_4, 100 kg/ha of manure and at 100 kg DAP/ha.

Maobe, S., N., Kidula, N. L. and Ondicho, A. R. (2002). Effect of green manure residue management practices on maize yield in Southwest Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 165-172.

A study was conducted at two sites in southwest Kenya from 1997-99 to investigate the effect of green manure residue management practices on maize yield. One of the sites was on-station at Kisii Regional Research Centre, Kisii district, and the other was on-farm at Bogetaorio village of Nyamira District. The on station experiments were researcher-managed while the on-farm were jointly managed by the farmers, extension staff and researchers. The herbaceous legumes used were sunnhemp (*Crotalaria ochroleuca*) and velvet bean (*Mucuna pruriens*). The green manure residue management practices evaluated were: incorporation, mulching and removal. The research recommended inorganic fertiliser rate of 60 kg N/ha and 60 kg P_2O_5/ha was used as a check. The control treatment received neither fertiliser nor green manure residue. Results obtained showed that under sowing green manure herbaceous legume two weeks after planting maize does not negatively influence maize grain yield. Yields from the green manure residue management trials did not differ significantly between the treatments over the three-season period. However, incorporation of green manure tended to have more grain yields compared to residue mulching and removal. The economic analysis of the result showed that incorporation of green manure gave higher net profit in maize production than mulching and residue removal practices.

Masinde, A. A. O, Ojowi, M. O, Mbugua, D. M, Odongo, J. A, Shisya, M. A. (2002). Effect of organic and inorganic fertilisers and their combination on napier grass dry matter yields in South west Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 91-94.

Inadequate quality feeds is a major constraint to livestock production in South in South-West Kenya. Participatory Rural Appraisals show that declining soil fertility and small holdings are some of the causes of low forage productivity in the region. A farmer participatory study was carried at Nyamonyo, Bogetaorio and Nyatieko villages to evaluate the effects of inorganic and organic fertilisers and their combinations on napier grass (*Pennisetum purpureum*) productivity when grown alone or intercropped with silver leaf desmodium (*Desmodium uncinatum*) and dolichos (*Lablab purpureus*). The following treatments were evaluated at Nyamonyo and Bogetaorio on Napier grass intercropped with silver leaf desmodium (1) no fertiliser application (farmer practice). (2) 5t farmyard manure (FYM)/ha, (3) 30 kg P_2O_5/ha (4) 30 kg P_2O_5/ha + 5 t FYM/ha and (5) 60 kg P_2O_5/ha. At Nyatieko only Napier grass was planted and the 5 t FYM/ha fertiliser treatments were replaced by 10 t FYM/ha. A randomized complete block design was used with eight farms acting as replicates. Total dry matter yield of Napier grass/ legume intercrops or Napier grass grown alone were significantly increased when 60 kg P_2O_5/ha (recommended rate of diammonium phosphate fertiliser) or 5 t FYM/ha + 30 kg P_2O_5 (half the recommended rate of diammonium phosphate and FYM) was used. Net benefits were also high when the two treatments were used but Benefit Cost Ratio was highest in the no fertiliser (control) and 60 kg P_2O_5/ha treatments.

Micheni A., Tuwei P., Mugwe J. and Kiruiro. (2002). Integration of organic and inorganic soil fertility improvement inputs for improved crop yields in central highlands of Kenya. *Proceeding of the 12th ISCO Conference*, Beijing pp. 362-367

Production of agricultural products has lagged behind population growth in most parts of sub-Saharan Africa. The problem is associated to a decline in soil productivity that is a consequence of continuous cultivation with no or inadequate external soil fertility enhancement inputs. This is a common situation in central highlands of Kenya where over 90% of farmers are resource poor smallholders and the soils are characterized by low levels of nitrogen and phosphorous. The situation is worsened by cultivation methods, which are more of nutrients conservation. The whole scenario contributes to inadequate food production leading to hunger and poverty among farming communities. In seeking for environmentally viable and economically feasible technologies for combating soil nutrients depletion, farmer managed on-farm trials using readily available inorganic and organic resources were conducted within the main maize/coffee/dairy land use systems of central Kenya. The soil fertility improvement resources were identified in focused survey conducted to prior to field experimentation with the aim of taking an inventory of soil fertility status and the most readily available soil fertility opportunities for smallholder farmers. Farmyard manure (FYM) and Tithonia diversifolia biomass were found to the most readily available organic resources and were both applied at an equivalent N content of 60 kg/ha, same as the inorganic fertilizers N recommendation for the area. Maize (*Zea mays L.* var Hybrid 513) was the crop and besides assessing the bio-physical crop performance, the trials had also an objective of assessing socio-economic effects of organic,

inorganic and their (organic-inorganic) combinations to improve crop productivity. Application of recommends (60 kg of both N and P/ha) of inorganic fertilisers gave an average maize grain yield of 7.5 Mg/ha and USD 681 total net benefits (NB). This was closely followed by the integration of Tithonia biomass and 30 kg/ha of both N and P/ha with 6.8 Mg/ha grain yield and USD 520 benefits. The survey found that the majority of farmers cannot afford to buy and apply enough inorganic fertilisers; hence, a recommendation was put forwards for smallholder farmers to embark on integration of organic and inorganic soil fertility improvement resources for an improved food security in the region.

Mutua, J. K. (2002). Nitrogen fertilizer equivalency values for organic materials of contrasting qualities based on maize performance at Kabete, Kenya. Msc. Thesis, Kenyatta University, Nairobi, Kenya

Decline in food production has been a major problem facing smallholder farming in Kenya and the entire Sub-Saharan region. This is attributed mainly to the mining of major nutrients due to continuous cropping without external addition of adequate nutrients. Inorganic fertilizers are expensive hence unaffordable by most smallholder farmers. Although organic nutrient sources are available, information about the right proportions of application is scanty. A completely randomized block experiment was set up in 1999 at the National Agricultural Research Laboratories (NARL) at Kabete with the overall objective of determining nitrogen fertilizer equivalencies based on high quality organic inputs. The specific objectives of the study included determination of the nitrogen fertilizer equivalency values of *Tithonia diversfolia*, *Senna spectabilis* and *Calliandra calothrysus* and the investigation of nitrogen use efficiency from combined organic and inorganic inputs. The effect of the organic material on the soil chemical properties was also investigated. The experiment consisted of maize plots to which freshly collected leaves of Tithonia (*Tithonia diversfolia*), Senna (*Senna spectabilis*) and Calliandra (*Calliandra calothyrsus*) (all with % N>3) obtained from hedgerows grown ex situ (biomass transfer from outside) and urea (inorganic nitrogen source) were applied. Results obtained indicated that a combination of both organic and inorganic nutrient source gave higher maize grain yield than when each applied separately, except for Tithonia whose sole application gave better grain yield than a combination of the same with mineral fertilizer. Maize grain yield production after organic and inorganic application was in the order of Tithonia>Tithonia + urea= Calliandra + urea> urea > senna + urea > Calliandra > Senna > control. The percentage N recovery was highest in sole application of Tithonia biomass had relatively lower percentage N recoveries. In both seasons, the mineral N content was high in sole application of Tithonia than in Senna and Calliandra treatments. The three organic materials (Senna, Calliandra and Tithonia) gave fertilizer equivalency values of 68%, 72% and 130% respectively.

Nzabi, A. W, Makini, F, Onyango, M, Kidula, N, Muyonga, C, Miruka, M, Mutai, E, Gesare, M, Mwangi, G. (2002). Effect of organic and inorganic fertilisers on maize yield and soil fertility improvement in Kisii and Gucha districts, South West Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya pp 31-35.

Participatory Rural Appraisal (PRA) exercise conducted in Nyamonyo and Nyatieko villages south west Kenya, indicated that farmers were getting low crop yields mainly due to low soil fertility. A trial was therefore initiated in order to determine the effect of organic and inorganic fertilisers on maize grain yield. Five treatments were tested in a randomized complete block design replicated on 8 farmers' fields. The treatments were: 1)10 t compost/farm yard manure/ha, 2) 15 kg N + 15 kg P_2O_5/ha + 10 t compost/farm yard manure/ha, 3) 30 kg N + 30 kg P_2O_5/ha + 10 t compost/farm yard manure/ha, 4) 60 kg N + 60 kg P_2O_5/ha (Research recommended rate) and 5) 75 kg N + 50 kg P_2O_5/ha (FURP recommended rate). At Nyamonyo site application of 60 kg N + 60 kg P_2O_5/ha gave the highest mean yield followed by application of 75 kg N + 50 kg P_2O_5/ha. At Nyatieko site, 75 kg N + 50 kg P_2O_5/ha gave the highest mean yield (2430 kg/ha) followed by 30 kg N + 30 kg P_2O_5/ha + 10 t compost/farm yard manure/ha. Use of 10 t compost/farm yard manure/ha alone resulted in the lowest yield.

Nzabi, A. W, Makini, F, Onyango, M, Kidula, N, Muyonga, C, Miruka, M, Mutai, E, Gesare, M, Mwangi, G. (2002). Effect of organic and inorganic fertilisers on maize yield and soil fertility improvement in Kisii and Gucha districts, South West Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya pp 3-12.

The aim of the study was to educate farmers through demonstrations and field visits on the importance of soil fertility in crop production with special emphasis on maize. Farmers were exposed to a range of locally available organic materials for soil fertility improvement. A multidisciplinary team of researchers, farmers and extension officers were involved in the trials. Demonstrations were held on methods of making high quality compost and also collection and preservation of farm yard manure (FYM). On-farm trials using organic fertilisers and in combination with inorganic fertiliser were compared to determine their effect on maize yield. Soil samples collected in the farms indicated phosphorus and nitrogen deficiencies. Organic fertilisers were high in pH, available P and organic carbon. The highest rates of compost or FYM (10 t/ha) gave yields that were significantly higher than control ($P<0.05$). Where mixtures of organic and inorganic amendments on half/half were used, maize yields were not

significantly (P>0.05) different from recommended fertiliser (60 P_2O_5 and 60 kg N /ha) plots. This trend was observed in the second and third years. Combining organic and inorganic fertilisers is the best option of realising high yields in the study area.

Obaga, S. M. O., Tana, P. O., Oyure, A. O. and Ngoti, B. (2002). Effect of green manure legume and combined low rates of organic and inorganic fertilisers on striga weed and maize yield in Kendu Bay, South West, Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 189-191.

Striga (*Striga hermonthica*) is a parasite weed that is a major cause of low crop yields in the Lake Victoria region where it has caused great reduction in yields of maize, sorghum and sugar cane for a long time. Farmers in Kamingusa village near Kendu bay are faced with this crop production constraint and have tried various methods to control Striga including uprooting the weed. In their endeavour to control this weed, scientists have tried the use of farmyard manure (FYM), legume/cereal in rotation as well as chemical means. These methods have not had a big impact as some are expensive to use. The farmers proposed the use of Sunnhemp (Crotalaria ochroleuca) as green manure in solving the weed problem. The farmers' knowledge of the green manure was based on work done with an NGO called Community Mobilisation against Desertification (C-MAD) working in the region. However, the duration of the cropping with the legume was not clearly understood. In this study, sunnhemp was grown for one and two years followed by a maize crop to determine its efficacy in controlling the weed in the subsequent maize crops. For comparison, half recommended rates of FYM and inorganic fertiliser, Diamonium phosphate (DAP) and farmers practice were treatments used. Plots under sunnhemp for two years gave the highest yields followed by plots under one year's sunnhemp cropping compared to half recommended rates of FYM and inorganic fertilisers (30 kg N + 5 t/ha FYM/compost) and farmers' practice. Arable land availability is diminishing in the area therefore farmers suggested that sunnhemp be grown as an intercrop with cereals like maize to avoid crop loss during the improved fallowing period.

Obaga, S. M. O, Maobe, S. N, Makini, F. (2002). Evaluation of organic and inorganic sources of phosphorus for smallholder maize production in Kisii, South West, Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 59-64.

Widespread low soil phosphorus levels in the Kisii highlands contribute towards low crop yields, particularly maize. Serious soil erosion, continuous cropping, removal of crop residue as wood fuel and livestock feed as well as burning of stover and limited use of inorganic fertilisers are the major causes of soil fertility decline in the area. Participatory on-farm work was done in three villages to assess the usefulness of applying different sources of phosphorus in addressing the problem using maize as a test crop. Diammonium phosphate (DAP) and Minjingu phosphate rock (RP) were sources of inorganic phosphorus while Farm Yard Manure (FYM) and Tithonia diversifolia biomass were sources of organic nitrogen and phosphorus. Results from two cropping seasons in 1998 indicated that combining either good quality FYM at 10 t/ha or 1-2 t/ha DM of T. diversifolia with 200 kg/ha RP gave comparable maize yields to application of the recommended agronomic rate of 60 kg N and 60 kg P_2O_5/ha for maize. Since Minjingu RP is cheaper than DAP, farmers preferred the organics and RP to the use of DAP and CAN in maize production.

Ojiem, J. O., Mureithi, J. G. and Okwuosa, E. A. (2002). Integrated Management of legume green manure, farm yard manure and inorganic nitrogen for soil fertility improvement in Western Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects,* June, 2000, Mombasa, Kenya. pp97-102.

The Western Kenya region is one of the most populated rural regions of the world. The soils are depleted of nitrogen (N) and phosphorus (P). Fertility replenishment is therefore necessary, in order to increase food production. Although inorganic fertilisers are important in the restoration of soil fertility, their use, especially N fertilisers, is quite low on smallholder farms due to their high cost. Biological N2-fixation can contribute to soil fertility enhancement, thereby improving productivity. Combining legume green manures with other organic or inorganic sources of nutrients may improve crop yields by increasing nutrient use efficiency. Three factors- legume green manure (GM), farm yard manure (FYM) and inorganic nitrogen (N) were evaluated on-station in 1998 and 1999 at the Regional Research Centre, Kakamega Western Kenya, in a 3 x 2 x 3 factorial fitted in a Randomized Complete Block Design (RCBD) replicated three times. Green manure was at three levels (no GM, Crotalaria ochroleuca, and Mucuna pruriens), FYM at two levels (0 and 2.5 t/ha) and N at three levels (0, 15 and 30 kg N/ha). Out of the three factors investigated, only legume treatments produced significant (p=0.05) effects on maize grain yield. Averaged over two years, inclusion of GM increased grain yield by 1.5 t/ha, from 5.1 to 6.6 t/ha. Though not significant, N had a positive effect on both GM and FYM. For GM, grain yield was 2.5 t/ha higher at 15 and 30 kg N/ha compared with no N, while FYM had a marginal grain yield increase of 1.0 t/ha at the highest N rate of 30 kg N/ha. These results suggest that maize grain yield can be greatly improved by integrating GM, FYM and inorganic nitrogen in the management of soil fertility.

Ojiem, J. O, Mureithi, J. G, Maobe, S. N., Okwuosa, E. A. and Nekesa, C. O. (2002). Effect of phosphorus on nodulation and dry matter yield of legume green manure species in the humid highlands of Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 183-188.

Legume green manure species have the potential for improving soil fertility by fixing atmospheric nitrogen. However, application of phosphorus (P) is essential for high dry matter (biomass) yield and effective nodulation. Recent research findings suggests that plant species and cultivars differ in ability to utilise available forms of P. Effect of four (0, 20, 30, and 40 kg P/ha) rates of P on nodulation and biomass yield of nine legume green manure species; *Crotalaria ochroleuca, Crotalaria juncea, Calopogonium mucuniodes, Lablab purpureus cv Rongai, Canavalia ensiformis, Mucuna pruriens, Glycine max, Neonotonia weightii*, and *Vicia benghalensis*, was determined at Kakamega, Kabete and Kisii, all within the humid Kenya highlands. Biomass accumulation was low at all sites due to pests, diseases, and drought. Phosphorus had no significant (P=0.05) effect on either biomass accumulation or nodulation at any of the sites. However, averaged across species, application of P increased biomass by 0.72 t/ha at Kabete and 0.62 t/ha at Kakamega. No increase was recorded at Kisii. P had no significant effect on nodulation but the number of nodules per plant increased slightly. The highest increases were obtained with *Crotalaria ochroleuca*) (11) *Mucuna pruriens* (4), and *Glycine max* (3). With the exception of *Crotalaria ocgroleuca*, the species had no nodules with red inner tissue indicating they were probably not active. These results suggest that P may not be critical for biomass accumulation and nodulation. However, there is need to establish the threshhold P levels for legume species in different sites in Kenya. In addition, use of more quantitative methods in assessing nitrogen fixation may be necessary.

Okoko, E. N. K. and Makworo, S. (2002). Evaluation of the effect of compost and inorganic fertiliser on maize yield in Nyamira district, South West Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya pp 23-29.

Declining soil fertility is a major constraint facing resource poor maize farmers. A participatory Rural Appraisal (PRA) carried out in 1994 showed that most farmers get less than 2.0 t maize grain ha-1 compared to on-station researcher yield of about 9.0 t/ha. Farmers attributed the low yields to declining soil fertility caused by continuous cropping, crop residue burning, soil erosion and inadequate use of organic and inorganic fertiliser partly because of high costs of inorganic fertilisers. In response, a study was initiated during 1995 short rains (SR) to address the problem of low maize yields. The objectives of the trial were to test the effect of combinations of organic and inorganic fertilisers on maize yield, and determine low cost and affordable fertiliser recommendation. Seven treatments were tested in a randomised complete block design replicated on 23 farms with farmers serving as replicates. The treatments were: (1) control (no fertiliser applied), (2) 5 t compost manure/ha (3) 10 t compost manure/ha (4) 5 t compost manure + 30 kg P_2O_5 + 30 kg N/ha (5) 10 t compost manure + 30 kg P_2O_5 + 30 kg N/ha, (6) 10 t compost manure + 15 kg P_2O_5 + 15 kg N/ha and (7) 60 kg P_2O_5 + 60 kg N/ha. Results obtained during the three and half year period indicated that use of 10 t compost manure in combination with 30 kg P_2O_5 + 30 kg/N ha or 5 kg P_2O_5 + 15 kg N/ha improved soil fertility and had the highest maize yields. These fertiliser combinations were promising low cost options to the recommended rate of inorganic fertiliser for maize production. Farmers also preferred these treatments.

Okoko E. N. K. and Makworo S. (2002). Evaluation of the effects of organic and inorganic fertilisers on yields of traditional vegetables in Bogetaorio village, Southwest Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya pp 83-89.

Traditional vegetables, black nightshade (*Solanum nigrum*) and spider flower (*Gynandropsis gynandra*) form an important part of the diet of the Abagusii people. A participatory rural appraisal (PRA) carried out in Bogetaorio village in 1994 confirmed that traditional vegetable production was low due to the declining soil fertility. The PRA further indicated that declining soil fertility was caused by continuous cropping and soil erosion. Thus, on-farm trials were started in 1995 to: determine the response of traditional vegetables to organic, inorganic fertilisers and their combination and to estimate the cost of production of the various fertiliser treatments. Three years results showed that the combination of farm yard manure (FYM) and a quarter (15 kg P_2O_5 + 15 kg N/ha) or half (30 kg P_2O_5 + 30 kg N/ha) research recommended rate (RRR) of phosphate and nitrogen gave higher fresh leaf yield of both black nightshade and spider flower. Farmers also preferred combination treatments of FYM and reduced rates of inorganic fertilisers because they are affordable compared to full research recommended rate of the inorganic fertilisers.

Onyango, J. W. (2002). Pigeon pea response to application of mineral fertiliser and farm yard manure at agroecologically contrasting sites in Kenya. *Proceedings of the 7th KARI Biennial Scientific Conference* 13-17th November 2000 at KARI Headquarters, Kenya

Trials were carried out between 1986 and 1992 at six sites mainly in semi arid areas of Kenya to test the effects of medium fertiliser and manure levels on pigeon peas. At each site two experiments with 4 levels each of nitrogen (N) and phosphate (P_2O_5 (P) and two levels of locally available Farm Yard Manure (FYM) with or without a combination of N and P at 50 kg/ha each were laid in farmers' fields in 6 x 6 M plots using the Randomised Complete Block Design (RCBD). The responses were determined by using Stepwise Regression Analysis and showed a general positive trend to P while N responded only as interactions with P. Five tonnes FYM increased the crop yields by between 11.4 and 34.2% but decreased it by 9.6% at one site. Lack of response to any inorganic fertiliser was attributed to low levels of P, Ca/K and organic Carbon in the soil, low soil moisture during the peak requirement period and/or poor crop management. Poor soil moisture conditions may be improved by use of locally available FYM but under adversely dry conditions, FYM may prove retrogressive and reduce yields by scorching the growing crop. Up to 50 kg P/ha should be applied but should be limited to moist conditions to avoid scorching. Where P is low however, 5 t FYM/ha may be added to improve soil moisture conditions for better yields. N application should be minimal (20-25 kg/ha) and applied at planting particularly where organic carbon is low. The management aspects of the crop like timely planting appropriate varieties and pest control measures should be closely followed for better results.

Onyango, M. (2002). Evaluation of response of Solanum nigrum vegetable to organic and inorganic fertiliser combination at Nyamonyo village, Kisii, Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 53-57

Solanum nigram (black nightshade) vegetable is popular in southwest Kenya. The production of this vegetable is dominated by smallholder who grows it in kitchen gardens mainly for subsistence and to sell surplus. The yields of this vegetable have been declining because of low soil fertility and poor production practices by the farmers. A participatory rural appraisal was carried out in Nyamonyo village in southwest Kenya to understand farmers' constraints and identify possible solutions. Following the appraisal, experiments were conducted in the village between 1995 and 1998 to evaluate the effects of organic and inorganic fertiliser on the yield of Solanum nigrum with the aim of improving vegetable production for domestic consumption and for cash income. Compost prepared by the farmers was used in the trial. The treatments were 200 kg Diammonium phosphate (DAP) 46% P_2O_5; compost at 10 t/ha; compost at 10 t/ha plus 50 kg DAP; compost at 10 t/ha plus 100 kg DAP and finally, a non-fertilised check. There were significant differences in the leaf yield obtained from the treatments. The vegetable yield of the treatments with combinations of the two fertilisers were not different from the recommended 200 kg DAP, but were better than the yields obtained from compost alone and the unfertilised check. Farmers evaluated the treatments and chose a combination of compost and a quarter or half of the recommended inorganic fertilser rates.

Onyango, R. M. A, Mwangi, T. J, Wanyonyi, M, Barkutwo, J. K, Lunzalu, E. N. (2002). Verifying the potential use of inorganic and organic fertilisers and their combinations in small holder maize production farms in Trans Nzoia district. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 71-76.

Maize is grown by both small and large scale farmers in Trans Nzoia district, North Rift Kenya to provide food and cash. Currently the productivity of maize is low as a result of continuous cropping, use of inadequate fertiliser inputs, poor organic fertiliser quality and inappropriate combinations of organic and inorganic fertilisers. In 1997 trials were set up at two sites in the district, Kipsaina and Suwerwa to verify the benefits of combinations of organic and inorganic fertilisers from other regions. Also the trials provided an opportunity to educate farmers on collection, storage and use of farm yard manures (FYM). Six treatments were tested on farmers' fields as farmer-extension-researcher managed trials. Three combinations of organic/inorganic fertilisers were verified against Fertiliser Use Recommendation Project (FURP) and research recommendations for the area. The soils were strongly acidic to moderately acidic (pH 4.9 to pH 6.0). Most farmers had marginal amounts of exchangeable bases (K, Ca, Mg and Mn). Results clearly indicated soils had phosphorus and nitrogen deficiencies. Most of farmyard manure used exhibited nutrient variation from farmer to farmer. All the FYM had very low P content ranging from 0.07 kg P/t to 1.3 kg P/t. The FYM samples contained more than 23 kg N/t, an amount normally present in high quality cattle manure. By 1998 all participating farmers had learned that the quality of their manures could be improved by keeping their FYM collections under trees and covering with leaves. Maize yields from FURP recommended treatment and any treatment where FYM was mixed with some form of inorganic fertiliser gave yields that were comparable to maize yields obtained from the recommended inorganic fertiliser rate. The treatments had similar results for two years giving farmers choices on how to use the right fertiliser and fertiliser/manure combinations on their maize, while improving the quality of their impoverished soils.

Rono, S. C, Osore, P, Kigen, J. K. (2002). Use of organic and inorganic fertilisers on vegetable (Brassica oleracea) production in Kitale Mandate region. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya pp 77-81.

A participatory rural appraisal (PRA) exercise was carried out in 1994 in both Matunda (Trans-Nzoia District) and Anin (Keiyo District) to identify farmers' constraints to crop production. The PRA indicated that there was declining crop yield due to low soil fertility. This was attributed to continuous cropping resulting from small farm sizes, soil erosion and inadequate or non-use of organic and inorganic fertilisers. The addition of fertiliser to the soil was therefore necessary to sustain intensive crop production. Trials were carried out between 1996 and 1999 at Anin in Keiyo District and Matunda in Trans-Nzoia District to assess the possibility of reducing production costs by supplementing or substituting inorganic with organic nutrient sources in order to reduce production costs. The organic manures under investigation were compost and farmyard manure (FYM) for Anin and compost and Tithonia green manure for Matunda. The test crops were cabbage for Anin and kales for Matunda. At both sites all manures and inorganic fertiliser applications gave significantly ($P<0.05$) higher yields than the non-fertilised (control) plots. However, the differences in yields between the fertilisers were not significant. In 1998 at the Anin site application of combinations of organic manure and inorganic fertiliser increased yields of cabbages from 3.92 (control) to 35.37 t/ha (5 t compost + 30 kg P_2O_5/ha). At the Matunda site 10 t compost/ha increased yield of fresh leaves of kales from 29.89 (control) to 66.72 t/ha and application of Tithonia green manure increased leaf yield to 74.9 t/ha for the year 1998. The same trend of results was seen in the 1999 kale results. Results have shown that organic manures including Tithonia can be used alone or in combination with reduced inorganic fertiliser rates to increase vegetable yield.

Saha, H. M. and Muli, B. M. (2002). Effects of combining green manure legumes, farmyard manure and inorganic nitrogen on maize yield in coastal Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 103-113.

A study was conducted in the coastal region with the primary objective of increasing smallholder food production through combined use of organic and inorganic sources of nutrients. The results showed that legumes depressed maize grain yields when they were intercropped with maize for the first time. However, continued use of the maize-legume intercrop system (with legume residue incorporation) increased maize grain yield. The results also showed that application of nitrogen at rates as low as 15-30 kg N/ha significantly increased maize grain yield. A significant three-way interaction effect on maize stover yield was observed during the SR season of 1999. Nitrogen response was highest where farm yard manure (FYM) (2.5 t FYM/ha) was applied to maize that received no legume residue. Legumes depressed maize stover yield when no manure was applied, regardless of the N rate used. However, mucuna and lablab residues applied in combination with 2.5 t FYM/ha increased maize stover yield by about 57 and 5%, respectively when no inorganic N was applied. The three-way combinations of nutrient sources also caused significant increases in maize grain and stover yields. Combinations containing half the recommended rates of FYM and inorganic N (with or without green manure legume) had similar effects to that of the recommended N rate, showing that farmers may use less fertiliser N without lowering maize yields.

Waigwa, M. W. (2002). The use of manure and crop residues to improve the solubility of Minjingu phosphate rock for phosphorus replenishment in depleted acid soils of Western Kenya. Msc. Thesis Moi University; Eldoret, Kenya

P is one of the most limiting nutrients to crop productivity in western Kenya. One of the common correction practices is the use of inorganic fertilizers. However, their use is limited by their high cost which is unaffordable to most small scale farmers. There is evidence indicating positive response of crops to direct Phosphate Rock (PR) application as well as its residual effectiveness. However there is need to improve the PR utilization efficiency. The key to this is to improve PR solubility and hence phosphorus availability. This can be done by incorporation of phosphate Rock (PR) with organic materials available at farms in order to meet P requirements of crops while maximizing the use of available organic resources to improve the soil organic matter and physical properties. Crop residues incorporated into soils are associated with an acid environment upon decomposition, which enhances solubilisation of PR. The main objective of this study was to improve the solubility of PR through its combination with crop residues, manure and compost and to determine the effectiveness of combinations on soil extractable P, pH, P content and uptake by maize and yield in highly P depleted soils of Western Kenya as compared to high cost soluble phosphate fertilizers. Thus, a 4 x 6 factorial greenhouse experiment was set up at Chepkoilel Campus, Moi University to study the appropriate rate of PR application, 0, 25, 50 and 75 kg P/ha for optimum crop yield when combined with 2 t/ha of readily available organic materials and sulphur. An on-farm experiment was also setup in March 2000 first cropping season at Busia, Siaya and Kakamega districts representing two soil types, Ferralsol and Acrisol. The treatments in the field were 2x5 factorial structure with PR applied at 0 and 60 kg P/ha, and maize Stover and FYM at 1 and 2 t/ha each. Soil samples were taken when the maize crop was at 1m height, tasselling,

harvesting, and planting residual crop and at harvesting the second crop and analyzed for soil extractable P and pH. Plant samples were taken at 1m height, tasselling, harvesting, and only at harvest for the second crop. These sampling times were chosen since this is the most critical time in terms of nutrient demand by the crop. The greenhouse experiments results indicate that application of PR combined with organic materials increased soil extractable P, implying improved solubility of PR with higher level of PR and between the sampling periods (4 and 9 weeks). Application of PR at different rates combined with organic materials also increased pH slightly but with sulphur combination lowering pH significantly. The same trend as that of extractable P was observed for P content and uptake with highest P content being obtained from sulphur combination with PR and highest P uptake from chicken manure combinations. A linear response was obtained between P application rates and dry matter yield per pot, suggesting that dry matter yield was related to P availability. Highest response was obtained at 50 kg P/ha PR combined with chicken manure or compost while for maize Stover, sulphur and FYM it was 60 kg P/ha applied as PR. In the field, application of all the treatments increased soil pH slightly over the growing seasons for all the sites. However, a decline in pH was observed at the end of the second season. Olsen test extractable P increased over the sampling periods. Highest Olsen extractable P was observed at harvesting second crop, at planting second crop and at tasselling in Siaya, Busia and Kakamega respectively. Combination of PR with FYM or maize Stover resulted in increased extractable P over the sampling periods. Combinations of PR with either maize Stover or FYM increased extractable P compared to when PR, maize Stover and FYM were applied alone, suggesting that the organic materials enhanced the dissolution of PR thus, increasing extractable P. Although application of organic materials and their combinations with PR increased extractable P, the level of extractable P remained below 10 mg P/Kg of soil, which is the threshold for fertilizer application. A positive response was also observed on tissue P content during the growing season. Combination of PR with FYM or maize Stover increased P content of the fifth leaf from tip at 1 m height, leaf below the cob at tasselling and grain and maize Stover P content of the two crops in Siaya and Busia. In Kakamega the response was only realized in the second crop maize Stover. Combined application of organic and inorganic fertilizer generally increased maize yields, but the effectiveness of the materials and their combinations varied with sites. In Siaya and Busia, application of PR and organic materials increased crop yield significantly. However, in Kakamega the response was positive although there were no significant differences among treatments. The yields of maize grain ranged from 1020 to 2527 in Busia, 2950 to 4770 in Siaya and 4153 to 5835 kg/ha in Kakamega. In general, application of PR combined with FYM or maize Stover at 1 t/ha. These results show that application of the organic materials and inorganic fertilizers can ameliorate soil fertility since the sites are heavily depleted of nutrients. The results from this study also suggest that the effectiveness of PR can be improved through its combination with organic materials tested. The results further suggest that there exist an economic potential to the smallholder farmers arising from combined use of organic and inorganic resources. Further long-term research is necessary to monitor residual effects and also to evaluate the effects of higher rates of application of organic materials and PR in the field.

Gitari, J. N., and Friesen, D. K. (2001). The Use of Organic/Inorganic Soil Amendments for Enhanced Maize Production in the Central Highlands of Kenya. Proceedings of the *Seventh Eastern and Southern Africa Regional Maize conference* pp.367-371

A study was conducted for four cropping seasons commencing March 1999 to determine the level of complementarily between organic and inorganic soil amendments that can be used to alleviate soil infertility for maize production. The sites of the study were at Kianjuki and Kivwe locations of Embu districts in central highlands of Kenya. The treatments consisted of organic, inorganic or combined organic/inorganic soil amendment. Soils at both sites are Ando-humic Nitosols with a moderately acidic (pH=5.3) reaction and low to medium levels of nitrogen (N) and phosphorus (P). Results of maize grain yield indicated that the use of combined organic/inorganic soil amendments appear to be superior to using either an inorganic or organic soil amendment source alone. Highest grain yields of 6.9 and 5.4 t/ha for Kivwe and Kianjuki, respectively, were obtained where combined cattle manure and inorganic fertilizer was applied during 1999 cropping seasons. These yields were 2.0 and 1.5 times more than those obtained in the unfertilized check at Kivwe and Kianjuki sites, respectively. During the participatory farmers' evaluation of the treatments, combined organic/inorganic soil amendments were ranked higher than straight treatments of either cattle manure or a compound fertilizer.

Kwabiah A., Stoskopf N., Palm C. A. and Voroney R. P. (2001). Phosphorus availability and maize response to organic and inorganic fertilizer in a short term study in western Kenya. *Agriculture Ecosystems and Environment Journal*; 95: 49-59

The use of organic materials as P resources is of considerable interest in smallholder farming systems in tropical Africa, mainly because of the potential as alternatives to inorganic P fertilizers. Field studies conducted in a Nitisol of western Kenya in 1995 (crop1) and 1996 (crop2) compared effect of organic and inorganic fertilizers of resin extractable P availability and maize (*Zea mays L*) yield (MY). Leaf biomass and small twigs of *Tithonia diversifolia, Croton megalocarpus, lantana camara L, senna spectabilis, calliandra calothyrus* and *Sesbania sesban* were applied at 5 Mg/ha (DW), supplying an estimated 9-15 kg P/ha and 30-212 kg N/ha. The inorganic fertilizer

was triple superphosphate (TSP), applied at 0 (control), 10, 25, 50 and 150 kg P/ha with each plot receiving 120 kg N/ha as urea. All plots received a blank application of 100 kg P/ha as potassium chloride. Between 92 and 98% ($p<0.001$) of the variation in Pext was explained by the P added (Padd) from the amendments. Response of MY to padd was best described by the logarithmic funtion as: MY=0.78 ln (Padd) +0.04 (R^2=0.91***) for crop 1 and MY 0.93 ln (Padd)-0.5 (R^2=0.90***) for crop 2. Response of MY to Pext was best described by a linear function with R2 ranging from 0.84 to 0.89 for crop 1, and 0.76 to 0.81 for crop 2. Effects of Tithonia and croton were similar to effects of 50 kg P/ha +120 kg N/ha as inorganic fertilizer. Although the cofounding effects of nutrients other than P in the organic materials on MY were isolated, it appears that reasonable MY can be achieved if adequate amounts of high quality organic materials such as Tithonia and Croton are used as P sources. A term 'phosphorous availability index' (PAI), calculated as: (Pext treatments-Pext control)/P added, was introduced to describe the P availability capacity of the amendments. The PAI values suggested a greater propensity for net mineralization following the addition of all organic materials (except *S.spectabilis*) than for the inorganic amendments. The PAI results indicate that improvements of the soil Pext can come from either P released from the inorganic inputs increased availability of native soil P following addition of organic and inorganic fertilizers.

Muthini J. (2001). Effects of starter rates of phosphorus and nitrogen on the establishment and productivity of the African clover cv. mealton 5 (*Triolium quatinianum*). Msc. Thesis; University of Nairobi, Nairobi, Kenya

A study was conducted at Kabete between October 1999 and July 2000 to determine the effects of starter of phosphorus, nitrogen and subtle height on establishment and productivity of African clover (*T. quartinianum* Cv. Mealton5). Soil was analyzed for available phosphorus and total nitrogen before planting and after harvesting. To determine establishment, Field plant counts were taken biweekly. Dry matter (taken at 120 and 180 days after planting), nodules per plant, cover and plant height (taken biweekly) were used to determine Mealton % productivity. Percent leaf crude protein (taken after the final harvests) was used to determine nutritive quality of the clover. Weather elements for the entire study period were recorded. The experiment was laid out in Randomized Complete Block Design (RCBD) in three blocks with four treatments. These were: Control (P0N0), Nitrogen alone (P0N1), at 27 kg N/ha as urea (46%N), Phosphorus alone at 30 kg P/ha as Triple Super phosphates (TSP) (20%P) (P1N0) and combination of phosphorus and nitrogen at 30 kg P/27kg N/ha (P1N1) First experiment was carried out from October 1999 to April 2000, while the second one was from January 2000 to July 2000. Four growth stages were observed in the growth life of this clover. Weather conditions affected the performance of this clover. Seed germination was 90-95% 11 days after the experiment was initiated. Plant field establishment was enhanced more by application of both nitrogen and phosphorus than application of each fertilizer alone. Seedling counts declined with time due to mortality. Plant cover was highest in TSP alone and TSP plus urea treatments from mid-second quarter of growth until final harvest. The control treatment had poorest cover throughout. The same trend was observed in plant height. Decline in the fourth quarter was possibly due to leaf fall. Nodules per plant were significantly (P=0.05) increased by phosphorus application. They were highest in TSP alone followed by TSP plus urea. Control and urea alone, respectively had fewer nodules. Dry matter yield were significantly (P=0.05) increased by phosphorus application while urea alone had a lesser effect. Cutting height had no significant effects. Percent leaf crude protein was significantly (P=0.05) higher in fertilizer plots than in the control. There was an increase in soil nitrogen with fertilizer application after harvesting clover than before planting. This was enhanced by phosphorus application. An Increase in soil available phosphorus was observed after harvesting plants under TSP alone TSP plus urea treatments. Correlation among variables was generally positive. Several of the variables are mostly definitely associated with dry matter yields in Mealton 5. Application of phosphorus at 30kg P/ha as Triple super phosphates (TSP) or phosphorus plus nitrogen at 30 kg P plus 27kg N (as urea) per hectare gave the highest dry matter yields and percent leaf crude proteins as well as soil nitrogen and phosphorus content under conditions of this study.

Ndufa, J. K. (2001). Nitrogen and soil organic matter benefits to maize by fast-growing pure and mixed species legume fallows in Western Kenya. PhD Thesis; University of London, UK

Declining yield of soil fertility depletion associated with continuous cropping without external inputs of nutrients is a major problem facing smallholder farmers in sub-Saharan Africa. Significant increases in crop yields have been reported following short duration leguminous fallows (9-18 months) with substantial residual benefits for following maize crops over at least two cropping seasons. However, despite large yield increases it is hypothesized that incorporation of fallow species residues may decompose too rapidly due to their high quality (high N, low lignin, low polyphenols) and N release will be asynchronous with crop demand. This may result in substantial N losses during the crop growth phase. Single species fallows may contribute to long-term build-up of soil organic matter than associated with mixed species resulting in shorter residual yield benefits. It also hypothesized that widespread use of single species fallows may lead to problems of pests and diseases and risks of fallow establishment failure. Mixed species fallows also have the potential to provide multiple products and increased biodiversity. Field and laboratory experiments were undertaken to investigate the effects of pure and mixed fallows on tree biomass productivity, maize yield, synchrony between N release and crop demand and soil organic matter build-up

after biomass incorporation. Short and long term soil fertility and crop yield sustainability of improved fallow systems were predicted under current and alternative management options. Field experiments were conducted on farmers' fields in western Kenya using *Sesbania sesban*, *Crotalaria grahamiana*, *Cajanus Cajan* and *Macroptilium atropurpureum* as single species fallows and mixtures of these with sesbania. Maize yields were increased by 175-309% in the first crop following 15 months of pure and mixed legume fallows and increased by 37-197% in the second crop compared with continuous maize cropping. These increases were comparable to an application of at least 100 kg N/ha of inorganic fertilizer in each of the two cropping seasons after the fallows indicating that fallows were able to supply large amounts of N. Leaching tube experiments showed that incorporation of legume fallow residues resulted in N mineralization patterns related to their qualities. Incorporation of Calliandra, a species high in polyphenols, resulted in temporary immobilization of N but did not affect N release from sesbania when applied in a mixture. In field experiments, net mineralization of residue N was greatest two weeks after biomass incorporation and maize planting. Continuous maize cropping, natural weed fallow and calliandra residues resulted in the lowest mineral N release and sesbania, macroplatinum, cajanus and crotalaria residues and the mixtures with sesbania resulted in the highest mineral N releases. Total N uptake by maize ranged between 40 to 120 kg N/ha and was lowest in the continuous maize cropping and natural weed fallow and highest in the improved fallow treatments. Application of ^{15}N-labelled residues showed that maize recovered more N from the higher quality (sesbania and macroplatinum) than from lower quality calliandra residues. A large fraction (50-60%) of the applied residue ^{15}N remained in the soil incorporation, particularly in the single and mixed calliandra treatments. About 14-15% of N applied as sesbania and macroptilium residues was recovered by first maize crop and 3-6% was recovered in the second crop. About 30-40% of applied N could not be accounted for. ^{15}N distribution in particle size fractions showed that most calliandra N was found in the >20 µm fraction but sesbania and macropltilium N was mostly in the >µm fraction. The ^{15}N stem injection technique showed that the contribution of fallow roots to maize N nutritution was less than 5%. Simulation of maize growth and yield using the WaNuLCUS model suggested maize growth to be N restricted after the first cropping season after the fallow, with significant leaching of below 1 m. The simulated SOM-C and SOM-N build-up was greater in the high biomass crotalaria treatment. Fallowing with sesbania after every two cropping seasons or with crotalaria every 4 seasons, or mixing of the two species are recommended as possible management options to remediate soil nutrient depletion in smallholder farming systems in sub-Saharan Africa.

Obura P. A. (2001). Effect of rock phosphate, urea and rhizobium inoculation on growth, yield and nutrient uptake of maize-soybean intercrop on the acid soils of western Kenya. MSc. Thesis, Moi University, Eldoret, Kenya

Soil fertility depletion in Western Kenya is a major cause of low agricultural productivity and its amelioration, through nutrient replenishment strategies is viewed as necessary component in the achievement of food security. The magnitude of soil fertility decline is huge, with widely distributed symptoms occurring through the expression of unproductive, nutrient-deficient "patches" within farmers' fields. Nitrogen (N) and phosphorus (P) are the most important plant nutrients but they are the most limiting in the tropical African soils and are often simultaneously deficient. Farmers intercrop maize with food legumes in Western Kenya and have grown to accept low yields as trade-off to dietary importance. There is need to develop low cost nutrient combination "kit" to treat the "patches" Phosphate Rock Evaluation Project-Package (PREP-PAC) is an inexpensive "kit" designed to treat the "low fertility patches". The PREP-PAC consists of 2 kg Minjingu Rock Phosphate (MPR), 0.2 kg urea, legume seed, Biofix, (rhizobial inoculant) and detailed use instructions, and is assembled at a cost of Ksh, 41.2 per unit. The research was conducted during the 1998 and 1999 cropping seasons in farms selected from Uasin Gishu, Siaya, Bungoma and Kakamega districts. These farms were on low soil pH and low available soil P. The components of PREP-PAC were examined in a 2*2*2 factorial treatment arrangement with four replicates in each of the sites in equal plot sizes of 5m*5m and maize (*Zea mays*), H614D intercropped with soybean (*Glycine max*), cv. Black Hawk. It was observed from the soil analysis data that farms where PREP-PAC was tested were different from one another in their characteristics. But in general, the soil pH in all the farms was below 6.0. On the other hand, the available P contents for all the soils were found to be very low, ranging from 1.2 ppm P in Siaya to 5.2 ppm P in Kakamega. The data obtained showed that Minjingu rock phosphate, Biofix and urea resulted in improved crop yield. Significant interactions were observed between different combinations of the main components. Maize yields ranged from 431 to 6525 kg/ha across all the sites and seasons. During the 1998, the yields were higher in Siaya as compared to Chepkoilel farm and ranged from 3995 to 6525 kg/ha (for the control and PREP-PAC treated plots, respectively). But the maize yields in Chepkoilel farm were disappointingly very low, <1000 kg/ha. For the 1999 long rains cropping season, the sites were found to be significantly different (P≤001) and maize yields varied with the treatment and ranged from 1171 to 4814 Kg/ha for the three sites. The average contributions of each PREP-PAC components for urea, Biofix and MPR respectively were; +428, +680 and +1511 kg/ha in Siaya, +139, +40, and + 78 kg/ha in Chepkoilel, -6, +141, and +804 kg/ha in Kakamega and +74, -205 and +1362 kg/ha in Bungoma. In spite of significant site and treatment differences observed for soybean yield, these yields were very low and between 250 and 504 kg/ha in 1998 and 45 and 320 kg/ha in 1999. ANOVA indicated significant residual effect of PR at P≤0.05 on maize and soybean yield in the second season crop in Siaya. Nutrient uptakes varied greatly between maize and soybean, across the sites and seasons. The use of PREP-PAC resulted in higher

uptake of N, P and K from the experimental plots. With the exception of the first season at Siaya, for which nutrients uptakes were partitioned, the total nutrient uptakes were as follows: The total nitrogen for grain stover/ trash uptake in grain and stover/trash across the sites and seasons ranged from 15 to 171 kg N/ha for maize and 4 to 48 kg N/ha for soybean, while phosphorus uptake was between 1 and 110 kg P/ha for maize and 0.1 to 2.6 kg P/ha for soybean. For the partitioned grain and stover/trash N and P uptakes were as follows: 109.6 and 61.6 kg N/ha in grain, 6.92 and 2.84 kg P/ha in stover/trash for maize and soybean respectively. However, some treatments caused significantly greater N and P uptake in the grains plus stover. Significant site differences were also observed with respect to total returns ($P \leq 0.001$), return ratio (≤ 0.01), value of maize ($P \leq 0.001$) and value of soybean ($P \leq 0.05$). These findings indicate that the combinations of PREP-PAC components behave in a synergistic manner, particularly where both soil N and P limit crop production. The PREP-PAC is effective in replenishment of these in western Kenya.

Amolo, R. A, Karanja, N. K, Palm, C. A. (2000). Nitrogen mineralization from cattle manure, filter-mud, factory ash and nitrogen uptake by maize (*Zea mays*) in a glass house experiment. *Soil Science Society of East Africa, Proceedings of the 15th Annual General Meeting* Sportsman's Hotel, Nanyuki, Kenya; August 19th - 23rd 1996 pp 132-142.

A study was conducted to improve nitrogen release ability from filtermud (FM) through reduced curing time. Chemical analysis of filtermud, cattle manure, factory ash and soil samples were carried out. Laboratory incubation experiments using filtermud alone or in mixtures at various ratios with factory ash and mineral nitrogen was conducted for a period of 12 weeks. Cattle manure and factory ash (alone or in combination with mineral nitrogen) were included to make 15 treatments. Miwani FM was found to be strongly acidic (pH 4.93) and relatively with less lignin content compared to that from Muhoroni and Chemelil. In terms of nitrogen release Miwani FM was superior to that from Chemelil and Muhoroni, as it released 53% of nitrogen (available) after 12 weeks. Regression analysis of nitrogen release showed that there was a negative linear relationship with the following; % lignin content ($r=-0.99$), lignin to nitrogen ratio ($r=-0.93$) and carbon to nitrogen ratio ($=-0.85$), hence lignin was the predominant factor controlling the nitrogen release from these organic materials. A maize crop was grown for 9 weeks in pots containing soils with FM from Miwani mixed with or without nitrogen at the following rates; 0, 7.5, 15, 30, and 45 t/ha, soil mixed with 100 kg N/ha was included giving a total of six treatments. FM at 45 t/ha amended with mineral nitrogen at the rate of 9 kg N per ton of FM gave significantly ($P \leq 0.05$) higher dry matter (19 g/plot) and nitrogen uptake (13%) than the rest of the treatments. Therefore, for an inherently low fertile soil such as Cambisol addition of 45 t/ha FM amended with mineral nitrogen at 9 kg N (calcium ammonium nitrate) per ton of FM would be required to improve the fertility and hence nutrient availability. Field trials need to be conducted, since the results were laboratory based.

Hartermic, A.E., Buresh, R. J., van Bodegom, P.M., Braum, A. R., Jama B., Janssen, B. H. (2000). Inorganic nitrogen dynamics in fallow and maize on an oxisol and Alfisol in the highlands of Kenya. *Geoderma Elsevier B* Vol.: 98:11-33

Fallows with naturally regenerated or planted vegetation are important in much subsistence agricultural systems of tropical regions, but the underlying soil process in fallow are not properly understood. We have investigated N dynamics under different fallow vegetations on a Kandiuldafic Eutrudox (2372-mm rain in 16 months) and a Kandic paleustalf (1266-mm rain in 15 months) in the Kenyan highlands. The treatments, which extend for three cropping seasons (15-16 months) were maize (*Zea-mays*), natural re-growth of vegetation (natural fallow), planted sesbania sesban (*Sesbania* fallow) and uncultivated soil without vegetation (bare fallow). Inorganic N (nitrate + ammonium-N) top 2-m depth under bare fallow increased by 242 kg N/ha per year on the oxisol and 54 kg N/ ha per year on the Aflisol, indicating that N mineralization exceeds N losses. Subsoil inorganic N (0.5-2.0 m) remained relatively unchanged after three crops of unfertilized maize, which produced limited total biomass because of P deficiency. Inorganic N decreased during natural and sesbania fallow, and both fallows similarly depleted subsoil inorganic N. The fallow depleted inorganic N at 0.5-0.2 m by 75-125 kg N/ha per year down to an N minimum content between 40 and 80 kg N/ha, soil inorganic N increased within two months by 136 kg N/ha on the oxisol and 148 kg/ha on the Alfisol. Inorganic N increased after cropping the bare fallow on the oxisol with maize, indicating that inorganic N was prone to leaching during heavy rains when the maize was small. A considerable N in the biomass of the natural fallow was recycled. Much of the total N accumulated by the sesbania fallow was removed with the wood and the amount of N recycled was similar on the Oxisol and the Alfisol. We conclude that sesbania fallow can retrieve considerable subsoil inorganic N on deep soil with high subsoil N and effectively cycle this N through its rapidly decomposable biomass to subsequent crops.

Kathuli, P. and Maingi, S. W. (2000). Evaluation of agronomic effectiveness of Minjingu rock phosphate using ^{32}P Isotope dilution technique. Proceedings of the 15th Annual Conference 19th -23rd August 1996. Nanyuki, Kenya. pp 107-111.

Agronomic effectiveness of Minjingu Phosphate Rock (MPR) and Tororo Phosphate Rock (TRP) was compared to triple superphosphate (TSP) in a glass house pot experiment using wheat as a test crop. TPR and TSP were applied at 120 mg P/2kg soil while MPR was applied at 240 mg P/2kg soil. 32P was added at 80 µCi + 2.5 mg P as KH_2PO_4 per pot (2 kg soil). Basal fertilizer N and K were applied at 120 kg N/ha as CAN and 100 kg K/ha as KCl respectively. The treatments were replicated four times. The test soil was of good fertility status except it was acidic (pH 4.75), deficient in P (6.5 ppm), low in Ca (1.70 m.e. /100 g soil) and unfavourable Ca: Mg and Ca: K ratios. The test crop was harvested after 6 weeks and the results showed that TSP (120 mg/2 kg soil) gave similar dry matter yield to MPR (240 mg/2 kg soil) but TSP had a greater P (112.90 mg P/pot) uptake than MPR (92.64 mg P/pot) and TRP (38.16 mg P/pot). The phosphate fertilizer use efficiency for TSP, MPR and TRP were 94.1%, 38.6% and 31.8% respectively. The relative phosphate fertilizer use efficiency for MPR and TPR was 40% and 34% respectively. It was tentatively concluded that MPR and TPR have very low agronomic value for the study soils.

Kihanda, F., Micheni, A., Ndwiga, C. and Kinyua, A. (2000). Effect of manure application on maize yields: Long-term experiment at Machang'a semiarid eastern Kenya. Kenya Agricultural Research Institute-Regional Research Centre –Embu. Annual Report 2000 pp 12-13

Manure application is one of the most effective ways of improving soil fertility in tropical African conditions. In semi-arid Kenya, inadequate soil nitrogen (N) and phosphorus (P) restrict crop production, and hence manure and fertilizer application can give yield increases. Improved cropping systems are also needed, which are both more efficient with plant nutrients and more attractive to farmers in semi-arid Kenya. A study was carried out in Machanga, Mbeere district to evaluate goat manure and its residual effect on maize and pigeon peas yields. Inorganic fertilizers were also tested. The results showed that the residual manures had no significant differences. There were no significant differences (P=0.05) in maize grain yields between plots receiving 5 or 10 t/ha of the goat manure. Although inorganic fertilizer increased maize grain and stover yield above the control and residual plots, the yields however were lower than any of the manure treatments. This increase in crop yield due to manure application may have been due to other intrinsic factors of the manure e.g. moisture retention and provision of micronutrients. Therefore manure can be used to improve crop productivity in the semi-arid Mbeere district.

Kihanda, F. and Micheni, A. N. (2000). Changes in extractable P and organic carbon under continuous cultivation at Machang'a in semiarid Kenya. Kenya Agricultural Research Institute-Regional Research Centre -Embu Annual Report 2000 pp 11-12

Soil fertility is the second most important factor after the low and erratic rainfall limiting food crop production in semi-arid Mbeere district. Farm yard manure produced at farm level can be used to improve soil fertility and hence crop productivity. Along-term experiment to determine the influence of manure on crop yields and soil fertility improvement was set up. Goat manure was applied at varying quantities for 12 years with the purpose of establishing whether farm yard manure could be used to maintain and improve soil organic matter under continuous cultivation in the semiarid environments. The result showed that soil organic carbon decreased with increasing soil depth. Application of manure for the 12 years doubled the organic matter of the tops soil. Application of manure increased the exchangeable phosphorus. The declining soil fertility in the semi-arid areas of Mbeere district can be restored through application of manure.

Kinyua, I. S. (2000). The response of Maize to split Application of Urea and *Tithonia diversifolia* Green Leaf Manure in Western Kenya. Msc Thesis, Moi University, Eldoret, Kenya

Soil in western Kenya have low nitrogen and phosphorus due to inherent low soil fertility aggravated by continuous cropping with little or no use of fertilizers leading to very low crop yields. Addition of nutrients, particularly nitrogen and phosphorus is necessary in order to increase crop yields. A study was carried out to assess split application of *Tithonia diversifolia* green leaf manure as a source of nitrogen for maize. The aim was to determine whether Tithonia could substitute urea as a nitrogen source. A field experiment was conducted in a Kandiudalfic Eutrudox soil at Khuwisero, Butere District, Western Kenya during long Rains (April to August 1998) followed by a residual crop during the short rains (September 1998 to January 1999). Nitrogen, at the rate of 60kg N/ha was split applied at planting and also at six weeks after sowing as follows: 60:0, 40:20, 20:40 and 0:60. Tithonia and urea were used as nitrogen sources on both low P (10 kg P/ha) and high P (100 kg P/ha) soils. Results for cumulative maize grain yields for two seasons were comparable with either *Tithonia diversifolia* or urea as the nitrogen source for maize in both low and high P soils, suggesting that Tithonia could substitute urea. However, with high P application of Tithonia all at planting time gave significantly higher yields (5.4 t/ha) compared with the other

N application timings. For urea, split application of 1/3 at planting followed by 2/3 at six weeks later gave the highest yields (6.1 t/ha). In contrast with low P soils, Tithonia showed lower yields when applied at planting (2.4 t/ha) compared with the other N timings, which were similar. However, for urea, split application of 2/3 at planting followed by 1/3 at six weeks gave the highest yields (3.8 t/ha). The results showed that the mode of application of Tithonia as N source for maize differed from urea and varied with the level of phosphorus applied. In low P soils, Tithonia gave net negative economic returns of Kshs -2176/ha because of high labour costs compared with the net positive returns of Kshs 5740/ha for urea during the first season. A similar, but slightly improved trend was observed when the two seasons were combined when Tithonia gave net negative economic returns of -350/ha compared with urea Kshs 6580/ha. Tithonia application at six weeks after planting showed higher net economic returns of Kshs 5600/ha compared with Kshs 980/ha for urea in low P soils, hence is recommended for the region. This is likely to appeal more to farmers since it coincides with low peak season for labour. However, the best application strategy for urea is two thirds at planting and one third six weeks later.

Mwangi, T. J., Ngeny, J. M., Wekesa, F., Mulati, J. (2000). Acidic soil amendment for maize production in Uasin Gishu district, North Rift, Kenya. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. pp 37-46

Soil acidity is one of the factors limiting maize production in some parts of Kenya notably in Uasin Gishu plateau. Several means of amending the problem such as liming, use of organic farm yard manure (FYM) alone or in combination with inorganic fertilisers and also use of non-acidifying fertilisers have been suggested. Several formulations of fertilisers that can be used as alternatives to Diamonium phosphate (DAP) fertiliser which is said to aggravate the acidity problem have been produced. The objective of the trial was to investigate the effects of various amendments on soil chemical properties and to determine the best inorganic fertilisers or organic manure combinations for higher maize production. Maize hybrid 614D was planted in two sites namely Soy and Turbo in Uasin Gishu District following the recommended cultural practices except fertiliser application. The trial had the following treatments: 23:23:0/CAN, DAP/CAN, DAP + Lime/CAN, FYM/CAN, FYM + maize stover, Minjingu phosphate/CAN, TSP/CAN, TSP + α CAN/CAN, TSP + FYM/CAN and TSP + maize stover/CAN. Results indicated that soil acidity improved with the application of agricultural lime in some seasons. Farmyard manure also improved soil pH but the change was not as instant as was for lime. However, soil acidity improvement through manure would be more sustainable with time than use of lime. The increase in pH could not be directly associated with maize yields. Soil pH as low as 4.5 did not reduce maize yields provided the limiting nutrients were supplied at the recommended rates. Soil extractable phosphorus accumulation due to lime, phosphatic fertilisers and organic manures occurred within the first six seasons. Although phosphorus was limiting, planting with farmyard manure and then topdressing with CAN produced yields that were equivalent to maize planted with either phosphorus or phosphorus with lime and then top dressed with CAN. Compound phosphatic fertilisers with starter nitrogen gave higher maize yields than straight phosphatic fertilisers.

Okalebo, J. R, Simpson, J. R, Probert, M. E, Okwach, E. G, McCowan, R. L. (2000). Maintenance of soil fertility under intensive maize cropping in Machakos District, Kenya. *Proceedings of the 15th Annual Conference* 19th -23rd August 1996. Nanyuki, Kenya. pp 55-62.

There is an urgent need to develop farmer acceptable methods of maintaining soil fertility in medium-potential areas such as those in Machakos District where low input dry land cropping continues every season on acrisols, alisols and luvisols of low organic matter content. On some of the farms, maize yields are already very low. In this paper we report the effects of treatments involving differential applications of stover mulch, nitrogen (N) and phosphorus (P) fertilizers, and increased plant population, in an experiment at the National Dryland Farming Research Centre, Katumani. This experiment began in 1989 and has been continually cropped for over five years (11 crops). The effects of treatments on maize yields have been marked (means yield varied from 1.3 to 2.9 tonnes/ha) but the effects so far on total soil carbon (C) and N are less obvious, with a decline of about 20% at 'low inputs' and maintenance of the initial levels at 'high inputs' (40-40 kg N, 10 kg P/ha and stover return). The return of stover mulch increased available soil moisture, by reducing run-off, but an analysis showed no residual accumulation of fine particulate organic matter in the soil (by the TSBF method). Therefore the C and N added as stover appeared to be continually dissipated under cultivation. The inorganic fertilizers caused some acidification (0.36 pH units in H_2O) at 0.15 cm depth on this low CEC soil.

Ikombo, B. M., Nguluu, S. N., Simiyu, C. S. (1999). Effects of a combined application of manure and nitrogen in a semi-arid environment. *Proceedings of the 6th KARI Scientific Conference* 9-13th Nov. 1998. Kenya pp 336-344

A study was conducted under field conditions at Masii to examine maize response to a combined application of cattle manure and nitrogen (N) in a sandy soil. The treatments consisted of 0, 10 and 20 tons of manure per hectare (t/ha) applied in a band along the maize rows. The manure was combined with 0, 30, 60 and 120 kg N/

ha all applied at planting in the first year, and 0, 45, 90 and 150 kg N/ha split into two applications in the second year. Maize plants grown without either manure or nitrogen were stunted and yellow. Grain yields were low ranging from 175 to 246 kg/ha, in the two years of study when no manure or fertiliser was applied. Application of 10 t/ha of manure alone increased the grain yield to a maximum of 850 kg/ha while application of 120 kg N/ha alone increased the yield to a maximum of 1529 kg/ha. Grain yield increased significantly with combined application of manure and nitrogen to 3145 kg/ha, when a combination of 20 t/ha of manure and 120 kg N/ha was applied in the first year. Even then, a yield plateau could not be attained. The study indicated that low soil fertility is a major limitation to maize growth and production in the study area. Maize production can be improved by application of manure or nitrogen; however, higher yields could be achieved when manure and nitrogen are applied in combination.

Kaduki, C. M. (1999). The effect of composite and di-ammonium phosphate on maize and sesbania sesban growth and yield on a ferralsol at Chepkoilel campus Uasin Gishu District Kenya. Special project for Bsc, Moi University, Eldoret, Kenya

Maize responded but to a combination of fortified compost plus DAP at the rate of 2 t/ha fortified compost + 60 kg DAP/ha. The application of DAP alone at 60 kg/ha also gave very encouraging results. The differences in maize heights and yields did not show a very significant difference from treatments. Probably because maize is fast growing and takes up the readily available nutrients whereas fortified compost takes a longer period in decomposing and releasing nutrients through mineralization that could take up to 3-5 years on the site. Fortified compost if given time to decompose completely can prove very vital as indicated in the weight of shelled maize i.e. 3 t/ha fortified compost gave 4485 kg/ha. DAP and fortified compost produce the highest number of cobs. The rate of 2ton/ha compost + 60 kg DAP/ha gave maize yield (dry weight) on cobs of 10471 kg/ha. Thus for Chepkoilel campus, the combination of fortified compost and DAP are very effective in growth and yield of maize. Responses to combine fortified compost and DAP at the rate of 2ton/ha compost + 40 kg DAP/ha gave highest dry matter yield, N-uptake, P uptake and K uptake. However, a better picture can be obtained under more vigorous controlled glass house studies. There was root nodulation with pink nodules reflecting N_2-fixation particularly under adequate P nutrition. of great interest was the control that gave the highest number of nodules. This could be probably that other treated pots had adequate nutrient (N and P) supplies and were not induced to produce a high number of nodules. This implies the need to study Sesbania production at Chepkoilel and in Uasin Gishu district as a whole. Sesbania has a potential in this area in the improvement of soil fertility and in the provision of scarce fuel wood. Farmers should be advised in Uasin Gishu to combine the use of fortified compost and Di-ammonium phosphate, preferably at the rate of 2 t/ha fortified compost + 60 kg DAP/ha. Burning of crop residue should be stopped in order to incorporate them into the soil in order to provide the necessary nutrients locked up in them and to improve soil physical and chemical properties. Burning causes the nutrients to escape through volatilization. A repeat experiment for the maize should be allocated on a site other than where this one was experimented on. This is due to probably the influences of the fertilizer and compost used in the past experiments, some of which could still be mineralizing and realizing nutrients. Other maize varieties for highland regions other than H614D which was used, should be tried using the same treatments in order to see the performance and variety differences. A study on the right time of application of fortified compost should be determined for various crops. Composting procedures should be tested for quality, composting time and agronomic effectiveness. A more thorough study of S. Sesban should be enhanced relative to the use of fortified compost and DAP vis a vis nodulation. Sesbania is a very vital tree in N_2-fixation and provision of fuel wood and other materials for farms in Uasin Gishu.

Kimani, S. K, Mangale, N, Lekasi, J. K, Wamuongo, J, Gichuru, M, Palm, C. A. (1999). Nitrogen and carbon mineralisation of some manure produced under different management systems in central Kenya. *East Africa Agricultural Forestry Journal*. Vol. 65 (1) pp 1-5 Kenya

Animal manure is used in smallholder farms to improve soil fertility but the quality is often poor. The quality of the manure in the inherent nutrient levels is low and mostly associated with diets fed to the animals and the management of the manure. A study was carried out to investigate carbon and nitrogen (N) mineralisation of cattle manure processed under different management systems. Manure was produced in smallholder farms and in a research station. A detailed laboratory analysis was done to characterise the manure. The manure was subsequently incubated with humic nitisol, the dominant soil group in central highlands of Kenya. In the incubation study, data were collected on carbon dioxide evolution and nitrogen mineralisation (NO_3^- and NH_4^+). An on-farm trial was conducted to test the effect of two types of manure with different N release rates on maize yield. The on-station manure and manure from farmers' fields showed a net nitrogen release up to 12 weeks of incubation. Some manure from farms immobilised N for most of the incubation period. Carbon dioxide evolution at weeks two and four indicated that there was microbial activity in most of the manure. The release of N in the incubated manure was confirmed in the field study where the on-station manure showed a yield response in maize during the first season. This study shows that manure management affects the rate of N release can affect crop growth in the field. Level of soluble carbon correlated most with N mineralisation.

Kimani, S. K., Mangale, N., Gathua, K. W., Delve R., Cadisch, G. (1999). Effect of bean-maize intercropping, phosphorus and manure additions on N2 fixation and grain yield of *phaseolus vulgaris* in the central Kenya highlands. *Proceedings of the KARI Scientific Conference*, 19-13 November 1998; KARI Headquarters. Kenya. pp 205-211

Sole bean and intercropped bean crops were studied for four seasons from 1996-1998. Addition of inorganic P at the recommended rate of 60 kg P_2O_5/ha increased bean standing biomass and grain yield during the first season. Cattle manure, applied at the rate of 12 t/ha (25% moisture content), had a negative effect on bean yield during the first season possibly due to short-term nutrient immobilisation induced by the high C:N ratio of the manure. In subsequent seasons, manure addition resulted in higher grain yields compared with inorganic P. Intercropping beans with maize lowered grain yields by 10-100%. N_2 fixation was evaluated using the natural ^{15}N abundance method. Intercropping increased the proportion of N_2 fixed in beans on average from 55 to 69%. Intercropping thus provides a strategy for a better N resource use where the maize crop competes efficiently for available soil mineral N and the legume replenishes part of the extracted N via atmospheric N_2 fixation. However, the amounts of N_2 fixed appear not to be enough to replenish whole systems N exports in grain crops and thus additional N_2 inputs are needed. Thus more attention needs to be given to manure management and its long-term impact on soil fertility.

Kimutai, L. J. (1999). The effect of incorporating maize Stover (organic residue) and varying levels of nitrogen fertilizer in soils on growth, yield and quality of seed maize. Msc Thesis; Moi University Eldoret, Kenya

Farmers have been using low coast organic resources to improve the fertility of their soils over the years. However these materials differ significantly in quality and (0.533). Uptake of total effectively in order to maintain positive results and consequently improved yields. This observation formed the basis of this research. The overall objective was to determine the optimal levels of incorporating the low quality maize Stover material with inorganic fertilizer for improved soil fertility and productivity. The study therefore determined the response of seed maize (test crop) to maize Stover (MS) and nitrogen (N) additions. The sun-dry and chopped Stover was incorporated uniformly with nitrogen fertilizer at varying rates into the soil at plough depths (0-15cm) using a hoe at a uniform rate of 2 tones maize Stover (SM)/ha for six out of eight treatments. The N fertilizer was applied at 0, 20, 40, 60, 80 and100 kg N/ha Treatments were replicated four times in a nitrogen deficient Chepkoilel site Uasin Gishu district. During the vegetative reproductive and maturity growth of maize physiological and developmental parameters were measured. Secondly the optimum seed output and quality focussing on the aspects of organic and inorganic fertilizer treatments were determined. A qualitative and a qualitative data assessment was of data was done including the statistical analysis to determine treatment differences. Response to treatments was noted in the majority of parameters. In plant height for instance 100N + MS treatment gave the tallest plants (133.7cm) as compared to control plots (126.7 cm). Likewise the largest leaf surface area (281.4cm^2) clearly reflecting the significance of N in increasing leaf size. On seed quality parameters seeds with the smallest surface area (0.511 cm^2) were found in control and MS treated plots while 80 N + MS gave the largest area (0.537) followed by 100N + MS treatment (0.533 cm^2). Uptake of total N and P by seed plus Stover was lowest in control (34.0 kg N/ha and 4.09 kg P/ha and MS treated plots (29.4 kg N/ha and 3.88 kg P/ha) while the largest treatment value was in 80 N + MS (53.4 kg N/ha and 6.51 kg P/ha) for uptake of these nutrients. Ms treated plots maintained the highest moisture 26% reflecting the significance of maize Stover in increasing soil moisture retention capacity. No Stover was applied in control plots which explains why it had the lowest moisture levels 21.7% .There is need to change land cultivation patterns in Uasin Gishu or elsewhere where maize Stover and other crop residues are abundant. It is therefore recommended that smallholder farmers need not to burn this Stover but incorporate them with inorganic fertilizer for enhanced crop yields and improved soil fertility.

Lelei J. J. (1999). The effects of lime, manure, n and p fertilizers on nitrogen and phosphorus available ability, microbial biomass and maize yield in acidic soil. Msc. Thesis, Egerton University, Njoro, Kenya

The experiment on the effect of lime (L), manure (M), N and (NP) fertilizers on nitrogen and phosphorus availability, microbial biomass and maize yield in an acid soil, was conducted at KARI, Molo. The experimental design was a randomized complete design (RCBD) with a 23 factorial arrangement. L, M and NP fertilizers each at two levels were the factors. In a second study, the effect of lime on P availability was studied. A RCBD was used with 2.5 t/ha of lime and four rates of P (0, 25, 50, 75 kg/ha) as the treatments. Incubation studies to determine potential N and P mineralization of the soil as affected by lime. N and P fertilizers were conducted in the laboratory for 120 days. Maize grain and DM yields were significantly increased through N and P fertilizers and manure application. L*M*NP treatment gave the highest grain and DM yields (4387 and 7410 kg/ha respectively) while control gave the lowest (3067 and 5250 kg/ha respectively). The yields from control treatment were not significantly different from those of lime (3158 and 5300 kg/ha). Liming did not reduce P application rates, because higher rates of TSP (50 and 75 kg P/ha) with liming resulted in better maize grain and DM yields than lower rated of TSP (0 and 25 kg

P/ha). Soil available N was significantly increased by M*NP (7483, 70 70, 61 97, and 5928 ugN/g dry soil) and NP (92 75, 71 33, 52 95 ugN/g dry soil) application at the four stages of maize growth (seedling, tasselling, cobbing, and maturity). Liming did not significantly promote soil N mineralization. Its application resulted in low soil and plant tissue N at the four stages of maize growth, Control treatment had the lowest plant tissue N (1 23, 1 01, 0.89, 0.76 (grain) and 0.32 (stover) % at the four respective stages of maize growth. These values were not significantly different from those of lime treatment. L*M*NP and M*NP treatments gave relatively higher concentrations for P in soil (5.80 11 60, 9 40, 7 30 ppm and 5.80. 8.50, 5.70 and 5.50 ppm) and plant tissues (0.74, 0.96, 0.58, 0.09 (stover), 0.20 (grain) % and 0.48, 0.63, 0.48, 0.06 (stover) 0.14 (grain) %, respectively than other treatments at the four stages of maize growth. Correlations between yield and leaf P were positive and significant (0.775, 0.921 and 0.916 at seedling, tasselling and cobbing stages of maize growth. They were positive for N (0.653, 0 841, 0 657) but only significant at tasselling. There were seasonal variations in soil microbial biomass (SMB) in all treatments with decreases coinciding with periods of high plant N demand and vice versa. Application of manure significantly increased SMB. The M*NP,*L*M*NP and M treatments had higher SMB than other treatments throughout the cropping period.; The total average potential N mineralization in the soil profile (0-60cm depth) was 4.7 mg/N/kg dry soil per day with the 0-15xm depth contributing 42.7% of the mineral N Liming (laboratory) increased N mineralization of the soil substantially (666.1 mg/kg N) treatment had significantly higher levels of mineralized P (74.1 mg/kg) than the control (43.9 mg/kg), lime (47.4 mg/kg,) and urea (34.2 mg/kg) treatments. Comparison on N and P mineralization rates per day using t -tests showed significant differences in lime, control, and urea treatments. N mineralization was faster and higher than that P. There were however no significant differences between N and P mineralization rates in the TSP treatment.

Odera, M. J. (1999). Effect of Phosphorus and Nitrogen application and inoculation on growth. Nodulation and pod yield and quality of French bean (*Phaselous vulgaris L*) plants. MSc. Thesis; University of Nairobi, Kenya

An experiment was conducted at Kabete Field station, the faculty of Agriculture, University of Nairobi for two seasons (between November 1991 and March 1992 and between July 1992 and August 1992). The experiment investigated the effect of Nitrogen (N) (0, 52 kg N/ha) and phosphorous (P) (0, 45, 90, 135 kg P/ha) application and inoculation with *Rhizobium Leguminosarum* on plant growth nodulation and pod yield and quality of French bean (*Phaselous vulgaris L. var Monel*) plants. The factorial experiment was laid down in a randomized complete block design with three replications. Phosphorous application significantly increased plant height, nodulation and pod yield. However, the nitrate content decreased significantly with the application of phosphorous fertilizer. There was no significant effect of phosphorus fertilizer application on the protein content of the pods. Nitrogen application caused a significant increase only in the yield of extra fine pods in the second season. The application did not significantly affect plant height, dry matter accumulation, nodulation and pod quality. Inoculation significantly decreased plant height, pod yield and nitrate content of the pods. Interaction between phosphorous, nitrogen and inoculation was significant for plant height during the first season. In the second season, an interaction of nitrogen and inoculation caused a significant increase in plant height. In the same season significant increases in pod yield occurred as a result of an interaction between phosphorus and inoculation. Phosphorus in combination with nitrogen and inoculation caused a significant increase in total pod yield in the second season. The protein content of the pods decreased significantly as a result of an interaction between phosphorus, nitrogen and inoculation. Phosphorus in combination with inoculation significantly decreased the nitrate content.

Okalebo, J. R., Palm, C. A., Gichuru, M., Owuor J. O., Othieno, C. O., Munyampundu, A., Muasya, R. M. and Woomer, P. L. (1999). Use of wheat straw, soybean trash and nitrogen fertiliser for maize production in the Kenyan highlands. *African Crop Science Journal* Vol., 7, No. 4 pp 423-431

Making best use of available crop residues is an important component of integrated nutrient management. A field study was conducted over two seasons (1997 and 1998) in Kenya that examined use of wheat straw, soybean trash and nitrogen fertilizer as nutrient inputs for maize (*Zea mays L.*) production. The organic inputs were applied at the rate of 2 t/ha per season and urea were added at rates of 0, 20, 40, 80 and 100 kg/ha in an incomplete factorial treatment structure that also included a complete control (no inputs) and 80 kg/ha in as urea without organic inputs. Maize grain yield ranged between 751 and 6836 kg/ha with lowest yields observed in the treatment receiving wheat straw alone and higher yields associated with soybean residue incorporation and during the second, wetter growing season. The 1998 crop benefited from more favourable rainfall, providing grain yield increase of 141% above control treatment as a result of combining 2 t/ha soybean trash and 100 kg N/ha urea. The general high yields from soybean trash are explained in terms of its higher quality, faster decomposition and nutrient release compared to lower quality wheat straw. A positive in increases of soil pH, C, N, and P status as a result of cumulative use of crop residues was observed. Larger yields were obtained when organic and inorganic inputs were applied to soils, particularly when soil moisture was adequate and the organic inputs higher in mineralisable nutrients. Early indications of additional longer term benefits through soil quality improvement were also measured. These findings suggest that better use may be made of crop residues than the burning following harvest as is currently practiced by many farmers in this area of western Kenya.

Onyango, M. O. A. (1999). The effect of organic and inorganic sources of fertiliser on growth and yield of *Braccica Oleraceae* Var. Acephala D. C. *Proceedings of the 6th KARI Scientific Conference* 9-13th Nov. 1998. Kenya pp. 351-357

Kale (*Brassica oleraceae* var. Acephala *D. C.*) cultivar, collard green was planted in the field between October 1997 and March 1998 in the experimental plots at Maseno University College in western Kenya. The experiment was set up to study the effect of organic and inorganic sources of fertiliser on growth and yield of kale. The kale seedlings were first raised in a nursery and transplanted 8 weeks after sowing. The treatments included farm yard manure (150 kg N/ha, 8 kg P/ha), *Tithonia diversfolia* (Tithonia) leaf biomass incorporated in combination with Diammonium phosphate (DAP) (150 kg N/ha and 30 P/ha), and Tithonia leaf biomass incorporated. DAP in a combination with Urea, DAP in combination with Calcium Ammonium Nitrate (CAN) at the rate of 150 kg N/ha and 15 kg P/ha and the control. Non-destructive measurements on plant height, leaf number and stem thickness were taken regularly commencing 6 weeks after planting. Leaf yield was assessed by both cumulative leaf weight per given area and leaf number per plant. Both organic and inorganic sources of fertiliser significantly increased growth and leaf yield of kale. In all parameters measured, farm yard manure gave the best response. Tithonia leaf biomass incorporation in the soil either on its own or in combination with DAP gave leaf yields comparable to those applied with exclusively inorganic sources of fertiliser. With the prices of inorganic fertilisers increasing, organic sources which are locally available to the farmer can be alternative sources of fertiliser without compromising the yields.

Rao M. R., Mwasambu G., Mathuva M. N., Khan A. A. H. and Smithson P. C. (1999). Effects of phosphorus recapitalisation and agroforestry on soil, water and nutrient conservation in phosphorus-deficient soils of Western Kenya. *East Africa Agriculture and Forestry Journal* 65(1), 37-53

In the highlands of western Kenya, poor crop growth due to severe nutrient depletion over the past two to three decades has exacerbated soil erosion. The potential benefits and agroforestry in terms of soil, water and nutrient conservation were investigated on P-deficient soils in western Kenya for 3.5-years. The agroforestry systems compared were one-season sesbania (sesban) fallow followed by annual crops and contour hedgerows of calliandra (*Calliandra calothyrsus*) plus Napier grass (*Pennisetum purpureum*). Continuous cropping without P fertilizer produced an average runoff of 367mm (37% of rainfall) and soil displacement of 105 t/ha per season, with a loss of 159 kg of N and 46 kg of total P/ha. Phosphorus application reduced runoff by 31% and soil loss by 59% compared to non-fertiliser applied cropping. In P-replenished soils, neither one season sesbania fallow nor contour hedgerows affected water runoff but one - season sesbania fallow reduced soil loss by 5% and contour hedgerows reduced soil loss by 20%, over P alone. Nutrient losses due to erosion occurred mainly through sediment movement, and losses proportionate to their effects on reducing soil erosion. Intergrating P and short-duration sesbania fallows in P- deficient soils increases crop yields and can also contribute to soil, water and nutrient conservation by providing a rapid and prolonged ground cover with good crop growth and increased water infiltration into the soil. The hedgerows have the added advantage of yielding fodder besides effectively reducing soil and nutrient losses

Savini I. (1999). The Effect of organic and inorganic amendments on phosphorus release and availability from two phosphate rocks and triple superphosphate in phosphorus fixing soils. Msc. Thesis, University of Nairobi, Kenya

Phosphorus deficiency limits crop production in Western Kenya due to low native soil P, continues cultivation without adequate P fertilization and often high soil P fixation. The use of commercial P fertilizers by small scale farmers is limited by their cost. The use of finely ground phosphate rock (PR) is viewed as an attractive option to alleviate phosphorus deficiency. Two 16- week laboratory soil incubations were carried out to evaluate the effect of organic and inorganic amendments on the dissolution of two PR materials (Minjingu and Busumbu) in Oxisol from Western Kenya. Treatment with triple superphosphate (TSP) served as a reference. The effect of Tithonia (*Tithonia diversifolia*) leaves added at 2 or 10 t/ha on dissolution of moderately reactive Minjingu PR (Tanzania) and uncreative Busumbu PR (Uganda) was investigated in the first incubation experiment. The effect of inorganic amendments ($CaCO_3$ or $CaCl_2$) on dissolution of moderately reactive Minjingu PR was investigated in the second incubation study. Dissolution was determined from the increase in anion resin (AER), $NaHCO_3$ and NaOH- extractable P in soil amended with PRs, compared with the TSP treated soil. In the third study maize (*Zea mays* L.) and cowpea [*Vigna unguiculata* (L.) Walp] were grown as test crops in pots on soil treated with 30 mg P/kg soil as Busumbu PR and TSP applied either singularly or in combination with 5 or 10 t/ha of Tithonia to determine P uptake and dry-matter yield. In soils without added Tithonia, AER-P followed the order TSP> Minjingu PR>> Busumbu PR. By week 16, AER-P from Minjingu PR and TSP were similar. Busumbu PR solubility was low, and did not increase significantly in 16 weeks. ACER-extractable P was generally greater than AER-P. The difference was greater for PRs than for TSP. The ACER extraction may be a better estimate of plant P availability, particularly when poorly soluble P sources are used. This may be due either to the ability of the Ca sink CER to remove accessory $CaCO_3$ and Ca from the decomposition of Tithonia or to act directly to dissolve solid PR in the

soil. Application of Tithonia at 10 t/ha in combination with Minjingu PR caused a small but significant depression in AER-P relative to Minjingu PR alone at all sampling dates except week 16 while ACER-P was not significantly affected by Tithonia addition.

Watiki, J. M, Gichangi, E. M, Itabari, J. K, Karuku, A. M, Nguluu, S. N. (1999). The effects of rate and placement of Boma manure on maize yield in semi-arid Eastern Kenya. *Proceedings of the KARI Scientific Conference*, 19-13 November 1998; KARI Headquarters, Kenya. Pp. 321-328

A six seasons study on the response of maize to boma manure was conducted on farmer's field in Wamunyu, Machakos District in the Eastern province of Kenya to: a) determine the yield response of maize to application of boma manure in the 0-100 t/ha range, b) evaluate the benefits of banding of boma manure as compared with broadcasting, c) determine the residual response to boma manure application; and d) compare the response of boma manure with that of inorganic fertiliser. The soil on the experimental site was well drained, dark red, loamy sand with an average of 16.64 mg/kg extractable P and 0.065% total N in the 0-100 cm depth. Maize grain yields and total dry matter markedly increased with increasing rates of boma manure while placement method and the interaction between placement and rate of application had no effect. A combination analysis indicated that there was no significant increase in grain yield above the rate of 40 t/ha of manure. Using inorganic fertiliser at the rate of 20 kg N/ha + 20 kg P/ha was found to be the best option in terms of economic benefits. The residual effects of manure were, however, still very evident in the last season, indicating that more benefits would have been obtained from manure over a number of succeeding seasons, especially from the high rates (60-100 t/ha).

Nziguheba, G., Palm, C. A., Buresh, R. J. and Smithson, P. C. (1998). Soil phosphorus fractions and adsorption as affected by organic and inorganic sources. *Plant and soil*, Netherlands, Kluwer Academic 1998 Volume 198 pp.159-168

The effect of organic and inorganic sources of phosphorus (P) on soil P fractions and P adsorption was studied in a field without plant growth on a Kandiudalf in western Kenya. A high-quality organic source, Tithonia (*Tithonia diversifolia Hemsley*) A. Gray leaves, and a low-quality source, maize (*Zea mays L.*) stover, were applied alone or in combination with triple superphosphate (TSP). The P rate was kept constant at 15 kg P/ha. Soil extractable P (resin, bicarbonate and sodium hydroxide), microbial biomass P and C and P adsorption isotherms were determined during 16 weeks after application of treatments. Application of Tithonia either alone or with TSP increased resin P, bicarbonate P, microbial P, and sodium hydroxide inorganic P. Tithonia alone reduced P adsorption at 2-16 weeks. Maize stover had no effect had no effect on any of the P fractions or P adsorption. At 8 weeks, the application of Tithonia reduced microbial C-to-P ratio (20) as compared to maize stover, TSP and the control (31-34). The reduction in P adsorption by Tithonia was accompanied by increase in all measured P fractions, the sum of P in those fractions (resin, bicarbonate and sodium hydroxide) being larger than the P added. The reduction in P adsorption apparently resulted from competition for adsorption sites, probably by organic anions produced during decomposition of the high quality Tithonia. Integration of inorganic P (TSP) with organic materials had little added benefit compared to sole application of TSP, except that combination of Tithonia with TSP increased microbial biomass. The results indicate that a high quality organic input can be comparable to or more effective than inorganic P in increasing P availability in the soil.

Helga Recke, Muchena, F. N., Qureshi, J. N., Ayaga, G. O., Chek, A. L., Gateri, M., Kinyanjui, S. M., Kathuli, P., Milikau, R. L., Muriuki, A., Onyango, J. W., Thuranira, E., and Wamae, D. (1997). Fertilizer use Recommendations, Kisumu District. Technical FURP Report Vol. 13. Nairobi, Kenya

In Kisumu District, fertilizer experiments were carried out at two sites, namely Paponditi (3.1) and Muhoroni (3.2). Two experiments were carried out concurrently. Response to nitrogen (N) and phosphorus (P_2O_5 mostly referred to as P) was tested in experiment 1. In experiment 2, farmyard manure (FYM) and sulphur were tested in addition to phosphorus and nitrogen. The soils at Paponditi are moderately deep and imperfectly drained leading to frequent water logging. The inherent soil fertility is moderate. At Muhoroni, the soils are deep and consist of friable to firm clay. The inherent soil fertility is high. At Papondi and similar sites, crop production was limited more by water management than by soil fertility. Monocropped maize in season 1 showed an economic N response at 30 kg N/ha. N response in intercropped maize (season 1) does not warrant N fertilizer application. Yields of intercropped maize were considerably lower than those of monocropped maize and could not be compensated for by the additional bean yields. Therefore, maize should be grown as a sole crop. Yields of sorghum were generally higher than those of maize as sorghum is better adapted to the frequent dry spells encountered at this site. The water management problems, i.e. drainage and infiltration of water should be addressed before soil fertility constraints are considered. At Muhoroni in season 1, both monocropped and intercropped maize responded to application of N fertilizer. While the N response in intercropped maize was uneconomic, the economic optimum rate for monocropped maize was 30 kg N/ha. As intercropping reduced maize yields considerably, monocropping of maize is the recommended practice. The same applies for maize grown in season 2. Beans produced good yields

only if grown as a sole crop. Response to farmyard manure was generally poor. Recommended fertilizer rates for maize are based on a price input/output ratio (N or P/maize) of 10. The economically optimum fertilizer rates for smallholder were generally calculated with a value/cost ratio of 2. For every shilling invested in fertilizer, the farmer should have obtained an additional income of 2 shillings; 1 shilling to pay for the fertilizer plus 1 additional shilling to cover his risks and to give him some net benefit. If we assume fertilizer costs of 80 shillings per kg of N or P_2O_5 and a price ratio input/output of 10), then the limit would be a yield increase of 20 kg per kg of nutrient applied (price-ratio) multiplied by the value/cost-ratio 10x2=20). For other crops, average market prices from December 1993 were used for the calculation. Economic optimum fertilizer rates based on other input/output price ratios and VCR's are given in Annex III. For the calculation of economically optimum fertilizer rates in general, reference is made to Heinzmann (1993)1). Details on identification and representativeness of trial sites can be found in the final Report, FURP Phase 12). For the purpose of comparing the productivity of monocropping and intercropping systems, it was assumed that one kg of beans equals two kg of maize in market value. This means, yield losses of 500 kg of maize per hectare in the intercropping system are compensated for by a yield of 250 kg of beans/ha. It has to be emphasised that the recommended fertilizer rates were based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and a decline in soil fertility. These nutrients will have to be replenished in the long run in order to maintain the productivity of the land. Particularly constant removal or burning of crop residues instead of their incorporation into the soil leads to severe declines in soil and increase the organic matter content of their soils through better management (e.g. incorporation of crop residues, manure, and composts). This not only improves soil fertility itself, but it also increases moisture storage capacity and microbial activity. In addition it provides a more favourable temperature for root growth amongst other soil parameters.

Jama, B., R.A. Swinkels,. and R.J. Buresh. 1997. Agronomic and economic evaluation of organic and inorganic sources of phosphorus in western Kenya. Agronomy Journal *89:597-604*

Manys oils in the highlands of East and Central Africa are depleted of soil nutrients, particularly P. Ouro bjective was to comparec attle manure, *Calliandra calothyrsus* Meissner leaf biomass, and triple superphosphule (TSP) as sources of P for maize (*Zea mays* L.), both individually and as mixtures of organic (manure or calliandra) and inorganic (TSP + urea) sources. Field experiments were conducted on a Kandiudalf at two sites in western Kenya. Net benefits were computed as the difference between the value of additional maize yield accruing from nutrient inputs and the associated additional costs. Maize grain yield was 0.6 Mg/ha for application of urea without P. Application of 10 kg P/ha as organic, inorganic, and mixtures of organic and inorganic sources significantly increased maize yield. Grain yield for manure at least equaled and sometimes exceeded ($P \leq 0.05$) yield for calliandra and TSP + urea. Net benefits in U.S. dollars (USD) for two seasons were highest for manure spot placed in the planting bole (293 USD/ha), broadcast manure (255 USD/ha), and broadcast TSP + 44 kg urea-N/ha (313 USD/ha at P = 30 kg/ha and 98 USD/ha at P = 10 kg/ha). Net benefits for calliandra leaf biomass were highest (136 USD/ha) when biomass was valued at cost of production and integrated with TSP, such that it provided all the N for maize and TSP provided the additional P not supplied by calliandra. Cailiandra valued at its opportunity cost as a protein supplement for dairy cattle was not an economic source of P. Sensitivity analyses suggest that organic materials most suitable for use as P sources have high P content and low cost of production.

Nandwa, S. M. (1997). Impact of organic and inorganic fertilizers with and without crop residue restitution on maize yields and soil properties (long-term trials at NARL). Kenya Agricultural Research Institute -National Agricultural Research Laboratories. Annual report pp 16.

A long-term field trial established in 1976 on a humic nitisol at the National Agricultural Research Laboratories, Kabete, in Nairobi, Kenya is used to investigate the short-term and long-term effects of continuous application of farm yard manure, residues and nitrogenous and phosphatic fertilizers on maize yields and soil physico-chemical properties in a maize-bean rotation system. Results obtained demonstrate that integrated nutrient management is a feasible strategy for attaining productive and sustainable maize yields under smallholder farming systems. While nitrogen and phosphorus (NP), Farm Yard Manure (FYM) and NP + FYM significantly increased yield (above 3 t/ha) over the control (<3 t/ha) during the first ten years, only the latter two treatments could sustain this yield beyond 10 years. The steady-state yield pattern attained then was in the order of NP+FYM>FYM>NP>Control. The ability of the FYM treatment compared to NP to maintain maize yields above 3 t/ha was attributed to improvement in soil physical properties, more macronutrient inputs as well as the supply of micronutrients by FYM compared to NP treatment. During the first 3 years, residue restitution depressed maize yields by between 3.3 and 5.2% which was attributed to N immobilization on the low quality stover in asyncrony to N uptake. In spite of high inputs of C and K through organic amendments, these elements showed a declining trend throughout the restitution period in comparison to P, Ca and Mg. High rates of decomposition may be the primary cause of decline in soil organic carbon. The P and Ca status of the soil is probably maintained by continuous application of TSP and CAN

fertilizers respectively. No significant differences between treatments were observed, when effects on soil physical properties were compared.

Ojiem, J., Odongo, O. M. and Wakhonya, H. (1997). Effects of combining Organic and Inorganic fertilisers on maize grain yield in Kabras, western Kenya. Kenya Agricultural Research Institute (KARI) Kakamega; Annual Report 1997 pp. 76-78

Low soil fertility ranks first among the important factors constraining crop production in Western Kenya. APRA conducted in Kabras Division, Kakamega District (Ojiem and Odendo, 1996) indicated that low soil fertility is the principal factor constraining productivity. Smallholder farmers are unable to apply recommended rates of inorganic fertilizers due to high cost of this input (MDB, 1993). However, a number of organic resources with potential for improving soil fertility exist in many small-holder farm situations. These include cow dung, leguminous species (for green manure), and compost. Nevertheless, these P organic resources are rarely available in sufficient quantities to have meaningful impact on soil fertility and crop yield. Also, the quality of the materials is usually low thus large quantities would be required to achieve the recommended nutrient rates. Recent research has shown that combining organic and inorganic resources results in greater benefit than using either resource alone. The effect combining FYM and inorganic nitrogen (N) was compared to FYM alone, green manure and farmer practice.

Ikombo, B. M, Nguluu, S. N, Simiyu, C. S. (1996). Effects of a combined application of manure and nitrogen in a semi-arid environment Technical Annual Report 20-29

An important source of plant nutrients in the semi-arid areas is boma manure; limited farm resources do not allow purchase of fertilizers. In an attempt to minimize the use of the expensive fertilizer and the limited quantities of manure farmers use small amounts of each but in combination. A study was carried out in Masii, Machakos district with a major goal of examining the effectiveness of a combined application of manure and nitrogen fertilizer in a system where the current production is extremely low. The treatments consisted of four levels on nitrogen (0, 30, 60 and 120 kg N/ha) and three levels of farmyard manure (0, 10 and 20 t/ha) arranged in a randomized complete block design. The results showed that soil fertility was a major limitation to maize growth and productivity in the region. The use of manure or nitrogen fertilizer could alleviate the problem associated with the low soil fertility. However, the best results are achieved when manure and nitrogen fertilizers are applied in combination.

Itabari, J. K, Watiki, J. M, Nguluu, S. N, Gichangi, E. M, Karuku, A. M. (1996). Yield response of maize to rate and placement of boma manure. Annual Report pp 14-19

A study was carried out in Wamunyu location in Machakos District in 1993 to evaluate the effect of rate and placement of boma manure on maize yields. The results showed that the rate of application had a significant effect on total dry matter and grain yield. Sixty to 100 t/ha of residual boma manure significantly increased both total dry matter and grain yields. There was no significant difference between the yield obtained with the recommended rate of inorganic fertilizer and that obtained with residual boma manure in the 60-100 t/ha range. 20 N + 20 kg P_2O_5/ha increased total dry matter but had no significant effect on grain yield.

Kihanda, F. M. (1996). The role of farmyard manure in improving maize production in the sub-humid highlands of central Kenya. PhD Thesis, University of Reading (UK)

The farming systems in the highlands of central Kenya are characterized by continuous cultivation and cropping due to pressure on agricultural land and low nutrient input resulting in low crop yields. N is one of the major soil nutrients limiting maize production in the region and farmers rely heavily on farmyard manure (FYM) produced at the farm level to improve soil and crop productivity. Soil acidity is also a major constraint in maize production in the Ando-Humic Nitisol soil. A study was therefore conducted to determine the role of FYM as a source of plant N under field and controlled experiment in two of the major soil types in the area. Recovery of plant N derived from FYM and inorganic N fertilizers was determined using N^{15} isotopic techniques. FYM samples produced from the study area were collected, characterized and based on their C: N ratio and ash content, N mineralization studies were conducted in pot experiments using mineral N measurements and crop uptake. Maize yields were increased with increasing rates of FYM application but maize grain yields above 3.5 t/ha were only obtained when both FYM and NP fertilizer were applied. Removal of acidity constraint through liming was essential in order to obtain response to applied FYM or NP fertilizer to maize growth and yield in the acidic Ando-humic Nitisol. Combined application of FYM and K resulted in maize grain depression in the Humic Nitisol of Embu. A decline in soil organic matter was observed in the two field trial sites which were under continuous cropping and cultivation but combined application of FYM and NP fertilizer reduced the organic carbon loss by 1-3 t/ha in the soil (0-20 cm). Plant N derived from soil organic matter decreased by 30% where both FYM and NP fertilizer were applied.

Based on the N uptake by maize from plots that had received NP fertilizer, it was concluded that the uptake of N from FYM was not in synchrony with the period of rapid growth in maize. The recovery of fertilizer N by the maize plants was low and less than 20% while the recovery of FYM N in the maize plants applied at similar rate to that of inorganic N fertilizer was 25% in both soil types. FYM samples collected from the study area were variable in their chemical composition notably organic C, total N and the C:N ratio. The C:N ratio of the FYM was a useful index in predicting mineralization and immobilization patterns of the FYM tested. Net N mineralization was observed from FYM of C:N ratio of less than 17 while net immobilization was observed from FYM of C:N ratio equal to or greater than 17. However, N immobilization was observed in all the FYM during the first four weeks of incubation. The proportion of N mineralization from FYM expressed as a percentage of the total N in the FYM was 20-40% from FYM of C:N ratio less than 17 and 0-6% from FYM of C:N ratio equal to or greater than 17. The soil type influenced the quantity of N mineralized from FYM, higher mineralization being observed in the near neutral pH soil.

Muasya R. M., Mwakkha E., Othieno C. O. and Okalebo J. R. (1996). Initial wheat response to low and high rates of nitrogen and phosphate fortified compost in a Kenyan ferrasol. Conference proceedings; *Proceedings of the 5th KARI scientific conference*, 14 to 16th October, 1996, Kaptagat road, Loresho. Nairobi, Kenya. pp 447-459,

A two year study was conducted to determine the effect of phosphate fortified wheat straw compost on a crop. In the preliminary study the compost were at the lower levels 0, 2.5, 5.0, 10.0, 20.0 t/ha and in the succeeding study header rates were 0, 5.0, 10.0 20.0 40.0 80.0 t/ha. Diammonium phosphate at the recommended rate of 40 kg P_2O_5 /ha was used as the standard for the two years. Two separate adjacent fields were used for the two experiments. The first year crop indicated no significant treatment effects on the soil chemical properties. A statistical analysis of variance of the growth and yield parameters showed a non significant difference in compost treatments compared to the control. The DAP treatment significantly out yielded the low compost rates. In the second season, the high compost rates mainly 80 t/ha significantly out yielded the other compost rates and the standard DAP treatment in terms of wheat yield.

Schnier H. F., Recke H., Muchena F. N., Muriuki A. W. (1996)Towards a practical approach to fertilizer recommendations for food crop production in smallholder farms in Kenya. Nutrient Cycling in Agroecosystems. Volume 47, Issue 3, pp 213-226

A comprehensive long-term fertilizer trial programme for annual crops was established in 1985 at 70 sites in the high and medium rainfall areas of Kenya testing N and P, farmyard manure and other critical nutrients. Sites were selected according to their representativeness regarding soils and climate in agro-ecological units. The fertilizer trial programme included all major food crops typical for the respective area, both monocropped and intercropped in the case of cereals. Economic optimum fertilizer rates were calculated taking into account input/output price ratios and value-cost ratios. The majority of sites showed responses to N or P, only at one site response to both N and P with a significant interaction was found. Price elasticity of crops such as potatoes and cabbages was higher than that of maize or sorghum. Critical soil P levels were determined for maize at 13 ppm P for modified Olsen extract and 32 ppm P for Mehlich I extract. Variability of rainfall was found to greatly influence viability of fertilizer recommendations. First attempts to extrapolate fertilizer recommendations from areas of representativeness to areas with similar conditions by means of GIS and modelling approaches are discussed.

Chui, J. N. (1994). The effects of nitrogen fertilization, bean residue, and maize-bean cropping systems on nutrient uptake, yields and soil chemical properties in a semi-arid area. MSc. Thesis; University of Nairobi; Kenya.

Nitrogen fertilizers have assumed a prominent role in the cultivation of maize especially in pure stands in Kenya. However, knowledge on N utilization in the maize-legume cropping systems which are commonly used in Kenya is lacking. A field study was therefore conducted between 1987 and 1990 at two sites, Kimutwa and Masii in Machakos District, a semi-arid region in Eastern Province of Kenya to determine the effects of N, bean residue and maize-bean cropping systems on nutrient uptake, yields and soil chemical properties. Soil types used were sandy clay loam (dystric Nitisol) for Kimutwa and sand (Acrisol) for Masii. A split-plot design was used in which N levels (0, 25, 50 and 100 kg N/ha) formed the main plots and cropping systems formed the sub-plots. Single superphosphate at 40 kg P_2O_5 was applied uniformly to all plots. Fertilizer N significantly increased dry matter yields, yield components, seed yields and uptake of N, P, K, Mg and Ca by maize and beans in Sole, intercropping and rotation systems and also improved growth and development of maize in the three cropping systems. Response to N by both crops depended on cropping system, site and season. Bean response to N occurred where soil mineral N prior to planting was 18 and 23 ug/ N/g or below the Acrisol and dystric Nitisol,

respectively. For maize, response occurred where mineral N was 36 and 60 ug N/g highest response to N by both crops in continuous sole cropping, rotation and those intercropped in the alternate rows was at 50 kg N/ha while that of crops intercropped in the same row was at 100 kg N/ha. Regression analysis indicated that cropping systems with highest response to N at 50 kg N/ha could respond to N rate of 75 kg N/ha while crops intercropped in the same rows could have maximum response to N at 50 kg N/ha in the same rows could have maximum response either 75 or nitrogen rates of 50 and 100 kg N/ha were often not significantly different, and therefore, 50 kg N/ha could be used for the production of both crops. But, 25 kg N/ha rate was not adequate although it was better than zero N. Intercropping was a superior cropping system in both low and high input agriculture with respectively. Fertilizer ratio (LER) and total grain yields, respectively. Fertilizer N improved soil total N, maintained organic C and increased residual mineral N, maintained organic C and increased residual mineral N which consequently improved dry matter, seed yield and nutrient uptake of a test sole maize. Residual mineral N and uptake of nutrients by a test sole maize were higher in plots previously under continuous beans than continuous sole maize at both sites; higher in intercropping and rotation than in continuous sole maize in Masii while the reverse was true in Kimutwa. However, N lowered soil pH, CEC and resulted in greater depletion of soil extractable P and exchangeable K, Mg and Ca relative to zero N treatments. The levels of these chemical properties in the soil were influenced by cropping systems. Competition between maize and bean intercrops was manifested as early as 20 days after seedling emergence up to maturity, through reduction of total dry matter, growth and development, yield components, seed yield, nutrient uptake and response to N by the intercrops. Intercropping systems, however, resulted in high LER's of 51-176% on average, which depended on bean spatial arrangements and site. Competition was influenced by bean spatial arrangements and generally, the same row intercrops individually or combined performed those in alternate rows. Rotation benefited both crops, improved maize response to N and had a supplementary effect to N fertilizer. Bean residue returned to plots had negative effects on beans but improved LERs, maize yields, response to N by maize in rotation and that in the same row while the effect on nutrient uptake by maize was either positive or negative depending on cropping system season and site. The returned bean residue also lowered soil pH, extractable P, exchangeable K, Mg, and Ca; it had no effect on total N but had effects on mineral N which were seasonal and dependent on the site. In Masii, soil pH, organic C, mineral N, exchangeable K, Mg and total N uptake and total grain yield. In Kimutwa there were negative correlations between soil pH and extractable P, total N uptake and total grain yield. In Kimutwa, positive correlations were found between total grain yield and organic C and N uptake; between mineral N and exchangeable Mg and Ca and between exchangeable Mg and total grain yield.

Heinzmann, F. X., Muchena, F. N., Qureshi, J. N., Ayaga, G. O., Schniner, H. F., Check; A. L., Gateri, M., Kanyajua, S. M., Kathuli, P., Milikau,R. L., Muriuki , A., Onyango, J.W., Thuranira, E., Wamae, D. (1994). Fertilizer use recommendations, Kisii District. FURP Report Vol-8

In the Kisii District fertilizer experiments were carried out at 3 sites, namely Otamba, Kiamokama and Kisii NARS. At all 3 sites, precipitation is > 80% of the potential Evaporation. The soils at Otamba and Kisii are mollic nitisols with clayey texture, a high inherent fertility and a moderate (Otamba) respectively low (Kisii) P availability, whereas the soil at Kiamokama is a humic Nitisol with clayey texture, very low P availability and moderate fertility. At Otamba, maize responded well to application of N fertilizer with an economical optimum rate of 75 kg N/ha. Fertilizer rates higher than 75kg N/ha may be economical and should be tested. Preferred cropping sequence should be maize intercropped with beans as the combined yield of the maize /beans intercropped was superior to the yield of maize grown as a sole crop. The recommended N rate for the intercrop is 75 kg/ha in season 1 and 40 kg/ha in season 2. Beans responded exceptionally well to P application as compared to other trial sites with as economical optimum rate of 45 kg P_2O_5 /ha. Direct P fertilization of beans should also be tested in the maize/beans intercrop. Potatoes and finger millet were grown in season 1 and exhibited a strong response to phosphorus but no response at all to nitrogen. Recommended fertilizer rates are 45 and 65 kg P_2O_5/ha, respectively. The trial site Kisii NARS represents the same areas as the Otamba site. Available nutrients, however, are lower at the Kisii site but still not in a critical range except for phosphorus. The results confirmed those obtained at the Otamba recommended for both modules and both seasons. A clear response to P application was recorded only to N application. Its yields, however, declined from the 3rd experimental year onwards and were not satisfactory on average. The Kiamokama trial site has a higher N supplying capacity that was reflected in the absence of any considerable response to nitrogen application. All crops tested, however, responded well to P fertilization. Recommended rates for maize and the maize/beans intercrop are 50 and 40 kg/ha P_2O_5 for season 1 and 2, respectively. For potatoes and cabbages, 75 respectively 65 kg of P_2O_5 /ha are recommended, while for finger millet a small dose of 15 kg/ha was economical. In experiment 2, the applications of potassium and farmyard manure (FYM) were included as additional treatments. At neither of the sites K had any positive effect on crop yields. The application of 5 t/ha of FYM had no significant effect at Kisii NARS, but raised yields of finger millet, beans and potatoes significantly at Otamba. At Kiamokama, yields of maize and maize and potatoes responded strongly to the application of FYM with a yield increase for maize of 1270 and 600 kg/ha in season 1 and 2, respectively. No economic assessment of FYM application was carried out for several reasons. First, quality and prices of FYM vary considerably, second, not only the direct effect on maize yields but also the long term effects on soil physical and chemical properties like soil structure, humus content, cation exchange

capacity, available moisture capacity etc. have to be taken into account. As a general rule and from a long term view application of FYM may be economical if additional yield pays for a good part of the cost of the application. Recommended fertilizer rates are based on a price ratio input/output (N or P/maize) of 10 and a value/cost ratio of 2. For the calculation of economically optimal fertilizer rates, reference is made to Heinzmann (1993). Details on identification of trial sites can be found in the final report FURP Phase I. The recommended Fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run.

Heinzmann, F. X., Muchena, F. N., Qureshi, J. N., Ayaga, G. O., Schniner, H. F., Check; A. L., Gateri, M., Kanyajua, S. M., Kathuli, P., Milikau,R. L., Muriuki , A., Onyango, J.W., Thuranira, E., Wamae, D. (1994). Fertilizer use recommendations, Embu District. FURP Report Vol-6

In the fertilizer trials were conducted at three sites, namely Kavutiri (24.1), Gachoka (24.2) and Embu A.R.S (24.3). The first experiment tested crop response to nitrogen (N) and phosphorus (P) while the second tested crop response to farmyard manure (FYM) and other site specific treatments such as lime and potassium. The soil at Kavutiri is an ando-humic Nitosol with a low fertility, the soil at Embu a humic Nitisol with a high fertility status and the soil at Gachoka a Rhodic Ferralsol with low fertility. All soils are deep, well drained and have a clayey texture. At Kavutiri, the soil is very acidic and exhibits aluminium toxicity. While Kavutiri and Gachoka have moderate P availability, Embu has low P availability. At Kavutiri, performance of maize and beans was generally poor. All crops strongly responded to application is an absolute prerequisite for reasonable crop production at this site. Only after elimination of aluminium toxicity significant responses to N, P and FYM application can be expected. For potatoes and cabbages fertilizer application was economical with optimum rates of 50 kg P_2O_5 and 75 kg N/ha for potatoes, and 50 kg P_2O_5/ha for cabbages. Cabbages exhibited the best response to the application of FYM (5 t/ha) with an average yield increase of 6500 kg/ha. Considering the necessary management practices and the general production potential, the suitability of this soil for food crops like maize has to be questioned. It seems to be more profitable to grow a cash crop, i.e. tea and buy the maize in the market, a common practice of farmers in the area. At Gachoka, crop production was generally limited by water availability. Intercropping maize with beans involves a high risk of severe yield reductions or crop failures. It should be omitted or done with a lower plant population. Drought resistant crops like bulrush millet or sorghum seemed to be better adapted and more suitable for the climatic conditions at this and similar sites. Bulrush millet responded well to P application with a recommended rate of 75 kg P_2O_5/ha. Bulrush millet also responded best to application of FYM. At Embu, Maize and Napier grass responded to both N and P application though its application was not very economical at current input-output price ratio. Although in season 2 yield of intercropped maize was lower than that of sole cropped maize, the additional yield of beans still provided an overall economical benefit. Therefore, the preferred cropping sequence for all seasons should be maize intercropped with beans. As N- fixing capacity of beans appeared to be weak, inoculation with rhizobium should be tried. The production of Napier grass declined continuously over time reaching very low yields in the 5th year, an observation which has also been made at other sites. It is therefore recommended to replant Napier grass after approximately every 4 years. Of all crops, maize showed the best response to FYM application with an average yield increase of 670 kg/ha in the season (Season 2) when FYM (7.5 t/ha) was applied and a residual effect of 400 kg/ha yield increase in the following season (season 1). No economic assessment of FYM application was carried out for several reasons. First, quality and prices of FYM vary considerably. Second, not only the direct effect on maize yields but also the long term effects on soil physical and chemical properties like soil structure, humus content, cation exchange capacity, available moisture capacity etc. have to be taken into account. As a general rule and from a long term view application of FYM may be economical if additional yield pays for a good part of the cost of the application. Recommended fertilizer rates are based on a price-ratio input/output (N or P/maize) of 10 and a value/cost ratio of 2. For the calculation of economically optimum fertilizer rates, reference is made to Heinzmann (1993). Details on identification of trial sites can be found in the final Report, FURP phase I2). The recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run.

Heinzmann, F. X., Muchena F. N., Qureshi J. N., Ayaga G. O., Chek A. L., Gateri M., Kinyanjui S. M., Kathuli P., Milikau R. L., Muriuki A., Onyango J. W., Thuranira E., and Wamae D. (1994). Fertilizer Use Recommendation Project (FURP); Meru District, Kenya. Technical FURP Report Vol. 3

In the Meru District fertilizer experiments were carried out at 3 sites, namely Kaguru, Tunyai and Mitunguu. The soil at Kaguru is a humic nitisol with clayey texture and a moderate fertility whereas the soils at Tunyai and Mitunguu are nito-rhodic Ferrasols with clayey texture and low fertility. While the Kaguru site has a moderate

P availability are the soils at Tunyai and Mitunguuu P- efficient. At Kaguru, maize and potatoes responded well to application of N fertilizer with economical optimum rates of 75 and 50 kg N/ha for maize and potatoes, respectively. For maize rates higher than 75 kg/ha may be economical and should be tested. Preferred cropping sequence should be maize intercropped with beans. As N-fixing capacity appeared to be weak inoculation with rhizobium should be tried. Sustained bean production requires liming to neutralize excess soil acidity. The production requires liming to neutralize excess soil acidity. The production of cabbage, although tested in one season only, does not seem worthwhile. At Tunyai crop production is generally limited by water availability especially during the short rains (season 1) and no fertilizer should be applied here. Intercropping in season 1 involves high risk of severe yield reductions or crop failures. It should be omitted or done with a lower plant population. During the long rains small fertilizer applications to maize are economical at rates of 20 and 10 kg P_20_5/ha for intercropped and monocropped maize, respectively. Direct P-fertilization of cowpeas should be tested. At Mitunguu, maize responded to N and P applications though fertilizer application is not economical at current input/output price ratio. Although yield of intercropped maize was lower than of sole cropped maize, the additional yield of cowpeas still provided an overall economical benefit. Of all crops tested maize exhibited the best response to the application of farmyard manure (FYM). 5 t FYM /ha applied during the long rains increased maize yields on average by approximately 600 kg/ha. No economic assessment of FYM applications was carried out for several reasons. First, quality and prices of FYM vary considerably. Second, not only the direct effect on maize yields but also the long term effects on soil physical and chemical properties like soil structure, humus content, cation exchange capacity, and available moisture capacity e.t.c have to be taken into account. As a general rule and from a long term view application of FYM may be economical if additional yield pays for a good part of the cost of the application. Recommended fertilizer rates are based on a price ratio input/output (N or P/ maize) of 10 and a value/cost ratio of 2. For the calculation of economically optimal fertilizer rates, reference is made to Heinzmann (1993). Details on identification of trial sites can be found in the Final report, FURP Phase I. The recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run.

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In the Trans Nzoia District, fertilizer experiments were carried out at one site only, namely Kitale NARS. The first experiment tested crop response to nitrogen (N) and phosphorus (P) while in the second farmyard manure (FYM) was included as additional treatment. Maize was grown as a monocrop in module 1. In module 2, maize was intercropped with beans, while in module 3 the performance of Napier grass was tested. The soil at the Kitale trial site is classified as a humic Ferralsol. It is very deep and well drained with a high moisture storage capacity. The texture is sandy clay to clay. The soil reaction of the topsoil is in the moderately acid range. The site has a low to moderate P availability. The N supply capacity was rated low. In both module 1 and 2, maize exhibited a strong response to application of nitrogen. An N*P interaction was not confirmed by the results of experiment 2. The recommended N-rate for maize is 75 kg/ha. The linear response functions indicate that N-fertilization rate higher than 75 kg/ha could be economical and should therefore be tested. Application of P was not economical, but available P should be monitored as considerable amounts of P are removed from the field with the high yields recorded at this site. Napier grass responded fairly well to the application of N. The yield increase averaged approx. 160 kg dry matter per kg of N applied for the first 4 years the crop was grown. The crop should not be grown for more than 3-4 consecutive years as yields then tend to decline considerably. The application of 5 t/ha of FYM raised maize yields by 440 kg/ha on average. However, this yield increase was statistically not significant. No economic assessment of FYM varied considerably and second, it is difficult to quantify the direct effect of FYM application on maize yields, as well as the long term effects on soil physical and chemical properties like soil structure, humus content, cation exchange capacity, and available moisture capacity. As a general rule, and from a long term point of view, application of FYM may only be economical if the additional yields pays for a good part of the cost of the application. Recommended fertilizer rates for maize were based on a price-ratio input/ output (N or P/maize) of 10 and a value/cost-ratio of approximately 2. Response functions are given in the text and may be used for re-calculating economic fertilizer rates, if this becomes necessary with changing prices. For the calculation of economically optimal fertilizer rates, reference is made to Heinzmann (1993)1). Details on identification of trial sites can be found in the Final report, (FURP Phase 12).The recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run.

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In the Coastal Districts (KILIFI, KWALE and LAMU), two fertilizer experiments were carried out at 5 sites, namely; Mtondia Tezo, Mtwapa, and Lutsangani in Kilifi District. The first experiment tested crop response to nitrogen (N) and phosphorus (P_2O_5, always referred to as P) while the second tested crop response to farmyard manure (FYM) in all sites, and other treatments which were site specific such as potassium, sulphur an coconut frond mulch (Cfm). At two sites, Lutsangani (Vertisol with a high clay content) and Mpeketoni (chronic Luvisol with a loamy sand to sandy clay texture), no significant response to the application of phosphorus was recorded for any two of the crops tested, but maize exhibited a strong response to nitrogen. The high values for available P at these trial sites are at least partly due to available P at these trial sites are at least partly due to regular use of P-fertilizer before the start of the experiment. At Mtondia-Tezo and Mtwapa CARS, maize responded to both N and P, with N having a stronger effect than P. However, especially at Mtwapa CARS the response to N was rather weak due to low inherent soil fertility. The soil at both sites is very sandy; it has low humus content and a low moisture storage capacity. At Kichakasimba, maize responded to both N and P, but phosphorus had a stronger effect on crop yields than nitrogen. The soil texture at this site is sandy loam, and the moisture storage capacity is moderate. Cowpeas were grown as a relay crop with maize in season 1 at all trial sites. They were very efficient in fixing atmospheric nitrogen which proved to be a cheap source of nitrogen for the maize crop. Maize yields in the zero (control) treatments were on average approximately 600 kg per ha per year higher in the maize-cowpeas relay cropping sequence as compared to the cropping sequences without cowpeas. Consequently, the recommended cropping sequence for all trial sites for season 1 is maize-cowpeas (relay plants). Of all the crops tested, maize showed the best response to the application of farmyard manure (FYM) at all trial sites. On average, FYM applied at 5 t/ha increased maize yields by approximately 450 kg/ha. Unfortunately no economic assessment of FYM application was carried out for several reasons. First, quality and prices of FYM varied considerably and second, it is difficult to quantify the direct effect of FYM application on maize yields, as well as the long term effects on soil physical and chemical properties like soil structure, humus content, cation exchange capacity, and available moisture capacity. As a general rule, and from a long term point of view, application of FYM may only be economical if the additional yield pays for a food part of the application. Recommended fertilizer rates for maize were based on a price-ratio input/output (N or P/maize) of 10 and a value/cost -ratio of approximately 2. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run. All fertilizer rates are given in intervals of 25 kg/ha. Response functions are given for all sites and crops tested and may be used for more exact calculations, if this becomes necessary. For the calculation of economically optimal fertilizer rates, reference is made to Heinzmann F.X., 1993; and for identification of areas represented by one of the trial sites; reference is made to the Final Report, FURP, and Phase II.

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In Nyeri District, fertilizer experiments were carried out at three sites, namely Muirungi (22.1), Cheche (22.2), and Kiganjo (22.3). The effects of nitrogen and phosphate were tested in experiment 1, and in experiment 2, the effects of N,P, Potassium and farmyard manure were tested. Maize was grown as a monocrop throughout the years in module 1 and 2, it was intercropped with beans. Other crops such as potatoes and cabbages were planted in module 3. At both sites planting time was found to be an important factor. Early planted maize gave considerable higher yields than late planted maize. Due to poor site management and lack of supervision, virtually no results were available from the trial site at Muirungi. Nevertheless, the area around the Muirungi site, particularly to the West and north of Othaya, is well represented by the Kandara-Kareti (21.1) trial site in Murang'a District (see Fertilizer Use Recommendations, Volume 21). The soil and climatic conditions of the Muirungi trial site are similar to those at Chehe site in Nyeri District. Extension staff and farmers in the area around Muirungi are therefore referred to the recommendations given for Chehe and Kandara-Kareti. The soil at Cheche is very deep and well drained. The inherent fertility is moderate with high organic matter contents. The soil pH is low and aluminium saturation is high affecting crop growth negatively. Ca and Mg contents are very low. The soil at Kiganjo is deep and well drained. It has a high organic matter content and low amounts of available phosphorus. Soil reaction is neutral and potassium supply is adequate. At Cheche, crop production is limited by low soil pH and accompanying aluminium toxicity. Thus, application of lime and/or magmax is recommended to raise soil pH and reduce aluminium saturation. Application of lime increased crop yields significantly. Maize, beans and potatoes showed a slight response to P. In view of the very low available P contents in the soil, direct fertilization of beans with P should be tested. Application of farmyard manure had no effect on crop yields. Available P contents should be monitored closely and continuous cropping may lead to stronger responses to P in future. Recommended fertilizer rates for maize were based on a price input/output ratio (N or P/maize) of 10. The economically optimum

fertilizer rates for smallholders were generally calculated with a value/cost ratio of 2. For every shilling invested in fertilizer, the farmer should have obtained an additional income of 2 shillings; 1 shilling to pay for the fertilizer plus 1 additional shilling to cover his risks and to give him some net benefit. If we assume fertilizer costs of 80 shillings per kg of N or P_2O_5 and a price for maize of 8 shillings per kg (thus a price-ratio input/output of 10), then the limit would be a yield increase of 20 kg per kg of nutrient applied (price-ratio multiplied by the value/cost-ratio 10x2=20). For other crops, average market prices from December 1993 were used for calculation. Those were per kg of produce Ksh 16 for beans, KSh 6 for potatoes and KSh 4 for cabbages. For the calculation of economically optimum fertilizer rates in general, reference is made to Heinzmann (1993)1). Details on identification and representativeness of trial sites can be found in the Final Report, FURP Phase II. For the purpose of comparing the productivity of monocropping and intercropping systems, it was assumed that one kg of beans equals two kg of maize in market value. This means, that yield losses of 500 kg of maize per hectare in the intercropping system were compensated by a yield of 250 kg of beans/ha. It has to be emphasised that the recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long-term basis, since continuous cropping causes nutrient depletion and a decline in soil fertility. These nutrients will have to be replenished in the long run in order to maintain the productivity of the land, particularly, constant incorporation into the soil leads to severe declines in soil fertility. Farmers should be strongly encouraged to maintain better management (e.g. incorporation of crop residues, itself but it also increases moisture storage capacity and microbial activity. In addition, it provides a more favourable temperature for root growth amongst other soil parameters.

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In the Uasin Gishu District, fertilizer experiments were carried out at 2 sites, namely Moi TTC and Turbo. The first experiment tested crop response to nitrogen (N) and phosphorus (P) while the second tested crop response to a combined N*P-treatment, to farmyard manure (FYM), potassium and lime. Both sites have similar soil characteristics except for the available moisture capacity. At Moi TTC (Ferralic Cambisol, clay) the soil has a limited rooting depth of 25-55cm, thus available moisture is also limited and in the low range. At Turbo (ferralo-chromic Acrisol, sandy clay texture) the soil is deep with a very high moisture storage capacity. At Turbo, maize exhibited a strong response to nitrogen. The yield potential at this site is rather high 75 kg/ha of nitrogen is the recommended fertilizer rate, which corresponds with the highest rate tested. Higher rates of nitrogen could still be economical and should be included in future experiments. A response to P was recorded only in the last experiments. A response to P was recorded only in the last experimental year and could have been caused by the high maize yields of the previous years and the consequent depletion of available P in the soil solution. With the high yield potential given at this site, maintenance fertilization of phosphorus should be considered. At Moi TTC, maize responded also to nitrogen but to a lesser extent that at Turbo. Again at this site, the effect of phosphorus seemed to have become stronger after some years of intensive cropping. However, due to a rather in homogenous experimental plot, results are not as conclusive as at the Turbo trial site. At both trial sites, potatoes did not respond to the application of nitrogen, while P had a positive effect on the yield of potatoes in isolated years. The magnitude of this effect should be clarified in further studies. Cabbages were grown at Moi TTC only, and like at most other trial sites, responded strongly to P but not to N. The recommended rate of phosphorus fertilization is 50 kg/ha. A strong response to farmyard manure (FYM) was also recorded. FYM could be tested as a substitute for mineral P-fertilizer. Maize showed a good response to the application of FYM at both trial sites. On average, FYM applied at 5 t/ha increased maize yields at Moi TTc and Turbo by approximately 320 and 510 kg/ha, respectively. No economic assessment of FYM application was carried out for several reasons. First, quality and prices of FYM varied considerably and second, it is difficult to quantify the direct effect of FYM application on Maize yields, as well as the long term effects on soil physical and chemical properties like soil structure, humus content, cation exchange capacity, and available moisture capacity. As a general rule, be economical if the additional yield pays for a good part of the cost of the application. An annual application of 500 kg/ha of lime raised maize yields at Turbo by 450 kg/ha on average. The pH of the soil at this site is at the lower limit and should be maintained or even slightly raised by regular liming. At Moi TTC with a slightly higher pH, application of lime had no significant effect on maize yields. At both trial sites, neither of the crops tested showed a significant response to the application of potassium. Recommended fertilizer rates for maize were based on a price ratio input/output (N or P/maize) of 10 and a value/cost-ratio of approximately 2. In cases where the response to the application of fertilizer was very constant over the years, a lower value/cost ratio was used. For the calculation of economically optimal fertilizer rates, reference is made to Heinzmann (1993)1. Details on identification of trial sites can be found in the Final report, FURP Phase 12.The recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run. Maize showed a good response to the application of FYM at both trial sites. On average, FYM applied at 5 t/ha increased maize yields at Moi TTC and Turbo by approximately 320 and 510 kg/ha respectively. No economic assessment

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In Taita Taveta District, fertilizer experiments were carried out at one site only, namely Werugha (30.1). The effects of nitrogen and phosphate were tested in experiment 1. In experiment 2, the effects of N, P, Potassium and farmyard manure (FYM) tested. Maize was grown as a monocrop throughout the years in module 1 and in module 2, it was intercropped with beans. Other crops grown in the area were planted in module 3. The soils at Weruga are deep and the inherent soil fertility is low. Maize showed positive yield responses to N in both cropping systems, but the response was stronger in the intercrop. Yields obtained from intercropped maize were generally lower than those obtained from monocropped maize, and the additional bean yield on average could not compensate for the yield loss in maize. Whereas potatoes, cabbages and monocropped beans showed a positive response to N fertilizer application, potatoes and cabbages strongly responded to P application, too. In potatoes N and P should be applied together because a clear positive interaction of these nutrients was found. Application of 5 t FYM/ha resulted in clear yield increases in potatoes and cabbages. A combination of mineral N and P fertilizer with FYM resulted in significant yield increases, hence cannot be recommended for the time being. Nevertheless, soil potassium levels should be monitored every three to four years and corrective measures should be taken accordingly. Recommended fertilizer rates for maize are based on a price input/output ratio (N or P/maize) of 10. The economically optimum fertilizer rates for smallholders were generally calculated with a value/cost ratio of 2. For every shilling invested in fertilizer, the farmer should have obtained an additional income of 2 shillings; 1 shilling to pay for the fertilizer plus 1 additional shilling to cover his risks and to give him some net benefit. If we assume fertilizer costs of 80 shillings per kg (thus a price-ratio input/output of 10), then the limit would be a yield increase of 20 kg/kg of nutrient applied (price-yield increase of 20 kg/kg of nutrient applied (price-ratio multiplied by the value/cost-ratio 102=20. For other crops, average market prices from December 1993 were used for the calculation. Those were per kg of produce KSh 16 for beans, KSh 6 for potatoes and KSh for cabbages. Economic optimum fertilizer rates based on other input/output price optimum fertilizer rates based on other input/output price ratios and VCR's are given in Annex III. For the calculation of economically optimum fertilizer rates in general, reference is made to Heeinzmann (1993)1), Details on identification and representativeness of trial sites can sites can be found in the Final report, FURP phase 12).For the purpose of comparing the productivity of monocropping and intercropping systems, it was assumed that one kg of beans equals two kg of maize in market value. This means, yield losses of 500 kg of maize per hectare in the intercropping system are compensated by a yield of 250 kg of beans/ha. It has to be emphasised that the recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and a decline in soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run. Particularly, constant removal or burning of crop residues instead of their incorporation into the soil leads to severe declines in soil fertility. Farmers should be strongly encouraged to maintain and increase the organic matter content of their soils through better management (e.g. incorporation of crop residues, manure, and composts). This not only improves soil fertility itself, but it also increases moisture storage capacity and microbial activity. In addition it provides a more favourable temperature for root growth among other soil parameters.

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In the Meru District fertilizer experiments were carried out at 3 sites, namely Kaguru, Tunyai and Mitunguu. The soil at Kaguru is a humic nitisol with clayey texture and a moderate fertility whereas the soils at Tunyai and Mitunguu are nito-rhodic Ferrasols with clayey texture and low fertility. While the Kaguru site has a moderate P availability are the soils at Tunyai and Mitunguuu P- efficient. At Kaguru, maize and potatoes responded well to application of N fertilizer with economical optimum rates of 75 and 50 kg N/ha for maize and potatoes, respectively. For maize rates higher than 75 kg/ha may be economical and should be tested. Preferred cropping sequence should be maize intercropped with beans. As N-fixing capacity appeared to be weak inoculation with rhizobium should be tried. Sustained bean production requires liming to neutralize excess soil acidity. The production requires liming to neutralize excess soil acidity. The production of cabbage, although tested in one season only, does not seem worthwhile. At Tunyai crop production is generally limited by water availability especially during the short rains (season 1) and no fertilizer should be applied here. Intercropping in season 1 involves high risk of severe yield reductions or crop failures. It should be omitted or done with a lower plant population. During the long rains small fertilizer applications to maize are economical at rates of 20 and 10 kg P_20_5/ha for intercropped and monocropped maize, respectively. Direct P-fertilization of cowpeas should be tested. At Mitunguu, maize responded to N and P applications though fertilizer application is not economical at current input/output price ratio. Although yield of intercropped maize was lower than of sole cropped maize, the additional yield of cowpeas still provided an overall economical benefit. Of all crops tested maize exhibited the best response to the application of farmyard manure (FYM). 5 t FYM /ha applied during the long rains increased maize yields on average by approximately 600 kg/ha. No economic assessment of FYM applications was carried out for several reasons. First, quality and prices of FYM vary considerably. Second, not only the direct effect on maize yields but also the long term effects on soil physical and chemical properties like soil structure, humus content, cation exchange capacity, and available moisture capacity e.t.c have to be taken into account. As a general rule and from a long term view application of FYM may be economical if additional yield pays for a good part of the cost of the application. Recommended fertilizer rates are based on a price ratio input/output (N or P/ maize) of 10 and a value/cost ratio of 2. For the calculation of economically optimal fertilizer rates, reference is made to Heinzmann (1993). Details on identification of trial sites can be found in the Final report, FURP Phase I. The recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run.

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In Murang'a District fertilizer experiments were carried out at two sites, namely Kandara-Kareti (21.1) and Makuyu (21.2). Two experiments were carried out at concurrently. Response to nitrogen (N) and phosphorus (P_2O_5, always referred to as P) was tested in experiment 1. In experiment 2, farmyard manure (FYM) and potassium was tested in both sites in addition to phosphorus and nitrogen while lime was also included at Makuyu. Maize was grown as a monocrop throughout the years in module 1. In module 2, maize was intercropped with beans while in module 3, crops such as potatoes, cabbages and beans were grown at Kareti. There was no module 3 at Makuyu due to lack of space at the farm. The soils at Kareti are extremely deep and inherent soil fertility at the site is high. Maize showed significant yield responses to N in the second season where rainfall had been exceptionally high during the experimental years. Yields of intercropped maize were generally higher than those of monocropped maize which was due to differences in soil fertility at the site and not to differences of the cropping pattern as such. Potatoes showed a positive response to N, but results were only available from one year. the risk of applying fertilizer at sites like Kareti is generally high. Application of farmyard manure was much more profitable if mineral NP-fertilizer was applied in some years was noted, but it does not justify the recommendations of potash at current prices. The soil at Makuyu is extremely deep and consists of friable clay. The inherent soil fertility is moderate to high. IN experiment 1 monocropped maize showed significant yield response to N in the long rains, and only weak response in the short rains. In experiment 2 consistent positive yield responses to N and P application were recorded in both monocropped and intercropped maize in season 1, which lead to the recommendations given in table 1. IN the short rains, however, moisture availability was clearly the limiting factor, and no response to fertilizer was found in both cropping systems. Recommended fertilizer rates for maize are based on a price ratio input/output (N or P/maize) of 10. The economically optimum fertilizer rates for smallholders were generally calculated with a value/cost-ratio of 2. For every shilling invested in fertilizer, the farmer should have obtained an additional income of 2 shillings; 1 shilling to pay for the fertilizer plus 1 additional shilling to cover his risks and to give him some net benefit. If we assume fertilizer costs of 80 shillings per kg of N or P_2O_5 and a price for maize of 8 shillings per kg (thus a price-ratio input/output of 10), then the limit would be a yield increase of 20kg per kg

of nutrient applied (price-ratio multiplied by the value/cost-ratio 10x2 =20). For other crops, average market prices from December 1993 were used for the calculation. Economic optimum fertilizer rates based on other input/output price ratios and VCR's are given in Annex III. For the calculation of economically optimum fertilizer rates in general; reference is made to Heinzmann 1993) 1). Details on identification and representativeness of trial sites can be found in the Final Report, FURP Phase 12 It has to be emphasised that the recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical; it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and a decline in soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run. Particularly, constant removal or burning of crop residues instead of their incorporation into the soil leads to severe declines in soil fertility. Farmers should be strongly encouraged to maintain and increase the organic matter content of their soils through better management (e.g. incorporation of crop residues, manure, and composts). This not only improves soil fertility itself, but it also increases moisture storage capacity and microbial activity. In addition it provides for a more favourable temperature for root growth among other soil parameters

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In South Nyanza District fertilizer experiments were carried out at five sites, namely Rodi Kopani, Rongo, Homabay, Oyugis Ober, and Mukuyu Korondo. Two experiments were carried out concurrently. Response to nitrogen (N) and phosphorous (P) was tested in experiment 1. In experiment two, farmyard manure (FYM) and sulphur were tested in all five sites in addition to nitrogen and phosphorus. At none of the sites was any response to sulphate application found. At Rongo, Potash was also included in the nutrients to be tested in experiment 2. Maize was also grown as a monocrop throughout the years in module 1. In module2, maize was intercropped with beans while in module 3, crops such as sorghum, finger millet, potatoes and beans were grown. The soils in Rodi Kopani are deep and the inherent soil fertility is high. Both maize (monocropped and intercropped with beans) and sorghum showed a positive linear response to nitrogen application. Except for sorghum in season 2, no crop responded to the application of phosphate at this site. Farm yard manure application slightly increased yields of maize and sorghum. Crops showed positive responses to sulphate application. However, pure sulphate fertilization cannot be recommended at this point. Farmers should be encouraged to apply sulphate containing N fertilizers. Additionally sulphate contents of this soil should be monitored every four to five years and corrective measures should be taken accordingly. The soils at Rongo are moderately deep and consist of friable loamy sand to sandy loam. The inherent soil fertility is poor. Both monocropped and intercropped maize showed significant yield responses to N in both seasons, which was expected with organic matter content at the site being under 1. Sorghum displayed a weak response to N, and a strong to response to phosphate fertilizer in the first season. The ratoon crop showed no response to N or P fertiliser. Only a weak positive response of both maize and sorghum were observed when farmyard manure (5 t/ha) was applied. The soils at Homabay are deep and consist of friable to firm clay. The inherent soil fertility is high. Both monocropped and intercropped maize showed significant yield responses to N in the long rains, while the response in the short rains was much poorer and yields only reached about two thirds of the yields in season 1. Sorghum displayed a weaker, but very consistent response to n in the long rains, while the ratoon crop showed no response to N and P fertilisers. Neither monocropped nor intercropped beans nor cotton showed any response to the application of N or P fertilizer. Sorghum responded weakly to the farmyard manure application (5 t/ha). The Oyugis Ober site has moderately deep soils consisting of friable to gravelly clay. The inherent soil fertility is high. Monocropped maize showed a significant yield response to N in the long and short rains, but the response in the short rains is weaker and yields only reached about two thirds of the yields obtained in season 1. Intercropped maize displayed a weak response to nitrogen in the long rains, while an erratic positive response to phosphate was found in the short rains (clear only in two out of five years.) Sorghum displayed a positive response to both nitrogen and phosphate fertilizer in the long rains. The response was weaker for N than for P, while the ratoon crop showed an even slower response. Sunflowers and pigeon peas were only grown on one season and showed a positive, but not very strong response to phosphate fertilizer. Only weak positive responses in maize and sorghum were observed when 5 t of farmyard manure per hectare were applied. The soil at Mukuyu Korondo is characterised by a moderate to high inherent fertility. The friable silty clay to clay is well drained and deep. Both monocropped and intercropped maize showed positive yield responses to N in the long rains and to N and P in the short rains. Yields however were considerably lower in season 2 and N fertiliser application can only be recommended for maize in pure stand in the long rains under current economic circumstances. Phosphate fertilizer increased yields significantly in the maize/bean intercrop, but it is not economical to apply P at current price levels. In the short rains, intercropped maize should receive about 25 kg N/ha. Applications of potash cannot be recommended, while lime and farmyard manure should be applied as a measure of maintaining and/or increasing general soil fertility. Recommended fertilizer rates for maize were banded on a price input/output ratio (N or P maize) of 10. The economically optimum fertilizer rates for smallholders were generally calculated with a value/cost ratio of 2. For every shilling invested in the fertilizer, the farmer should have obtained an additional income of 2 shillings; 1 shilling to pay for the fertilizer plus 1

additional shilling to cover his risks and to give him some net benefit. If we assume fertilizer costs of 80 shillings per g of N or P_2O_5 and a price for maize of 8 shillings per kg (thus a price-ratio input/output of 10), then the limit would be a yield increase of 20 kg per kg of nutrient applied (price ratio multiplied with by the value/cost-ratio 10*2=20). For other crops, average market prices from December 1993 were used for the calculation. Those were per kg of produce Ksh 16 for beans, Ksh 8 for sorghum, Ksh 6 for potatoes and Ksh 10 for finger millet. Economic optimum fertilizer rates are based on other input/output price ratios and VCR's are given in annex III. For the calculation of economically optimum fertilizer rates in general, reference is made to Heinzmann (1993). Details on identification and representativeness of trial sites can be found in final report, FURP Phase I. If monocropping and intercropping systems are compared, it is assumed that one kg of beans equals two kgs of maize and sorghum in market value. This means, yield losses of 500 kg of maize or sorghum per hectare in the intercropping systems compared to monocropped maize or sorghum are compensated by a yield of 250 kg of beans/ha. It has to be emphasised that the recommended fertilizer rates are based on economic considerations. In cases where the fertiliser application is not economical, it should be borne in mind that such an economic analysis is not sustainable on long term basis, since the continuous cropping causes nutrient depletion and a decline in soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run. Particularly, incorporation into the soil leads to severe declines in soil fertility. Farmers should be strongly encouraged to maintain and increase the organic matter content of their soils through better management (e.g. incorporation of crop residues, manure and composts). This not only improves soil fertility itself, but increases moisture storage capacity and microbial activity. In addition it provide

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In South Nyanza District fertilizer experiments were carried out at five sites, namely Rodi Kopani (2.1), Rongo (2.2), Homabay (2.3) Oyugis Ober (2.4) and Mukuyu Korondo (2.5). Two experiments were carried out concurrently. Response to nitrogen (N) and phosphorous (P) was tested in experiment 1. In experiment two, farmyard manure (FYM) and sulphur were tested in all five sites in addition to nitrogen and phosphorus. At none of the sites was any response to sulphate application found. At Rongo, Potash was also included in the nutrients to be tested in experiment 2. Maize was also grown as a monocrop throughout the years in module 1. In module 2, maize was intercropped with beans while in module 3, crops such as sorghum, finger millet, potatoes and beans were grown. The soils at Rodi Kopani are deep and the inherent soil fertility is high. Both maize (monocropped and intercropped with beans) and sorghum showed a positive linear response to nitrogen application. Except for sorghum in season 2, no crop responded to the application of phosphate at this site. Farm yard manure application slightly increased yields of maize and sorghum. Crops showed positive responses to sulphate application. However, pure sulphate fertilization cannot be recommended at this point. Farmers should be encouraged to apply sulphate containing N fertilizers. Additionally sulphate contents of these soils should be monitored every four to five years and corrective measures should be taken accordingly. The soils at Rongo are moderately deep and consist of friable loamy sand to sandy loam. The inherent soil fertility is poor. Both monocropped and intercropped maize showed significant yield responses to N in both seasons, which was expected with organic matter content at the site being under 1. Sorghum displayed a weak response to N and a strong to response to phosphate fertilizer in the first season. The ratoon crop showed no response to N or P fertiliser. Only a weak positive response of both maize and sorghum were observed when farmyard manure (5 t/ha) was applied. The soils at Homabay are deep and consist of friable to firm clay. The inherent soil fertility is high. Both monocropped and intercropped maize showed significant yield responses to N in the long rains, while the response in the short rains was much poorer and yields only reached about two thirds of the yields in season 1. Sorghum displayed a weaker, but very consistent response to n in the long rains, while the ratoon crop showed no response to N and P fertilisers. Neither monocropped nor intercropped beans nor cotton showed any response to the application of N or P fertilizer. Sorghum responded weakly to the farmyard manure application (5 t/ha). The Oyugis Ober site has moderately deep soils consisting of friable to gravelly clay. The inherent soil fertility is high. Monocropped maize showed a significant yield response to N in the long and short rains, but the response in the short rains is weaker and yields only reached about two thirds of the yields obtained in season 1. Intercropped maize displayed a weak response to nitrogen in the long rains, while an erratic positive response to phosphate easy found in the short rains (clear only in two out of five years.) Sorghum displayed a positive response to both nitrogen and phosphate fertilizer in the long rains. The response was weaker for N than for P, while the ratoon crop showed an even slower response. Sunflowers and pigeon peas were only grown on one season and showed a positive, but not very strong response to phosphate fertilizer. Only weak positive responses in maize and sorghum were observed when 5 t FYM/ha were applied. The soil at Mukuyu Korondo is characterised by a moderate to high inherent fertility. The friable silty clay to clay is well drained and deep. Both monocropped and intercropped maize showed positive yield responses to N in the long rains and to N and P in the short rains. Yields however were considerably lower in season 2 and N fertiliser application can only be recommended for maize in pure stand in the long rains under current economic circumstances. Phosphate fertilizer increased yields significantly in the maize/bean intercrop, but it is not economical to apply P at current price levels. In the short rains, intercropped maize should receive about 25 kg N/ha. Applications of potash

cannot be recommended, while lime and farmyard manure should be applied as a measure of maintaining and/or increasing general soil fertility. Recommended fertilizer rates for maize are banded on a price input/output ratio (N or P maize) of 10. The economically optimum fertilizer rates for smallholders were generally calculated with a value/cost ratio of 2. For every shilling invested in the fertilizer, the farmer should have obtained an additional income of 2 shillings; 1 shilling to pay for the fertilizer plus 1 additional shilling to cover his risks and to give him some net benefit. If we assume fertilizer costs of 80 shillings per g of N or P_20_5 and a price for maize of 8 shillings per kg (thus a price-ratio input/output of 10), then the limit would be a yield increase of 20 kg per kg of nutrient applied(price ratio multiplied with by the value/cost-ratio 10*2=20). For other crops, average market prices from December 1993 were used for the calculation. Those were per kg of produce KSHS 16 for beans, KHS 8 for sorghum, KSHS 6 for potatoes and KHS10 for finger millet. For the calculation of economically optimum fertilizer rates in general, reference is made to Heinzmann (1993). Details on identification and representativeness of trial sites can be found in final report, FURP phase I. If monocropping and intercropping systems are compared, it is assumed that one kg of beans equals two kgs of maize and sorghum in market value. This means, yield losses of 500 kg of maize or sorghum per hectare in the intercropping systems compared to monocropped maize or sorghum are compensated by a yield of 250 kg of beans/ha. It has to be emphasised that the recommended fertilizer rates are based on economic considerations. In cases where the fertiliser application is not economical, it should be borne in mind that such an economic analysis is not sustainable on long term basis, since the continuous cropping causes nutrient depletion and a decline in soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run. Particularly, incorporation into the soil leads to severe declines in soil fertility. Farmers should be strongly encouraged to maintain and increase the organic matter content of their soils through better management (e.g. incorporation of crop residues, manure and composts). This not only improves soil fertility itself, but increases moisture storage capacity and microbial activity. In addition it provides a more favourable temperature for root growth among other soil parameters.

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In Kakamega district fertilizer experiments were carried out at four sites namely Mumias (7.1), Kakamega WARS (7.2), Vihiga-Maragoli (7.3) and Mwihila (7.4). Two experiments were carried out concurrently. Response to Nitrogen (N) and Phosphorous (P_20_5), always referred to as P was tested in experiment 1 (Exp 1). In experiment 2 (Exp.2), farmyard manure (FYM) was a common treatment in all sites in addition to other treatments such as lime (L), potassium(K) and Nitrogen + Phosphorous (NP) which were site specific. Maize was grown as a monocrop throughout the years in module 1. In module 2, maize was intercropped with beans throughout the year while in module 3, other crops such as cabbages; potatoes and finger millet were grown. Monocropped maize (module 1) showed significant yield responses to N and P application at Kakamega WARS and Mumias while intercropped maize responded significantly to P at Mumias. Sorghum and finger millet showed significant yield responses to P at Mumias and Mwihila respectively. Napier responded significantly to N and P application at Kakamega WARS and Mumias while intercropped maize responded significantly to N and P application at Kakamega WARS and cabbages to P application at Mwihila. The soil in the upper part of Mumias trial site is shallow to moderately deep and it consists of friable sandy clay loam to clay which overlies murram within 70 cm. In the lower half of the trial plot, the soil is very deep to deep and consists of friable sandy clay loam. Inherent soil fertility at this site is poor and the soil reaction or pH is strongly acid, lime and FYM (5 t/ha). FYM increased the yields of maize, beans and sorghum significantly. At Kakamega WARS, the soil is extremely deep and consists of friable to firm clay. The inherent soil fertility is moderate to high, total N and organic Carbon (C) are adequate but P is low. The moisture storage is very high. Maize showed significant yield responses to P and Napier grass to N and P application. Application of K and FYM had no effect on the yields of Napier grass and beans but FYM increased the yields of maize by about 1.0 t/ha in season 1. The yields obtained without the application of N and P in maize (module 1) and Napier grass (module 3) were very high initially, 7.8 t/ha (maize) and 11.8 t/ha (Napier). However, they declined continuously to less than half after the sixth year of cropping, to 3.2 t/ha (maize) and 4.0 t/ha (Napier grass). Response to P which was weak initially increased over the years. Beans did not respond to either N or P application at this site. The initial high productivity of the land is attributed to its being under pasture just prior to opening the site. The soil at Vihiga-Maragoli consists of friable clay. The inherent soil fertility is low. Major nutrients are adequately supplied except for available P which is low. The cation Exchange Capacity (CEC) is low to moderate and the soil reaction is moderately acid. Farmers' field is all very low in P and low in total N. There were no significant responses to either N or P at this site. However, potatoes showed significant yield responses to K and application of FYM (5 t/ha) increased the yields of potatoes and maize significantly by 3.1 t/ha and 0.7 t/ha respectively on average. At Mwihila, cabbages and finger millet showed significantly yield responses to P, but the maize and beans did not. Maize, beans and finger millet did not show significant responses to K or FYM application. There were o significant responses to N from any of the crops grown at the site. For the intercrop at each site, a combined yield of maize + beans (as an average for all years) was calculated as: yield of maize + 2 * yield of beans. It was assumed that beans cost approximately 2 times the price of maize in the market. The combined yield of intercrop (maize + beans) in module 2 calculated in this way, was higher than the yield of

monocropped maize in all trial sites except at Kakamega WARS in season 2. Table 1 shows the yields of maize (module 1) and the combined yields of maize + beans (module 2) without application of fertilizer in Kakamega district. Recommended fertiliser rates for maize were based on a price input (N or P) output (maize) ratio of 10 (pn/py=10) and a value cost ratio (VCR) of 2. Where the response had been constant over the years and the pn/py*VCR (10*2=20) was less than 20, a lower VCR of 1.5 was used. The management of such a crop where a VCR of 1.5 has been used would be of high quality, if maize production were to become profitable. A summary of the findings and recommendations is presented. The recommended fertiliser rates are based on economic considerations. In cases where fertiliser application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run. All fertiliser rates are given in intervals of 25 kg/ha. For the calculation of economically optimal fertiliser rates, reference is made to Heinzmann (1993). Details on identification of trial sites can be found in final Report, FURP Phase II.

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In Nakuru district, fertilizer experiments were carried out at two sites, namely: Mau summit (16.1) and Bahati (16.2). The effects of N, P and farmyard manure were tested. Maize was grown as a monocrop throughout the years in module 1 and in module 2, maize was intercropped with beans at Bahati and with beans and garden peas alternately at Mau summit. Other crops grown in the area were planted in module 3 at Mau Summit, but not at Bahati due to lack of sufficient moisture in season 2. The soil at Mau Summit is classified as a mollic Andosol (FAO-Unesco, 1974). It is deep to moderately deep, clayey and the inherent fertility is high. Except for beans in the intercrop and monocropped garden peas all crops grown at Mau Summit, i.e. maize, potatoes, cabbages and garden peas (as an intercrop) showed significant positive yield responses to phosphate application. Significant responses to nitrogen and farmyard application were not observed in any of the crops grown at this site. The initial high yields of monocropped maize (module 1) observed at this site can probably be attributed to application of farmyard manure prior to the start of the experiment. The soils at Bahati are classified as a humic Phaeozem. It is a sandy clay loam, moderately deep and well drained. The inherent fertility is moderate to high. Monocropped maize responded to applications of phosphate while the response to nitrogen was too weak to be economical. Intercropped maize, however, showed a consistent linear response to N application. In the long run, the intercropping system out yielded monocropped maize at Bahati but not at Mau Summit. Table 1 compares the average performance of the monocrop with the intercrop. For the intercrop, a combined yield of maize + beans (or garden peas) was calculated as maize yield plus 2 * yield of beans (or garden peas). The performance of the monocrop declined with time while that of the intercrop improved over the same period at Mau Summit. It is for this reason that intercropping is also recommended for the Mau Summit area. Residual effects of the farmyard manure application at Mau Summit were evident in the initial years of the experiment. This explains the overall poorer performance of the intercrop. Nevertheless, intercropping maize with beans (or garden peas) is the recommendable option for both sites. Besides improving soil fertility the legumes provide dietary protein and soil cover thereby preventing malnutrition and soil erosion respectively.

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In the Northern Rift valley districts of West Pokot, Elgeyo Marakwet and Baringo fertilizer experiments were carried out as Kapenguria in the south of West Pokot District, at the two sites of Bugar and Tot KVDA in Elgeyo Marakwet District and at Eldama Ravine and Kasoiyo in Baringo District. The first experiment tested crop responses to Nitrogen (N) and phosphorous (P) and the second tested farmyard manure (FYM) and other nutrients such as potassium in addition to N and P. Maize or sorghum were grown as a monocrop in module 1, while in module 2, maize or sorghum were intercropped with beans or green grams. In module 3 the responses of potatoes, cabbages, beans and sunflowers were tested. An overview of the recommendations is given in table 1; detailed findings and conclusions are given in the text for the sites. Fertilizer responses at all sites in the Northern Rift valley districts were not very pronounced if recorded at all. On most sites, water was the limiting factor, and although the general soil fertility of the area is rather moderate or even low in some cases, responses to fertilizer were seldom found. The application of farmyard manure, however, is recommended at all areas in order and the general fertility of the soils. The soil at the Kapenguria site as well as farmers fields in the vicinity showed low to moderate fertility. Neither maize nor beans or potatoes responded to N, P, K or farmyard manure, although yields were generally very high. Cabbages showed a clear positive response to phosphate up to a rate of 45 kg P_2O_5/ha. It is therefore recommended to apply P fertilizer or farmyard manure (5 t/ha) to cabbages. N and P contents in the soil and performance of crops where no fertilizer application has been recommended should, nevertheless, be monitored

every three to four years. The two Tot KVDA sites (Elgeyo Marakwet District) showed no or even a negative response to nitrogen or phosphate fertilizers. Water was the most limiting factor at this site as irrigation increased yields considerably (Site Tot irrigated). The soil reaction was favourable for mineralization and the organic C content was high at the site which provided sufficient nitrogen, hence no response to N fertilizer was observed. There was no response to farmyard manure in maize, finger millet or green grams, only monocropped sorghum showed a positive yield response. Nevertheless, organic matter content should be further improved to enhance the water storage capacity and general soil structure. Nutrient contents in the soil should be monitored regularly in order to prevent a serious decline in soil fertility. At Bugar (Elgeyo Marakwet District) only maize and beans in the intercropping system responded to the application of nitrogen. Cabbage yields decreased with increasing amounts of N. Hence, mineral nitrogen should only be applied to the intercropped maize/Beans and farmers have to be made aware of the high risk involved. Responses to phosphates application, although somewhat inconsistent over the years, were observed in potatoes and cabbages only. Monocropped maize even displayed a negative response to the application of P fertilizer. An application of 70-75 kg P_20_5/ha to potatoes and cabbages is recommended, even though the economic risk in potatoes is high. The application of farmyard manure (5 t/ha) is highly recommended for cabbages (highest returns). Maize and potatoes also responded positively to farmyard manure applications (5 t/ha). The Eldama Ravine site in Baringo district gave no clear results in experiment1 while response to both N and P were observed in applications is generally high since droughts are frequent and yields are quite low. Nevertheless, a small amount of fertilizer (at most 50 kg/ha of N and 40 kg of phosphate depending on the crop) or farmyard manure should be applied if available to farmers at reasonable costs and in the form of "response farming", i.e. direct reaction to favourable weather conditions.

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In Machakos and Makueni districts, fertilizer experiments were carried out at four sites, namely: Kilome Upete (26.1), Makutano (26.2), Kampi ya Mawe (26.3) and Katumani NRC (26.4). Two experiments were carried out concurrently. Response to nitrogen (N) and phosphorus (P_20_5), mostly referred to as P, was tested in experiment 1. In experiment 2, farmyard manure (FYM) was applied at four levels (0, 2.5, 5 and 7.5 t/ha) with and without additional phosphorus and nitrogen. Maize was grown as a monocrop throughout the years in module 1. In module 2, maize was intercropped with beans while in module 3, crops such as potatoes and cabbages were grown. The soils at Kilome Upete are very deep and inherent soil fertility is low. Yield level in the area is fairly low due to insufficient rainfall in most seasons. Monocropped maize showed positive yield responses to N and P in both seasons. Intercropped maize showed a response to N application only. Sorghum was only planted in one year, but showed a positive response to P application to sorghum in season 2 was considered to be high. Application of 5 t FYM/ha resulted in slight yield increases in maize and beans. Sorghum showed a negative response to the application of FYM. The soils at Makutano are deep, well drained and inherent soil fertility is low. Maize yields in the area were fairly low due to insufficient rainfall in most seasons. Monocropped maize showed positive yield responses to N in both seasons. Intercropped maize showed a weak response to N application only in season 1. The cowpea intercrop responded positively to phosphate application but not to N. Pigeon peas responded to P application only. Application of 5 t FYM/ha resulted in weak yield increases in maize and cowpeas, while pigeon peas produced 340 kg/ha more yield. The soils at Kampi ya Mawe are very deep, well drained with low inherent soil fertility. Maize yields in the area were fairly low due to insufficient rainfall in most seasons, but higher on average than at Kilome Upete and Makutano. Both monocropped and intercropped maize showed positive yield responses to N in both seasons. Response to P was found in intercropped maize in both seasons but in the pure stand maize, only in season 1, and it was weak over the years. The cowpea intercrop responded weakly to phosphate application, but not to N. Pigeon peas also responded weakly to P application. Application of 5 t FYM/ha resulted in weak yield increases in maize, while pigeon peas and cowpeas showed no response. The soils at Katumani are well drained with poor inherent soil fertility. Monocropped and intercropped maize showed positive responses to nitrogen application in both seasons and response to phosphate application in season1 only. Under current prices, fertiliser application of either N or P is not economical. Neither intercropped beans nor monocropped pigeon peas displayed any response to N or P application. Application of 5 t FYM/ha resulted in weak positive responses in both maize and beans, particularly in season 2. Even if immediate yield responses to the application of organic manure cannot be expected, it is important to apply farmyard manure at a rate of about 5 t/ha every two to three years and incorporate plant residues into the soil in order to improve the moisture storage capacity and organic matter content of these soils.

Schnier H. F., Chek A. L., Gateri M., Kanyanjua S. M., Kathuli P., Milikau R. L., Muriuki A., Onyango J. W., Thuranira E., Wamae D., Helga Recke, Muchena F. N., Qureshi J. N. and Ayaga G. O. (1994). Fertiliser Use recommendations project (FURP), Kiambu district. Technical FURP Report. Vol. 4

In Kiambu district (including Nairobi area) fertilizer experiments were carried out at 2 sites, namely: Githunguri and National Agricultural Research Laboratories (NARL). The first experiment tested crop response to Nitrogen (N) and phosphorus (P), while the second experiment tested crop response to farmyard manure (FYM). The soils at Githunguri and NARL are both humic nitisols with clayey texture and a medium to high (Githunguri) and medium (NARL) fertility. While the NARL site has a moderate P availability, the soil at Githunguri is P-deficient. At Githunguri, although a linear response to P application was observed in maize no quantitative fertiliser recommendations are given because maize performance was generally very poor and not representative of the area. With higher yield levels P will be more limiting and hence a even stronger P response is likely to be expected. Potatoes and cabbages can be grown as alternative crops to maize during the long rains. Cabbage responded to P application with an optimum rate of 60 kg P_20_5/ha while potatoes responded to both N and P application with economical optimum rates of 25 kg N/ha and 75 kg P_20_5/ha. At NARL maize responded to N and P application though fertilizer application is not economical at current input/output price ratio. It will be only economical if it is applied to produce maize for the farmers own household demand. In order to make efficient use of the fertilizer, phosphorus should be applied during the long rains. Beans exhibited no response at all. Intercropping maize with beans should be the preferred option as it provides an overall economical benefit over solely grown maize. In addition, the intercrop serves as ground cover thereby reducing potential soil erosion. Of all crops tested cabbage exhibited the best response to the application of farmyard manure (FYM) followed by maize. 7.5 t/ha of FYM increased yield of cabbage by 7500 kg and yield of maize by approximately 400 kg. No economic assessment of FYM application was carried out for several reasons. First, quality and prices of FYM vary considerably. Second, not only the direct effect on crop yield but also the long term effects on soil fertility have to be taken into account. As a general rule and from a long term perspective application of FYM may be economical if additional yield pays for a good part of the cost of the application. Recommended fertiliser rates are based on a price ratio input/output (N or P/maize) of 10 and a value/cost ratio of 2. For the calculation of economically optimal fertilizer rates, reference is made to Heinzmann (1993). Details on identification of trials sites can be found in the Final Report, FURP Phase. The recommended fertiliser rates are based on economic considerations. In cases where the fertiliser application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the Land in the long run.

Schnier H. F., Chek A. L., Gateri M., Kanyanjua S. M., Kathuli P., Milikau R. L., Muriuki A., Onyango J. W., Thuranira E., Wamae D., Helga Recke, Muchena F. N., Qureshi J. N. and Ayaga G. O. (1994). Fertiliser Use recommendations project (FURP), Busia district. Technical FURP Report. Vol. 9

In Busia district fertilizer experiments were carried out at 2 sites, namely: Bukiri-Buburi and Alupe ARSS. There were two experiments running concurrently. The first experiment tested crop response to Nitrogen (N) and phosphorus (P_20_5) while the second experiment tested crop response to farmyard manure (FYM), potassium (K) and lime (L). Each experiment consisted of 3 modules. In module 1, maize was grown as monocrop and in module 2, maize was intercropped with beans. Other crops such as sorghum, cotton and cassava were grown in module 3. The soil at Bukiri is a ferrelo-chromic Acrisol. It is deep well drained and has a high moisture storage capacity. The inherent fertility is low, N and organic carbon are moderate, and available P is low. The soil at Alupe ARSS is a ferralo-orthic Acrisol. It is moderately deep to shallow and consists of friable clay overlaying murram between 30-70 cm depth. It is well drained and moisture storage capacity is low. Organic carbon is moderate but N and P are low. At Bukiri-buburi, all crops, i.e. maize, beans, sorghum, cassava and cotton exhibited a yield response to application of P fertilizer. There were also responses to application of FYM and potassium but not to N and lime application. At Alupe ARSS, maize and beans showed a response to N and P fertilizer, although at current input/output price ratio its application is economically justified. Sorghum did not show any response to N or P. For the intercrop, a combined yield of maize and beans was calculated assuming the price to be twice of that of maize. At both sites and in both season 1 and 2, the combined yield of the intercrop without fertilizer application was higher than the yield of monocropped maize. The differences were generally greater in season 1 than in season 2. Therefore, intercropping maize with beans should be the preferred option. Besides economic benefits and diversification of the human diet, the intercrop also provides ground cover and reduces soil erosion, especially on slopes. As N-fixing capacity of beans appeared to be weak inoculation with rhizobium should be tested. Recommended fertiliser rates are based on a price-ratio input/output (N or P/maize) of 10 and a value/cost ratio of 2. For the calculation of economically optimal fertilizer rates, reference is made to Heinzmann (1993). Details on identification of trial sites can be found in the final report, FURP phase 12. The recommended fertiliser rates are based on economic considerations. In cases where the fertiliser application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in order to maintain the productivity of the land in the long run. The trial site was started in 1988 and is on-going.

It lies within lower Midland semi-humid agro-ecological zone LM3. Average annual is 1495 mm with 600 and 470 mm in the first and second rains, respectively. Annual average precipitation is 50-65% of the potential evaporation (Eo). The soil is classified as ferralo-chromic Acrisol (FAO-Unesco). It is deep, clayey and well drained with a high moisture storage capacity. The inherent fertility is low; organic carbon and N are low. Available P is low. A detailed description of the site characteristics is given in the final Report of FURP (phase I), Annex III, volume 5. Within Busia district, the trial site has high and moderate representativeness for an extensive area in the southern part of the district. The Bukiri-Buburi site is also representative for areas outside Busia district, in particular, in the westernmost part of Kisumu district, many parts of Siaya district and on deep to very deep soils in the western parts of Kakamega district. As the available P content in the soil was rather low, all crops exhibited a strong response to application of P fertilizer except for beans which were grown as an intercrop in maize. Beans were not fertilized directly but had to scavenge from fertilizer applied to the maize rows only. For maize, beans and sorghum, the response to P application was greater in season 1 as compared to season 2. In season 1, yield of intercropped maize was substantially lower than that of maize grown as sole crop. Also, bean yields were much lower in season 2 than in season 1 indicating competition for limited moisture in season 2 which generally received less rainfall. However considering the higher market value of beans, intercropping in season 2 still provides an overall economic benefit. Intercropping should therefore be the preferred option. Furthermore, besides economic benefits, the intercrop also provides ground cover and thereby reduces soil erosion. Cassava (1989only) responded strongly to P application with an optimum application rate of 30 kg P_20_5/ha. Cotton grown as intercrop (1988 only) exhibited a response to P with an optimum rate of 15 kg P_20_5/ha. The low cotton yield observed in module 3 in 1990 are due to late planting and is therefore not representative. The economically optimal fertilizer rates for smallholders were generally calculated with a value/cost ratio of 2 i.e., for every shilling invested in fertiliser, the farmer should have obtained an additional income of 2 shillings, 1 shilling to pay for the fertilizer plus an additional shilling to cover for his risks and give him some net benefit. Assuming fertiliser costs of 80 Shillings per kg of N and P and the price for maize to be 8 Shillings per kg(thus a price-ratio input/output=10), application of N fertiliser to maize would pay off if the yield increase per kg N is above the threshold of 20 (price-ratio multiplied by the value/cost-ratio 10×2=20).Prices for beans, sorghum, cassava and cotton were assumed to be Ksh 16,12,4 and 10, respectively. In all cases the application of P to maize and sorghum was economically justified. Optimum fertilizer rates in season 1 were 25 and 75 kg P_20_5/ha for monocropped and intercropped maize, respectively while in season 2, the optimum rate was 25 kg P_20_5/ha. Economically optimum fertiliser rates for sorghum were 50 and 25 kg P_20_5/ha in season 1 and 2, respectively. With regard to the response to P application the results of experiment 2 confirm those obtained in experiment 1. Application of farmyard manure (FYM) in season 1 showed significant effects in maize, beans and sorghum. Average yield increase due to FYM application (5 t/ha in season 1) was 460 and 300 kg maize/ha for season 1 and 2, respectively while for sorghum, it was 900 sorghum/ha in season 1. Bean yields increased by an average of 140 and 60 kg/ha in season 1 and 2 respectively. Application of potassium or lime had no effect on crop yields. Continuous cropping over a 3 year period affected the soil properties. The organic carbon content decreased slightly whiles the pH 5.15 which is still in the acceptable range. Concentration of available nutrients (K, P, Ca and Mg) declined in all treatments except for P in treatments where P fertilizer had been applied. It should be kept in mind that under the experimental conditions all crops residues were returned to the field. Thus, part of the nutrients taken up by the crop has been returned. With farm management practices in which crop residues are not returned to the field the decline (or mining) of soil nutrients will be more pronounced.

Schnier H. F., Chek A. L., Gateri M., Kanyanjua S. M., Kathuli P., Milikau R. L., Muriuki A., Onyango J. W., Thuranira E., Wamae D., Helga Recke, Muchena F. N., Qureshi J. N. and Ayaga G. O. (1994). Fertiliser Use recommendations project (FURP), Kisii district, Kenya. Technical FURP Report. Vol. 8

For the calculation of combined response function for the maize/beans intercrop, bean yields were converted into maize yields by multiplying them by factor 2, which correspond approximately to the actual price ratio of beans/maize. Generally, the combined yield of the intercrop was considerably higher than the yield of maize grown as a sole crop, thus intercropping beans with maize should be the preferred option. The economically optimal fertilizer rates for smallholders were generally calculated with a value/cost-ratio of 2, i.e., for every shilling invested in a fertilizer, the farmer should have obtained an additional income of 2 shilling, 1 shilling to cover for his risks and to give him some net benefit. Assuming fertilizer costs of 80 shillings per kg of N or P and a price of maize of 8 shillings per kg (thus a price-ratio input/output=10), application of N fertilizer to maize is slightly below the threshold of 20 kg yield increase per kg N applied (price-ratio multiplied by the value/cost-ratio 10×2=20). However as the response of maize to N application was rather consistent, a value/cost-ratio slightly below 2 is still acceptable. For season 1, the recommended fertilizer rate is then 75 kg N/ha for both maize sole crop and the maize/beans intercrop. Application of P is not economical at the moment, but direct P fertilization of beans should be tested at the response of beans to P was generally good at this site. For potatoes and finger millet, P-fertilization rates of 45 and 65 kg/ha are recommended, assuming commodity prices of 2 and 12 Kshs/kg, respectively. In season 2, the optimum N-rate for maize and the maize/beans intercrop is 50 and 40 kg/ha, respectively. The combined yield of the intercrop showed a good response to P, and it can be expected that P fertilization will turn out to be economical if directly applied to beans. The recommended P-rate for beans

grown as a sole crop is 45 kg/ha. This rate applied directly to beans should also be tested as the intercrop. In experiment 2, potassium and farmyard manure (FYM) were included as additional treatments. A significant effect of K application was recorded in neither of the crops tested. FYM applied at a rate of 5 t/ha significantly raised yields of finger millet, beans (season) and potatoes. Average yield of maize increased by 400 kg/ha; this increase, however, was not significant. With regard to the effect of N and P application, the results of experiment 1 were generally confirmed. Generally, the effect of P application decreased over the years. This was most likely due to sharply decreasing maize yields and the P supplying capacity of the soil becoming more and more adequate for the decreasing yield levels. Table 4 shows the changes of organic C content, pH and available nutrients during the course of the experiment. Organic C and pH remained almost constant while the values for available nutrients decreased considerably without reaching critical levels, however. Consequently, these changes do not explain the decreasing yield levels. The strong response of finger millet, potatoes and beans is not in accordance with the relatively high levels of available P.

Helga Recke, Muchena F.N., Qureshi J. N., Ayaga G.O., Schnier H. F., Chek A .L., Gateri M., Kinyanjua S. M., Kathuli P., Milikau R.L., Muriuki A., Onyango J.W., Thuranira E. and Wamae D. (1992). Fertiliser Use Recommendation Project (FURP); Kirinyaga District, Kenya. Technical FURP Report vol. 22 1992

In Kirinyaga District, fertilizer experiments were carried out at two sites, namely Kerugoya and Karaba. The first experiment tested crop responses to nitrogen (N) and phosphorus (P) while in the second, farmyard manure (FYM), sulphur and potassium were included as additional treatments. Maize was grown as a monocrop in module 1. In module 2, maze was intercropped with beans or green grams while in module 3, the performances of beans, potatoes, cabbages, sunflower and green grams were tested. The soil at Kerugoya is classified as humic Nitisol. It is very deep and well drained. The inherent fertility is moderate with moderate N supply and adequate available P content, but extremely low potassium content. At Karaba the soil is classified as pellic vertisol. It is deep and poorly drained. The inherent fertility is low to moderate with very low organic matter, total N, Potassium and phosphorus contents. Available calcium and magnesium levels are high. At Kerugoya, without application of potassium, all crops showed a weak response to N application. Minimum blanket applications of 75 kg K_2O/ha are recommended to alleviate K deficiency before application of N becomes economical. In addition to mineral K fertilizer, crop residues should be returned to the field in order to improve the potassium status of the soil. Yields of maize and potatoes were increased almost two-fold with the combined application of K and N. Intercropped maize showed a weak N response with an economic optimum rate of 10 kg N/ha (without K application). With K application, economic N rates for maize could be as high as 50 kg N/ha. As potatoes responded linearly to N application, economically optimum N rate may therefore be higher than 75 kg N/ha especially if combined with K application. Application of farmyard manure (5 t/ha) increased the yields of maize, potatoes and cabbages by an average of 700, 1900 and 1000 kg/ha, respectively. Beans grown as sole crop or intercrop and cabbages did not respond to fertilizer application. Yields of intercropped maize were lower than those of monocropped maize and the yield loss was not compensated for by the additional bean yield. Therefore, monocropping maize is the recommended practice. At Karaba, crop production was generally more limited by available rainfall than by soil fertility. Monocropped maize only showed a response to N in season 1 in years with adequate rainfall. Therefore, fertilizer application implies a rather high economic risk at this site. Economic optimum N rate for monocropped maize was on average 25 kg/ha. Similar to mineral fertilizer application, the response to FYM was very poor. Because of limited moisture availability, timely planting is very essential. In dry years, yields of intercropped maize were considerably lower than those of monocropped maize. Intercropping should therefore not be practiced. Yields of sorghum, on the other hand, were generally higher than maize yields as sorghum was better adapted to the dry conditions found at this site. Green grams grown as sole crop gave much higher yields than if grown together with maize. Recommended fertilizer rates for maize were based on an input/output price ration (N or P/maize) of 10 and a value/cost ratio of 2.Response functions are given in the text and may be used for recalculating economic fertilizer rates, if this becomes necessary as prices change. Economic optimum fertilizer rates based on other input/output price ratios and VCR's are given in Annex III. For the calculation of economically optimal fertilizer rates, reference is made to Heinsmann (1993) 1). Details on identification of trial sites can be found in the Final report, FURP Phase 12). The recommended fertilizer rates are based on economic considerations. In cases where the fertilizer application is not economical, it should be borne in mind that such an economic analysis is not sustainable on a long term basis, since continuous cropping causes nutrient depletion and decline of soil fertility. These nutrients will have to be replenished in the long run in order to maintain the productivity of the land.

Qureshi, J. N. (1991). The cumulative effects of N-P fertilizers, manure and crop residues on maize and bean yields and some soil chemical properties at Kabete. *Proceedings of the 2nd KARI Annual Scientific Conference held at Panafric Hotel, Nairobi, Kenya* 5-7th Sept. 1990. pp 160-167

A long term trial was set up on a nitosol at Kabete in 1976 to study the effect of N-P fertilizers, farmyard manure and crop residues on crop yields and soil fertility under a continuous regime. Maize was grown in the long rains

while beans were grown on the residual treatments. Over a nine year period (up to 1985) maize grain yields declined by 34% in the absence of any fertilizer while application of manure and N-P fertilizers increased yields by 40-60% respectively. Grain yields were maintained at 2.7 to 4.0 t/ha by application of 5 t manure/ha and 60 kg each of N and P_2O_5/ha giving a good comparison between the two sources of plant nutrients. Dry bean yields were low and ranged from 95 to 1414 kg/ha. Incorporating crop residues in the soil depressed maize grain yields in the first three years but gave increase averaging 2.9 to 10% in later years, the increase being more pronounced where N-P fertilizers had been applied. Better dry bean yields were also recorded with crop residues incorporation. The contents of N, P, K in maize leaves at the silking stage averaging 2.36, 0.17 and 1.86% respectively for four season crops. The nutrient K was removed in most quantities (139 kg/ha) by a harvested maize crop followed by N (91 kg/ha), Ca (23 kg/ha), P (16 kg/ha) and Mg (11 kg/ha). Maize grains removed most N and P while stover removed most Ca, Mg, K, S and trace elements. Stover also removed a substantial amount of N. With a continuous cropping there was a decrease in the contents of soil available K, Ca, Mg, Mn and P, total N and organic C. Application of manure or N-P fertilizers did not maintain the levels of soil available K, Ca, Mg, Mn, organic C and total N. Unlike manure, N-P fertilization maintained the level of soil available P. Incorporating crop residues increased the contents of soil available K, Ca, Mg, P, organic C and total N. Soil fertility is on the decline in the high and medium potential areas of Kenya as a consequence of continuous cropping to meet increasing food requirements for the growing population. There is a reduction in crops production due to the low availability or even lack of nutrients and the deterioration of soil physical properties. Fertilizers, manures and crop residues are materials which can maintain soil fertility. A long term trial was started at Kabete in 1976 to find out appropriate methods of maintaining the productivity of the soil through the use of inorganic fertilizers, particularly nitrogen and phosphorus (N-P), farmyard manure and crop residues following small scale farmers husbandry practices bearing in mind that arable land is becoming limited and continuous cropping is the rule in most cases.

Achieng, J. Ngugi, A. and Mwania, N. (1989). Farm Yard Manure (F.Y.M), NP Fertilizers and maize stover experiment. 1989, Kenya Agricultural Research Institute, Kitale, Kenya. Annual, Report, Pp 55-57.

With the increase in the number of small farm holdings due to progressive subdivision of the formerly large scale farms, continuous cropping has become common practice in many parts of this country. In turn, crop nutrient availability in the soils had tended to decline as the soil chemicals and physical properties have deteriorated. It is believed that application of organic sources of manure, such as FYM and crop residues, would improve the situation. The objective of this experiment is to determine the long term effects of different rates of FYM, NP fertilizer, and stover per-se or their combination on, maize grain yield, content of N and Crude Protein in tissues and soil chemical/physical properties. The experiment was in its second year.

Achieng, J., Ngugi, A. and Mwania, N. (1989). Farm Yard Manure (F.Y.M), NP Fertilizers and maize stover experiment. Kenya Agricultural Research Institute. Annual Report, Pp 55-57, Kitale, Kenya

With the increase in the number of small farm holdings due to progressive subdivision of the formerly large scale farms, continuous cropping has become common practice in many parts of this country. In turn, crop nutrient availability in the soils had tended to decline as the soil chemicals and physical properties have deteriorated. It is believed that application of organic sources of manure, such as FYM and crop residues, would improve the situation. The objective of this experiment is to determine the long term effects of different rates of FYM, NP fertilizer, and stover per-se or their combination on, maize grain yield, content of N and Crude Protein in tissues and soil chemical/physical properties. The experiment was in its second year.

Lawsuit, C. M., Chide, J. E., Kamau, J. N. and Cheruiyot, D.T. (1989). Effect of liming, farmyard manure and phosphate fertilizer on performance of Lucerne. Kenya Agricultural Research Institute, Annual Report, 1989

Lucerne (*Nedicago sativa*) is considered as one of the most important forage legumes in Kenya, however, the performance of this legume in most parts of the mandated region (West Pokot, Trans Nzoia, Elgeyo Marakwet and Uasin Gishu) has been low possibly, because of acidic soils. This trial aims at evaluating the effect of different levels of lime, FYM and phosphate fertilizer on Lucerne herbage production.

Wapakala, W.W. (1976). Changes in some chemical properties of a red clay soil: Results of long term fertilizer and rotational trials in Central Kenya. *East African Agricultural and Forestry Journal* Volume 42 (2) pp. 201-218

Soil fertility has long been recognized as one of the major environmental factors limiting crop yields in Kenya; and in order to ascertain the place of fertilizer application in crop yield improvement a number of fertilizer trials have been laid down in many of the high and medium potential crop growing areas of Kenya. One such fertilizer trial was laid down at Embu Agricultural Research Station, on the outskirts of Embu Township in 1952. The objective of the trial was to determine the effects of NPK on a number of field crops planted in a rotation recommended for

the area. Soil samples were taken from the experimental site in 1955 and 1966. 1955 sampling was not detailed enough but showed that the soil was well supplied with organic matter, nitrogen and bases. It was, however, low in available P (Gatheca, 1970). In 1966 treatments were sampled individually, replicated samples being pooled. From analyses of these samples, it was observed that plots which had received nitrogen in the form of Ammonium Sulphate had very low pH values accompanied by low levels of available Ca and K was so significant that it was felt necessary that a study should be made on the data to determine if the nitrogen treatments had other chemical effects on the soil which were not easily observable. The investigations were also to include the effects of other treatments on the chemical properties of the soil under the experiment. Data from a similar trial planted in 1959 at Murinduko Agricultural Research sub-station, 6 Km S.W. of Embu Town and which has a slightly different environment, were also studied for a comparison.

Robinson, J. B. D. (1956). Growth of Poultry, Sheep Management, Fertilizers and manures in Coffee soil, investigations on coffee berry disease, Insect damage in stored groundnuts; The influence of fertilizers and manure on the pH reaction of a coffee soil. *East African Agricultural and Forestry Research Organization (EAAFRO) Journal*. Volume 35 pp 2

During the course of soil nitrogen studies on the Kikuyu red loam soils at the Coffee Research Station, Ruiru, it has become apparent that the soil pH reaction is being influenced very appreciably by treatments applied in the manurial trials on the station. A short-term investigation was undertaken to examine the effects of various manurial treatments on the soil pH reaction, with particular reference to the use of ammonium sulphate fertiliser and to the question of the position of application in relation to the coffee tree. It has long been generally recognized that the application of ammonium sulphate fertiliser will increase the degree of soil acidity, relative to the original soil pH value (1) (2) (3). Values obtained for the Kikuyu red loam coffee soil (a deep, free-draining lateritic soil developed over sheet lava, containing 55 per cent to 65 per cent clay fraction) suggest that the continued regular use of this fertiliser may produce extremely acid topsoil conditions, which would be indirectly harmful to the nutrition of the coffee tree. Data are also presented here for soil samples collected from plots that have received regular dressings of double super-phosphate fertiliser and cattle manure.

Kroll, U. (1953). The effect of fertilizers and manures on pyrethrum yields. East African *Agricultural and Forestry Journal*

During the past seven years a number of statistical and observational field trials with fertilizers and manures have been carried out on pyrethrum, both on the crop itself and on other crops in the rotation. Lime, mulch, compost, green manures, nitrogen, potash and phosphate as triple supers, Uganda rock, bone meal and soda phosphate have all been tested. While much remains to be done, the results obtained so far are of definite interest. The only increase in yield through liming was given on part of an experiment where the pH of the soil was 4.9, while no effect was noticed on the remainder of the trial where the soil pH was 5.2. In one trial, lime decreased the yield. Mulch gave indicative results, in that when applied to young plants it tended to depress the yield, possibly by inhibiting the growth of small splits. During the second season after planting, however, significant increases in yield were obtained with mulching; flowering continued for a longer period into the dry season, and plants seemed to weather the dry season better and to make a more vigorous start in the following year. Current trials include applications of nitrogen with mulch, in the hope that the depressing effects on younger plants will be corrected and that more clear-cut results will be obtained. No increases in yield have been obtained with farmyard manure applied directly to the pyrethrum crop; in fact, there are indications that flower production may be depressed. The possibility that farmyard manure may benefit pyrethrum when it is applied to other crops in the rotation is now being tested in a large-scale rotation experiment. No statistical results are available for compost applied by itself, but ten tons of compost plus 60 lb. triple supers per acre given over a period of three years increased the yield of pyrethrum flowers considerably in the second and third seasons. The total increase over the control plots was 500 lb. dry flowers per acre, which makes it appear likely that even this heavy dressing would be economical. As regards green manures, significantly greater yields were obtained by planting and digging in of sunflowers and lupins over a control treatment which consisted of a wheat crop. In general, nitrogenous fertilizers seem to have had no beneficial effect, and in several trials applications of sulphate of ammonia delayed flowering or decreased the final yield significantly. Applications of muriate of potash have not given any definite effect. It was thought at one time that lack of potash might be connected with the incidence of Ramularia bud disease, but no conclusions on this point can yet be drawn. There were signs that 50 lb. per acre of muriate of potash slightly increased the pyrethrin content, but this was not confirmed in the following season. The effect of phosphate applied in the planting holes has usually been to produce a short-lived increase in flower production during the first season only. Phosphate applied as a top dressing or drilled in between rows of established plants has not shown any effect. On the other hand, pyrethrum in the Southern Highlands of Tanganyika has responded to superphosphates placed at the base of the ridge, and it is possible that the trials in Kenya were not carried out on soils which respond markedly to phosphate applications with other crops. Another significant point is that most of the trials in Kenya were carried out with mixtures of Uganda rock and triple supers, whereas one trial, on a soil of known phosphate

deficiency, where 150 lb. per acre double supers was applied, a response was obtained which continued into the second season and gave a total gain over the control of 150 lb. dry flowers per acre, One trial in which the phosphate was mainly supplied as Uganda rock gave increased yields over the first two seasons. Obviously much more work on the response to phosphate of pyrethrum is required before conclusions can be reached.

Pereira, H. C. (1953). Effects of fertilizers and manures on Kenya Coffee. East African Agricultural and Forestry Journal 1953

The wide variation in coffee plantation practice and opinion is explained by the complexity of factors which mask the results of simple "trial and error" observations on coffee trees. The Kenya coffee industry has in the past spent very large sums both on phosphatic fertilizers and on manure from native cattle bomas, while until very recently nitrogen dressings have received very little attention. Results for five years of a 108-plot factorial field trial at the Coffee Research Station, Ruiru, are summarized. No response in yield or quality, and no beneficial subsidiary effects such as earliness of ripening or restriction in die-back have been obtained from five annual dressings of soda phosphate at 2 cwt. per acre (45 lb. P_2O_5 per acre) or cattle manure at either 31/2 or 7 tons per acre. Where the treatments occurred together, the phosphates were incorporated in the manure in order to reduce the possibilities of fixation by the red lateritic clay soil. Evidence that the coffee did in fact obtain extra phosphates from the treatments was obtained from results of foliage analysis. Sulphate of ammonia had no effect at 1 cwt. per acre but significantly increased yields in two years out of five when applied at 2 cwt. per acre. Over five years this gave a significant yield increased of 7 percent, a result which showed a moderate economic profit. This trial was capable of detecting a 6 percent yield difference at the 5 percent level of significance for five-year total yields so that the evidence of lack of response was well established. This confirmed a considerable amount of evidence from smaller and earlier Kenya trial, in a variety of soils and climates, the results of which had not previously been reviewed and presented. Additional evidence of lack of response by mature coffee trees to boma manure is supplied by an 81-plot factorial cultivation trial in which plots were split for the standard annual dressing of one 4-gallon tin per tree (3 to 4 tons per acre) which remains the practice in many large estates. Over five years this trial has been capable of establishing a 3 percent difference in yield, but no significant response has been obtained. A smaller manurial trial is described in which larger annual dressings are tested. Four cwt. per acre of double superphosphates and 4 tins per tree (14 t/acre) of cattle manure are combined factorially. The heavy nitrogen applications have given a yield response of 27% over the first three years, which has been both statistically and economically significant. The very great effect of rainfall on yields in the main coffee-producing areas of Kenya east of the Rift is illustrated graphically; a 100% increase in annual total rainfall (which fluctuated during the trials between 24 and 56 in.) more than doubled the crop. This sensitivity of yields to water supply explains the highly successful effects of grass mulching. Organic matter applied as grass mulch has been shown by field trials to increase yields whereas organic manure dug in as cattle dung has failed to do so. Recent soil moisture studies have shown that mulch should be applied before instead of after the wet seasons, since its quantitative effect on soil moisture was far greater in assisting the penetration of rainfall than in impeding its subsequent evaporation. When applied before the rains an all-row mulch has raised a low yield in a dry year by 100%, and a good yield in a wet year by 75%. The phosphate contents of grass mulches applied during these trials are shown to be greatly in excess of the loss of phosphates in the coffee crop. The quantities of nutrients removed from the soils on which mulching grasses are grown are correspondingly high, and it is at this point in the coffee plantation system that fertilizers should be added. The techniques of fertilizers supply to mulch grass areas are still unknown, and field trials, recently begun, have not yet given consistent results. The practice of applying the available cattle manure to the grass instead of to the coffee has been adopted at the Rukera Demonstration Farm at Ruiru.

Pereira, H. C. (1953). Effects of fertilisers and manures on Kenya Coffee. *East Africa Agriculture and forestry journal*

Coffee, in common with other tropical tree crops, requires considerable staff and equipment to conduct the large scale, statistically-efficient field experiments which are required to overcome its inherent variability of yield. Opinions and explanations among planters are unusually conflicting for this crop, in which simple "trial and error" observations are most unreliable. The apparent responses are complicated by the interactions of pruning policies of seasonal over cropping and biennial bearing, of damage by posts and of the hazards of factory preparation. Prior to the acquisition by the government of the Jacaranda Coffee estate at Ruiru in 1945 facilities and field staff had not been available in Kenya for field studies of Coffee on an adequate scale. Fertilizer practise was therefore based only on the results of soil analyses. Very numerous analyses of coffee soils, mainly drawn from the near surface had indicated potash to be in good supply throughout the coffee areas while phosphates, soluble in water or in dilute acids, were at very low levels. Phosphatic fertilisers were therefore generally advised and widely used, together with cattle manure, as routine plantation dressings. Several small unreplicated sets of observation plots, conducted by private planters with the assistance of the Department of Agriculture, had given no effective results, and had, in general, disappointed the expectation of substantial yield increases from cattle manure and from phosphatic fertilisers. Two small trials of valid design at Thika (Unshaded coffee; volcanic soil; 35" annual rainfall

and at Kitale (Shade trees; Basement Complex soil; 46" annual rainfall) respectively, had shown no total response, in six years, to annual dressings of cattle manure at 7 tons/acre, to bone meal at 400 lbs/acre or to Seychelles Guano at 200 lbs/acre. The only field applications showing promising results were copper spraying and grass mulching. Plot size and replication for more elaborate trials were decided after analysis of individual tree records available from Departmental seed selection work. In order to establish with confidence any yield responses of economic importance, four balanced replications of a partially confounded 3×3×3 design were laid down at the new Coffee Research station, Ruiru. This design has proved fully effective, the five year total yields reported below, giving a significant difference, at P_20_5 of only 6% of the mean. The trial was sited on level ground on a broad ridge typical of Kenya main coffee-producing areas. The trees were of genetically heterogenous"French Misiion" type some 30 years old. They had all been stumped two years before the trial began, in order to secure uniformity. The soil profile showed a normal top soil, in fair structural condition, with no severe signs of erosion losses. Rayner (1945) excavated root systems of sample trees and found them to reach depths of from 12 to 14 feet.

R.V.Holme, M.A; E.G.P.Sherwood, M.A. (1953). Crop responses to fertilizers and manures: A bridged report of highland fertilizer scheme covering wheat & maize only. Conference on Crop responses to fertilizers and manures. February 2nd and 3rd 1953; Department of Agriculture, Muguga, Kenya; volume 19 PP 19-57

Studies by the Kenya Department of Agriculture in the fertilising of annual crops fall conveniently for narrative purposed into 5 main stages. The first stage was when the pattern of extensive shifting monoculture which was the pattern of early development of European arable farming became clear. At that time there had been some realisation that phosphates were of peculiar importance and that the years during which cultivation is possible might be extended by the use of fertilizers. A consequence of this realisation was the development of a demand for appropriate investigation work; this demand was met by including fertiliser studies in the field of activity of the Chemical Department when it was formed late in 1924. The first trials were initiated in 1925, 2 being laid out at S.A.L. and 2 near Nakuru. At the S.A.L the major trial set out to be comprehensive and long term, being aimed at obtaining fundamental data on the fertilising of crops. This particular trial appears to have met a series of vicissitudes until eventually a rainstorm of 71/2 during the night of 7th May, 1928, caused so much damage that it was abandoned without any results of importance having been obtained. A minor trial in 1925 dealing with forms of phosphate failed thorough drought. When the trial was repeated in a slightly modified form in 1926, excessive rain during the growing season led to difficult harvesting conditions and inconclusive results. In 1928, however, a 4x4 Latin square trial involving comparison of an unfertilised control with 100,200 and 300lbs. Sychelles Phosphate per acre was carried successfully through to completion using Kenya Governor wheat as test crop.

Jama B., Palm C. A., Buresh R., Niang A., Gachengo C., Nziguheba G., Amadolo B. *Tithonia diversifolia* as *Green Manure for Soil Fertility Improvement* in Western Kenya. *Agrofestry Systems, Kluwer Academic Publishers* 49:201-221

Tithonia diversifolia, a shrub in the family *Asteraceae*, is widely distributed along farm boundaries in humid and sub humid tropics of Africa. Green biomas of Tithonia has been recognized as an effective source of nutrients for lowland rice (*Orza sativa*) in Asia and more recently for maize (*Zea mays*) and vegetables in eastern and southern Africa. This paper reviews the potential of Tithonia green biomass the potential of Tithonia green biomass for soil fertility improved based on recent research in western Kenya. Green leaf biomass of Tithonia is highly in nutrients, averaging about 3.5%N, 0.37%P and 4.1%K on dry matter basis. Boundary hedges of sole Tithonia can produce about 1kg biomass (tender stems +l eaves)/m/yr on dry weight basis. Tithonia biomass decomposes rapidly after application to soil, and incorporated biomass can be effective source of N, P and K for crops. In some cases, maize yields were even higher with incorporation of Tithonia biomass than with commercial mineral fertilizer at equivalent rates of N, P and K. In addition to providing nutrients, Tithonia incorporated at 5 t dry matter/ha can reduce P sorption and increase soil microbial biomass. Because of high labour requirements for cutting and carrying high-value crops such as vegetables than with relatively low-valued maize, the transfer of Tithonia biomass to fields constitutes the redistribution of nutrients within the land scape rather than a net input of nutrients. External inputs of nutrients would eventually be required to sustain production of Tithonia when biomass is continually cut and transferred to agricultural land.

Beneficial Microbes

Overview

A number of microbes are crucial for various soil functions such as plant nutrition, decomposition, mineralization, nitrification and denitrification. Legumes co-exist with rhyzobia bacteria that are crucial for nitrogen fixation. The rhizobium infects plant roots, creating nodules where nitrogen is fixed providing the plant with most of the nitrogen it needs for growth and development. Well nodulated plants with an efficient symbiosis may fix up to hundreds of kilograms of nitrogen per hectare per year. Some of this nitrogen is released to the soil as exudates from the roots. Most of the fixed nitrogen remains in the plant tissue and is released during decomposition to the benefit of the following or the associated crop. Dinitrification on the other hand is a process where useful nitrogen is converted to atmospheric nitrogen that is not useful for plant growth. Apart from this, the association of plants with mycorhizae enables the plants to scavage and access more nutrients and water. Mycorhizae are more effective than plant roots in accumulating water and can store excess nutrients releasing them to plants when needed. This section presents the work that has been done in Kenya concerning the role of beneficial microbe in crop production.

Kifuko-Koech M. N. (2013). Nitrogen dynamics, biological N_2 fixation and nitrogen concentration in desmodium-maize intercropping system. PhD thesis, Chapter four. University of Eldoret, Kenya

Low soil fertility in western Kenya region is a major limitation to maize production. Desmodium in PPT is capable of addressing this constraint. Field trials were conducted in Nyabeda and Matayo sites located in Busia and Siaya counties in western Kenya region respectively during LR 2010 and SR2010 to test the hypothesis that, changes in maize biomass, soil mineral nitrogen, soil carbon, ^{13}C isotope values ($\alpha^{13}C$) of maize shoot and maize nitrogen concentration over time in maize-desmodium intercropping system with desmodium cut at 18WAP is affected by desmodium spp and sampling time. In addition, effect of desmodium spp and cutting regime on BNF was assessed for three consecutive seasons (SR2009, LR2010 and SR 2010). Maize was intercropped with *D. uncinatum* or *D. inortum* and treatments with sole maize (with or without urea) were included for comparison. All treatments received basal P and N. The first two desmodium cutting events were fixed while the third cutting was varied and conducted at 9, 12, or 18 weeks after planting maize. N_2-fixation was estimated using the ^{15}N natural abundance method. Results showed that mineral N was higher in desmodium intercropping system with *D. intortum* relative to *D. uncinatum*. Nitrogen leaching in desmodium intercropping with *D. intortum* was lower than in sole maize system as evidenced by the low total mineral nitrogen in *D. intortum* intercrop beyond 60 cm soil depth. *D intortum* was superior to *D. uncinatum* producing the highest biomass, fixed N, soil carbon and total mineral N for two consecutive seasons $\alpha^{13}C$ contents in maize shoot did not differ significantly between desmodium intercropping and sole maize system, an indication of comparable environmental effect in both systems. The proportion of N_2-fixed in both sites ranged between 49-71, 50-63 and 44-64% during SR 2009, LR 2010 and SR 2010 respectively irrespective of desmodium species and cutting regime.

Kifuko-Koech M. N. (2013). The effect of desmodium species and cutting regime on the agronomic and economic performance of desmodium-maize intercropping system in western Kenya. PhD thesis, Chapter five. University of Eldoret, Kenya

Field trials were conducted in two locations in western Kenya during 4 consecutive seasons to test the hypothesis that maize yield, the degree of Striga suppression and economic returns of intercropping maize with desmodium are affected by (i) the related biomass production by different desmodium species and (ii) the cutting regime of the desmodium. Maize was intercropped with sole maize (with and without urea) were included for comparison. Starting from the second season (SR 2009, the first two desmodium cutting events were fixed at land preparation and 4 weeks later, following a recommended practice, while the third cutting was varied and conducted at 9, 12 or 18 weeks after planting maize. To eliminate phosphorus (P) and potassium (K) deficiency, all treatments received basal P and K fertilisers at a rate of 60 Kg P/ha and 60 Kg K/ha respectively. Maize yield in desmodium intercropping system was only higher in sole maize without urea from the third season. This implies that when P and K are not limit, inclusion of desmodium spp into maize cropping system would provide a substitute for inorganic N fertilizers to enhance crop growth and yield after two to three seasons when desmodium is well established. Cumulative maize grain yield over the four seasons with the *D. intortum* and *D. uncinatum* intercrops were 6.3 and 7.0 and 10.9 and 11.6 t/ha in Busia and Siaya sites respectively. Average net benefits from desmodium intercropping over the four seasons were increased by 1290 and 918 $/ha compared to the sole maize control in Busia and Siaya, respectively. Varying the time of the third desmodium cutting had little effect on desmodium biomass yield or maize grain in Busia, while in Siaya, *D. intortum* biomass yield were highest when cut at 12 weeks after planting. In the Desmodium intercropping systems, Striga counts were reduced by 95% in Busia and by 65-90% in Siaya with higher reductions recorded when desmodium was cut at 18 weeks after planting. In conclusion, the use of PPT provides robust and high economic benefits to smallholder farmers in western Kenya. Based on the results generated, the use of *D. uncinatum* with the third cutting at 18 weeks after planting is recommended, but can be modified according to the need for fodder without much effect on maize yield or revenue.

Majengo C. O. (2013) Effectiveness of promising commercial bio-fertilizers on soybean production in Bungoma County Western Kenya. Msc. Thesis, Moi University, Eldoret, Kenya.

The study was conducted to compare the performance of promising commercial bio-fertilizers that have been evaluated under the green-house conditions at TSBF-CIAT, in farmers' conditions through the use of promiscuous soybean variety (SB19). The trials were laid out on small scale farms in Bungoma County, situated in Western Kenya. The experiment was established in March 2010 during the long rains (LR) and repeated during the short rains (SR) of 2010; laid out in multi-locational one farmer field one replicate design. Treatments were not replicated within each field. During LR 2010, 50 farms were researched on and 100 farms in the second season (SR 2010). A promiscuous medium-maturity soybean variety TGx1740-2E (SB 19) was inoculated with Legumefix (Rhizobia) or/and Rhizatech (mycorrhizae) inoculants. The mycorrhizae inoculums was applied to the soil in the seed furrows at the recommended rate of 30 Kg/ha. Nodulation was examined at mid-podding (50% podding) by carefully uprooting all plants with their entire root system from a $1m^2$ section in each plot. Nodules were counted and weighed; the root and shoot parts separated and fresh and dry weights assessed. Analysis of variance was

conducted to determine the effects of (and interactions between) the two inoculants on plant parameters using a mixed linear model (MIXED procedure, SAS). Rhizobial inoculation resulted in significantly ($p<0.01$) higher module biomass (0.93 g/plant) compared to the control (0.27 g/plant) across many farms. Mycorrhizal inoculation had no significant effect on nodulation when applied solely (0.38 g/plant), but co-inoculation of Rhizobia and mycorrhizae increased nodule biomass further by 0.09 g plant-1. There was a significant difference ($p<0.01$) in terms of biomass yield between treatments. Rhizobial inoculated plants had the highest biomass production of 2086 Kg/ha. Rhizobial inoculation resulted in higher grain yields of 1116 Kg/ha above the control. Soybean inoculation increased both nitrogen and phosphorus uptake in the biomass. Rhizobial inoculation had the highest soybean N uptake of 48.6 N Kg/ha which was significantly different ($p<0.05$) from control and sole application of mycorrhizae. Statistical analysis showed that soil factors (pH, P, C, N) significantly ($p<0.001$) affected soybean grain yields during both seasons. It is concluded from this study that rhizobial inoculants have a high potential as commercial bio-fertilizers and can substitute the need for mineral N fertilizer in the legume farming systems. However, there is need to target these inputs to the most responsive fields. Further studies are needed to elucidate the conditions under which synergism between both inoculants may occur, with specific focus towards soil P availability and management of P inputs.

Omondi J. O. (2013). Tillage and variety effects on soil moisture content, biological nitrogen fixation and soybean (*Glycine max* L.Merril) yield in western Kenya. Msc. Thesis, Egerton University, Kenya

A two season study was conducted to evaluate the impact of tillage methods on soil moisture content of soybean varieties grown in four sites representing four different agro-ecological zones of western Kenya. The treatments were: zero tillage methods (no till and till-use of hand hoes of 15 cm width and 20 cm depths) and soybean varieties (Nyala, SB19 and SB20) in a randomized complete block design arranged in split-plot. Soil moisture content was determined at flowering and pod filling stages of 0-10, 10-20 and 20-30 cm using gravimetric method then converted to volumetric. Soil moisture content at Bungoma, Ugunja and Alupe were not significantly different between tillage methods. However at Rarieda no till had higher soil moisture content than till. Among the soybean varieties soil moisture content was high in plots with SB20 and SB19. Bungoma had the highest soil moisture content most probably due to high rainfall amounts and Rarieda had the lowest. Farmers should practise no till in areas that receive low and unpredictable rainfall and grow soil cover crops to increase soil moisture content.

Kundu C. A. (2012). Effect of *arbuscular* mycorrhizal fungi and phosphate solubilising bacterial inoculations on growth and phosphorus uptake by orange fleshed potatoes (*Ipomoea batatas* (L) Lam). Msc. Thesis, University of Nairobi, Kenya

Microorganisms and their interactions in the soil play a critical role in nutrient transformation and cycling and in sustaining soil productivity. *Arbuscular mycorrhizal* fungi (AMF) play a major role in nutrient cycling. Phosphate solubilising bacteria (PSB) on the other hand play a role in phosphorus nutrition by enhancing its availability to plants through release from inorganic and organic soil phosphorus pools by solubilisation and mineralization. Activity and composition of microorganisms in soil are influenced by management practises such as the choice of crop species and fertilization. Application of AMF in sweet potato production can contribute to increased growth, increased yields and improved soil nutrition with a reduction in chemical fertilizer input in a more sustainable agriculture. In this study, pot and field experiments were conducted after assessing the dependency of sweet potatoes to AMF to determine the effects of dual AMF and phosphate solubilising Bacteria (PSB) inoculants with varying rates of chemical phosphorus fertilizer on growth, yield, and soil in sweet potato production. A pot experiment was conducted under green house conditions to evaluate the effects of dual inoculants on Orange Fleshed Sweet Potato (OFSP) growth, yield and nutrition using varieties SPK004 and Kabode as the test crops. The commercial inocular were separate single species of Glomus intraradices in granular formulation containing spores, root fragments and other propagules. The Indigenous inoculum was a single strain of *Glomus aggregatum*. Local PSB isolates were *Azotobacter chrooccocum* and Pseudomonas 20 kg P/ha and 40 kg P/ha. Varieties responded differently to the different fertilizer rates and AMF inoculation. PSB inoculation did not show and significant effect on the parameters assessed ($P<0.05$). SPK004 had better growth and vine yield compared to Kabode and dry matter yield increased with the application of fertilizer at a rate of 40 kg P/ha (2.1 t/ha and 0.74 t/ha) for shoot and root dry matter yield respectively. In terms of AMF root colonisation, the mixed inoculum recorded a higher frequency of 30.7% and intensity of 17.4% that was in the line with a highest spore count of 5.4. The single species inoculums gave had a spore recovery of 5.0 and 4.5 spores for Gl. intraradices and Gl. *mosseae* respectively. Results of the field experiment showed that the varieties differed significantly in growth ($P<0.05$) with SPK004 giving a vine yield of 29.2 t/ha compared to Kabode with 19.4 t/ha. However, Kabode had better root yield (14.2 t/ha) and SPK004 (12.8 t/ha). In terms of AMF colonization, the mixed inoculum gave a 52% frequency of colonization that resulted from a higher spore count of 10.9 spores. With the single species, inoculants, Gl. *mosseae* (42 %). Increased chemical P fertilization inhibited AMF colonization and the benefits associated with it. Mycorrhixal inoculation significantly ($P<0.05$) influenced root colonisation and AMF spore

counts recovered in the soil. The highest colonization of 72.8% was in AM inoculated plants in combination with TSP at a rate of 20 kg P/ha. The highest spore number of 14.8 was observed in mixed AM inoculated plant with 20 kg P/ha fertilization. Gl. intraradices was the best performing single species in terms of growth promotion and root colonization followed by Gl. *mosseae*.

Mburu M. W. (2012). Performance of Soybeans inoculated with a range of commercial microbial products under different soils of Bungoma County, Western Kenya. Msc. Thesis, Moi University, Eldoret, Kenya

Nitrogen (N) and Phosphorus (P) are the major nutrients limiting crop production in sub-Saharan Africa contributing to food insecurity. Sustainable farming technology that replenishes these nutrients in soils is a major capital investment that cannot be afforded by most poor small-scale farmers, particularly in Bungoma County, western Kenya. Technology breakthroughs in soil fertility management have proven that some commercial inoculants (e.g. rhizobial and P bio inoculants) enhance the productivity of specific legumes such as soybean. This particularly important in developing countries where commercial fertilizers are costly and locally unavailable to small-scale farmers. On-farm trials were conducted during 2010 short rains (SR) and 2011 long rains (LR) to evaluate the effects of commercial inoculants on soybean production in Bungoma. Soybean seeds (SB 19) were inoculated with different rhizobia inoculants in plots 4.5 m × 5.0 m. All rhizobial treatments received 26 kg P/ha with no nitrogenous fertilizers. Some treatments also received 0, 26 kg P/ha, 60 kg N/ha or their combinations for comparison. Co-inoculation of most promising rhizobial inoculants (Legumefix) and one of the AM/PSMs inoculants was also evaluated; no inorganic fertilizers were applied on co-inoculated treatments. After identifying the most superior rhizobial and the P bio inoculants from field data at the end of the two growing seasons, the two inoculants were retested both sole and combined under greenhouse conditions to assess their effectiveness in a wide range of soil pH and other soil characteristics. During SR 2010 Legumefix rhizobium inoculants gave significantly ($p \leq 0.05$) higher nodule fresh weights per plant (1.4g/plant) and grain yields of 0.53 t/ha compared to the control which gave 0.29 g/plant and 0.32 t/ha during nodulation and at harvest, respectively. During the LR 2011 Legumefix, Histick and Rhizoliq-Top 2 inoculants resulted to 182%, 259% and 255% increase in nodule weight per plant respectively, above the absolute control. The higher nodulation resulted to significant higher ($p \leq 0.05$) grain yields and N and P uptake than control. In both seasons combined inoculation of legumefix inoculants and AM/PSM inoculants did not differ significantly between the treatment ($p \leq 0.05$), both the fresh weight nodules and grain yield at harvest in both seasons. However, all the co-inoculated treatments resulted to a significantly ($p \leq 0.05$), higher nodulation, grain yield and nutrient uptake (N and P) than the control (sole legumefix). Among the combined treatments, Rhizatech+Legumefix gave the highest nodules per plant of 1.17 g/plant and grain yield of 0.65 t/ha in SR 2010, as compared to the control which gave nodule weight of 0.91 g/plant and yield of 0.46 t/ha yield. Greenhouse results showed that increase in soil pH had a significant ($p \leq 0.05$) increase in plant biomass yield, nodulation and nutrient uptake (N and P). Overall, the results from the study showed that the use of rhizobial inoculants contributed significantly to soybean production in western Kenya; more positive effect was realised when rhizobial inoculants were combined with AM (Rhizatech) inoculants. Therefore, use of the identified agricultural commercial inoculants in this study would reduce the need for N and P mineral fertilizers.

Thuita M. N. (2012). Competitiveness and persistence of commercial Rhizobium Inoculants applied to promiscuously nodulating soybean in central and western Kenya. PhD thesis, Moi University, Chepkoilel Campus, Kenya

Nitrogen (N) is a major limiting factor in plant growth and development in sub-Saharan Africa and one of the major constraints among others to soybean production. Soybean is a specific nodulator and is only capable of establishing a symbiotic partnership and the process of biological N_2 fixation (BNF) with mainly strains of *Bradyrhizobium japonicum* and *B. elkanii*, and can fix up to 80% of its N needs. The international Institute for Tropical Agriculture (IITA) bred promiscuous soybean varieties designated TGx varieties capable of nodulating with indigenous rhizobia. Low effectiveness of indigenous strains has widely been reported and nitrogen fixation and grain yields have remained low. Commercial inoculants and strains were obtained and tested through screening in the greenhouse and field. Selected inoculants were then subjected to further testing in 38 farms across Bungoma and Meru south districts. The objectives were(1) to identify inoculants and strains with potential for use as commercial inoculants for promiscuous soybean(2) test the competitiveness of commercial inoculants in soils with low and high levels of indigenous strains capable of nodulating soybean, (3) test the persistence and adaptability of the commercial strains in our Kenyan soils and (4) understand the differences and similarities in nodulation, nitrogen fixation and biomass yield exhibited by major soybean inoculants strain. Nyala (non-promiscuous), TGx1740-2F and TGx1835-10E (promiscuous) were the soybean varieties used. There was significant increase in levels of nodulation, nodule occupancy, biomass yield, grain yield and biological nitrogen fixation both at the greenhouse and field trials. The Siaya site which was previously used as a soybean multiplication site showed the commercial inoculants with 5% nodule occupancy. An indigenous strain identified as *Bradyrhizobium elkanii* (after isolation) occupying most nodules. At the Meru south site with no soybean growing history, nodule occupancy was dependent on the inoculants with Legumefix and

1495MAR showing 100% occupancy. In the 2nd season where no inoculation was done, Legumefix showed better persistence with 75% nodule occupancy while 1495MAR had 50% occupancy. Rainfall was an important factor that influenced both nodulation and grain yields especially during 1st season (long rains 2009). In the multi-site trials Legumefix, Histick and Rizoliq Top showed high consistency in nodulation and nodule occupancy in the farms tested. This showed that commercial strains can be used to inoculate promiscuous soybean varieties. Molecular tests on major commercial bradyrhizobia strains showed they fall into two major groups based on the 16S rRNA gene through polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) and phylogenetic tree development. However by use of monoclonal antibodies more differences exists between the strains which was also shown by their differences in BNF on both Nyala and TGx1740-2F. It was concluded that commercial inoculants would be beneficial to use as inoculants on soybean and their persistence in the soil may depend on the variety used. Many of the commercial strains used were similar and that the cause of differences in BNF efficiency may need to be investigated.

Wanjau F. W. (2012). The influence of charcoal application on soil fauna and fertility in central and western Kenya. Msc. Thesis, Moi University, Kenya

The perennial constraints of food shortages and lack of a balance diet due to poverty significantly threaten human survival and overall development in sub-Saharan Africa. Within the east African region and especially Kenya, low and unreliable rainfall distribution and infertile soils largely account for low and unsustainable agricultural productivity. This is reflected in low seasonal crop yields at smallholder level, where the maize (staple) yields are frequently below 1 t/ha/ season, a result of lack of adequate nutrients and related inputs. The low yields can be compared against the potential 5 t/ha/season when using inputs in western Kenya. Research done in other parts of the world shows that charcoal addition to soil sustainably increases soil fertility and that charcoal amended soils maintain high inherent fertility for a long time. The aim of this study was to determine the ability of charcoal from acacia tree and an inorganic fertilizer (mavuno) to increase microbial populations and enhance other soil characteristics and hence improving soil fertility that would result in increased yields of maize. The study was carried out in four farms in Embu and Siaya on an on-going research project on carbon sequestration. The field experiment was arranged in a randomized complete block design with 6 treatments in 3 main plots (control, crop without fertilizer and crop with mavuno (10-26-10) fertilizer 50-60 kg N/ha in split applications of 30+20 or 30) kg N/ha each and 2 sub plots with and without charcoal additions. The results of the study showed that: 1) application of charcoal reduced the nitrogen mineralisation potential while it increased the microbial activity; 2) there was a significant increase in extractable phosphorus, total nitrogen, soil ph and carbon with application of charcoal. Further, charcoal was shown to reduce the soil bulk density, 3) in addition, charcoal application to soil increased microbial and macro fauna populations and maize yields. The results generated can be used by agricultural extension officers to advice farmers. However, further research to ascertain the long term effects of charcoal application on fertility of tropical soils is suggested.

Okoth S. A., Otadho J. A., Ochanda J. O. (2011). Improved seedling emergence and growth of maize and beans by Trichoderma *harziunum*. Tropical and subtropical Agroecosystem *Journal*, 13:65-71

An indigenous strain of Trichoderma spp. was tested for its ability to promote seed germination and growth of bean and maize seedlings grown in the field at Embu District Kenya. The trial was carried out for three seasons with the following treatments two types of fertilizers cow manure and trichoderma seed coat. Seeds were counted 14 days after emergence from soil and a sample gently uprooted using a spade. Shoot height, root length, stems and root diameter measurements were taken. Trichorderma inoculation significantly increased rate of maize seed germination but had no effect on germination but had effect on emergence of been seedling. Maize seed coated with trichoerma inoculum and planted on soils without fertilizer addition recorded the highest germination rate of 82.7%. Combination of the inoculum and planted in soils treated with manure (82.2%). Combination of inoculums and fertilizer performed better at improving maize seed germination compared with fertilizer applied singly. This was the case for shoot and root growth. Seeds planted with the inoculum and planted in soil amended with triple superphosphate and calcium Ammonium Nitrate recorded the greatest shoot and growth in both maize and beans. Increased growth of shoot and root caused by trichoderma implied that there was beneficial effect of inoculation on plant growth and development since root collar and stem diameter were a measure of survivability if seedlings.

Mbugua G.W., Wachiuri S. M., Karoga J., Kimamira J. (2010). Effects of Commercial Rhizobium strain inoculants and Triple superphosphate fertilizer on yield of new dry bean lines. *In: Ouda et al (Eds) Proceedings of the 12th KARI Bienniaal Scientific Conference* . KARI Headquarters, Kaptagat Road, Nairobi, Kenya 8 – 12 November, 2010. PP 370-376

Annual demand for dry beans of 749,000 metric tons in Kenya is far above the annual production of 380,000 metric tons. Beans yield can be increased through the use of improved bean varieties, phosphate fertilizer and Rhizobium inoculants. Small-scale farmers who are the major dry bean producers rarely apply fertilizers in bean

production; hence the crop is largely dependent on nitrogenous fertilizers. A trial was conducted in 2007 during the long and short rains at KARI- Thika on farmers' fields in Kirinyaga and Maragua districts in central Kenya to investigate the effect of three commercial Rhizobium strain inoculants and triple superphosphate (TSP) fertilizer on yield of new dry bean lines. TSP fertilizer consistently increased bean yield during the long and short rains seasons at the research site (Thika) and on farmers' fields in Kirinyaga and Maragwa Districts. Compared to fertilizer effects on yield, inoculation effects were not as consistent and of much lower magnitude. Most of the bean lines had their highest yield where both fertilizer and Rhizobium strain 2667 followed by mixed strain treatments tended to outperform the other inoculation treatments. Four of the bean lines gave consistently high yields under the same inoculation treatment in different seasons and sites.

Mugendi E., Gitonga N., Cheruiyot R. and Maingi J. (2010). Biological Nitrogen Fixxation by promiscuous Soybean (Glycine max L. Merril) in the Central highlands of Kenya: Response to inorganic fertilizer soil amendments. World Journal of Agricultural Sciences 6 (4): 381-387.

Biological nitrogen fixation (BNF) by promiscuous soybean cultivars offers a potential for minimizing the investiment made by resource-limited farmers in central highlands of Kenya. nitrogen fixation in this grain legume is influenced by factors such as availability of meneral elements and prevalent weather conditions. Nitrogen (N), Phosphorus (P), Potassium (K) and Sulphur (K) are intimately involved in plant metabolism, growth and N2 fixation. In this study, field, laboratory and greenhouse experiements were carried out to investigate the effects of PKS fertilizer application on nodulation and nitrogen fixation of two promiscuous soybean varieties. Early maturing TGx 1740-2F (SB19) and late maturing TGx 1448-2E (SB20) were the main factors while fertilizer inputs were the sub-factors. Nodulation status, plant biomassproduction and yield components were used for data generation. The transformed data was subjected to analysis of variance –ANOVA using PROC GLM package to determine the main effects of the treatments and their interactions. Specific pair-wise comparisons of treatment levels were done using the least significant differences (LSD) test at P=0.05 and correlations using 'PROC CORR'. In all sites the main effects of carbon level in the field, soybean varieties and treatments on nodulation, plant biomass production and yield components were significantly different at ($P \leq 0.05$). The effect due to the interaction of thesee factors were not significant. Laboratory and greenhouse results indicated that the isolates obtained were slow growing *Brandyrhizobium elkanii, Brandyrhizobium japonicum* and the fast growing *Sinorhizobium fredii*.

Muthamia J.G.N., Vanderlyden J., Ramaekers L., Kimani P., Mbugua G., Michen A. (2010) Harnessing microbial synergies for bush bean production under low nitrogen and phosphorus on eastern Kenya. . *In: Ouda et al (Eds) Proceedings of the 12th KARI Bienniaal Scientific Conference*. KARI Headquarters, Kaptagat Road, Nairobi, Kenya 8 – 12 November, 2010. Pp. 227-236

A field experiment was set up to evaluate the contributions of Rhizobium CIAT 899 and *Azosprillum brasilense* sp 245 under low and high phosphorus in Kaguru Meru and KARI- Embu sites. The bean varieties used were Embean 14, Nguaku nguaku, and non-nodulating BAT477. The bacterial inoculants used were; Rhizobium CIAT 899, *Azosprillum brasilense* sp 245, co inoculation of rhizobium and azospirillum and non inoculated seed. The non-nodulating BAR477 was not inoculated. Triple superphosphate was applied at the rate of 200 Kg/ha to variety x inoculants and no phosphorus to another variety x inoculants all coming up to eighteen treatments. The experiment was a completely randomized block design with a factorial treatment arrangement and was replicated 4 times. The data taken was chlorophyll measurements, nodule counts, nodule dry weight, shoot fresh and dry weight at flowering and root fresh and dry weight, number of pods per plant, number of seeds per plants, total biomass at harvest, and grain weight. Third chlorophyll measurements revealed the differences in treatments and phosphate applied treatments showing higher measurements. Nodulation seemed to be influenced by phosphorus. Asospirillum also seemed to induce nodulation by the local rhizobia. Kaguru site recorded higher nodulation than Embu site. The number of pods per plant depended on the bean variety and soil fertility. Embean 14 had significantly higher pod numbers than Nguaku nguaku. The application of phosphate resulted in significantly higher number of seeds. Biomass yield was found to be influenced many aspects. Embean 14 produced more biomass than Nguaku nguaku in both sides, while Kaguru site resulted in lower biomass production than Embu site. Phosphorus applied treatments resulted in significantly higher biomass production than in no phosphorus treatment. The experiment also showed that the inoculation of Embean 14 seed with rhizobia increased biomass production, Azospirillum inoculated on Nguaku nguaku improved biomass production significantly.

Mwangi P. W. (2010). Nitrogen fixation and nitrogen residual effects of butter bean, grass pea, chickpea, and common bean. PhD Thesis, Chapter five, University of Nairobi, Kenya

Butter Bean (variety (Ex-Kasuku) and grass pea (selection 1325) were identified as "promising" legumes for the cold semi-arid region of Laikipia district and comparable to the local checks (common bean (variety Katumani

3330) and chickpea (Variety Desi) in most performance attributes, intercrops of these legumes and maize were also demonstrated to have land use and monetary advantages over respective sole cropping. However, the nitrogen fixation potential and nitrogen residual effects of the legumes have not been established. A follow-up green house experiment was therefore conducted to determine the nitrogen fixation potential of the legumes relative to the local check. Collected data included: nodulation (number of nodules per plant, nodule dry matter and number of active nodules), dry matter and dry matter nitrogen yield, fixed nitrogen and soil mineral nitrogen. Butter bean and grass pea were comparable to common bean fixation potential and had significantly higher fixed N values that chickpea. Butter bean, grass pea and common bean significantly increased soil mineral nitrogen while chickpea had no influence on soil nitrogen. Butter bean and grass pea can therefore provide N to cropping systems in the cold semi-arid region through biological N fixation.

Thiuta M., Lesueur D., Herrman L. (2010). Evaluation and scaling up of new chemical and biological commercial products for improving and sustaining crop yields in selected agro-ecological zones in sub-Saharan Africa. *Proceedings of the 3rd Scientific Advisory Committee meeting 4-6 October, EAIR Assembly*, Addis Ababa. pp.1-15

The screening provided a chance to identify promising inoculants to be further tested in the farmers fields. The sites identified served the purpose of subjecting the inoculants to diverse but possible scenarios any new strain may encounter in various parts of farming communities. The major obstacle was the poor rain season experienced in most parts of the country which impacted negatively on nodulation, growth and grain production. Considering all the data collected and laboratory analyses, we can conclude the following: 1. The strains/commercial products produced elsewhere are able to nodulate both non promiscuous Nyala and the promiscuous TGx varieties and form effective nodules and nitrogen fixation, 2. When introduced to areas with high populations of native rhizobia capable of nodulating soybean infectivity will depend on the competitiveness of the individual strains contained in the product. It thus follows to say that before introduction of any product in an area it is advisable to check on the presence of native rhizobia and their competitiveness, 3. In an environment with little or no native rhizobia capable of nodulating soybean and form effective symbiosis, 4. Emphasis must be put on the need to ensure that apart from introducing soybean inoculation other important components are provided in adequate amounts for example phosphorous and 5.The experience with HiStick is also an important lesson, it contains the same strains as Vault IvI but differs in formulation. This implies that for the kind of farmers we have the formulation should be given due consideration. It is easier to teach the farmers to use single product but if you have to mix several components as is with vault may not be ideal handling also presents additional challenges. Finally with the results and lessons so far, we do have products that have shown high potential to impact positively the production of soybean in various agro-ecological zones and soil types represented in this study by the mandate areas. Once all data is processed then it can be said with certainty that certain products have tested and proven to work in these areas.

Kamau N. N. (2009). Effects of dual inoculation with mycorrhizae and rhizobium on growth performance of soybeans in acidic soils in Gatanga, Kenya. Msc. Thesis, Kenyatta University, Kenya.

Small land holdings and poverty in Central Kenya have made it difficult for farmers to adequately conserve and replenish soil nutrients in their farms. Soil erosion and leaching of nutrients leading to soil acidity have been the inevitable outcome. This study was designed to determine the effect of inoculating soybeans (*Glycine max*) with both mycorrhizae and rhizobium as a biological means of improving soil fertility in the acidic soils in Gatanga, Thika District. Field experiments were carried out in Gatanga and at Kenyatta University (on-station) in sterilized and non-sterilized soils collected from Gatanga. The field experiments were laid out in complete randomized design. Analysis of variance (ANOVA) was conducted on the data and means separated using LSD at 5% significance difference using Genstat for Windows Version 8.11. The growth parameters; height, root collar diameter, shoots and root dry weight all increased as a result of dual inoculation with mycorrhiza and rhizobium. Dual inoculation also led to increased nitrogen fixation by soybeans, evidence by increased nodulation, and grain yields. Dual inoculation with mycorrhiza and rhizobium did not have any significant effect ($p<0.05$) on germination of soybeans. Height of soybeans as a result of dual inoculation increased significantly over the control by 88% in the long rains while in the short rains the increment was not significant. In the on-station experiments, height increment over the control in sterilized and non-sterilized soil was not significant. Dual inoculation increased root collar diameter by 80% and 8.6% in the long and short rains respectively. Shoots dry weight in the on-farm long rains 2005 season increased by 140% as a result of dual inoculation while in the short rains season and the on-station experiments, the differences were not significant. Dual inoculation increased grain yields by 356% in the on-farm long rains 2005 season, while in the on-station experiments grain yield increased by 76% and 107% in the sterilized and non-sterilized soils respectively. Though nodulation was poor in all the experiments, the number of nodules increased significantly by 676% over the control in the long rains 2005 season. In the on-station experiments the control (S) had no nodules. The short rains crop performed poorer than the long rains crop as a result of insufficient rains. In conclusion, the biological organisms; mycorrhiza and rhizobium, could be utilized to increase productivity of the legume soybean, in acidic soils. However, technologies to avail the

microorganisms to the farmers need to be developed as the obligate nature of mycorrhizal fungi makes it difficult to culture and commercialize while the low shelf life of rhizobium at room temperature is a hindrance for its use by resource poor farmers.

Wagatwe S. W. (2009). Effect of N-fertilizer and farmyard manure application, rhizobium inoculation and irrigation on performance of snap bean (*Phaseolus vulgaris* L) in Central Kenya. Msc. Thesis, University of Nairobi

Improved management of soil fertility in low N soils is critical for increased land productivity and economic sustainability. Snap bean farmers in Kenya incur high costs on farm inputs, especially on chemical N fertilizers. Therefore, nutrient management practices that integrate the use of inorganic N fertilizer and organic manures are needed. A study was conducted at a farmer's field in Mwea, Central Kenya, to determine the effect of various combinations of farmyard manure and inorganic N fertilizer on growth and yield of snap bean. The study was carried out in two plantings (between April 2006 and July 2006 for the first planting and between September 2006 and December 2006 for the second planting) under furrow irrigation. The treatments tested were: four levels of inorganic N-fertilizer (0, 30, 60 and 90 kg N/ha) and four levels of farmyard manure (0, 4, 8 and 12 t/ha).The treatments were tested in a factorial experiment laid out in a randomized complete block design with three replications. A farmers practise consisting of 100 kg N/ha and 50 kg P_20_5/ha was included in each replications. The beans which were of variety Amy were planted in plots measuring 3 m by 3.5 m and furrows in between for irrigation. Furrow irrigation was done two times a week with 50 mm of water being applied each time. The data collected included: crop emergence, flowering and pot set percentages, plant heights, nodulation, shoot biomass, root biomass, pod yield and pod moisture content. The results showed that the application of 90 kg N/ha significantly had higher emergence rates. The interaction between the N-fertilizer and organic manure levels was significant with the highest emergence percentage being recorded in plots supplied with 60 kg N/ha and 8 t/ha Farmyard Manure (FYM). Higher fertilizer rates at 90 kg N/ha had higher pod set percentage. N-fertilizer had a significant effect on plant heights with 60 kg N/ha having the tallest plants. Farmyard manure significantly improved the root dry weights of snap bean. The farmers practise treatment (100 kg N/ha and 50 kg P_20_5/ha) had the highest shoot dry weight. N-fertilizer application had a significant effect on total pod yield meaning that the fertilizer is necessary for a higher snap bean pod yield. The interaction between N-fertilizer and manure affected total pod yield significantly with the plots treated with 60 kg N/ha and 4 t/ha FYM registering the highest total pod yield. In terms of marketable yield, the interaction between N-fertilizer and manure had a significant effect with the highest "extra fine" yield exhibited by the plots supplied with 30 kg N/ha and 8 t/ha FYM while for the "fine" grade of snap bean, application of 60 kg N/ha and 4 t/ha FYM had the highest yield. N-fertilizer had a significant effect on unmarketable yield, with more N-fertilizer resulting in more "reject" yield of snap ban. Overall, combining FYM and N-fertilizer performed better in terms of pod yield than the farmer practise treatment (100 kg N/ha and 50 kg P_20_5/ha). Higher rates of fertilizer at 90 kg N/ha had more yields but also produced more "reject" yield.

Karanja N.K, Mutua G.K., Kimenju J.W (2007) Evaluating the effect of Bacillus and Rhizobium. Bi-inoculants an nodulation and nematode control in *Phaseolus vulgaris* L. *In: Bationo et al (Eds) Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities.* ISBN: 13978-4020-5759-5 (HB). pp. 865-871

The study was undertaken to evaluate the effect of inoculating beans (*Phaseolus vulgaris* L.) with a bio-inoculants containing Bacillus spp. and Rhizobium spp. isolates on root damage by root-knot nematodes, nodulation and their interactions. Twenty Bacillus isolates from a previous experiment were selected based on their ability to reduce root-knot nematode populations and damage on beans. These isolates were screened to determine their compatibility with Rhizobium strains CIAT 899 and USDA 2674 in vitro. Seven Bacillus isolates were found to be compatible with the rhizobia strains. A greenhouse experiment to assess the effect of the dual inoculation of Bacillus and Rhizobium spp. on root damage by root-knot nematodes using sterile Leonard jar assembly revealed significant differences between the various treatment combinations. Damage by root-knot nematodes was generally lower in plants that were inoculated with both Bacillus and Rhizobium inoculation as compared to those that received rhizobia alone. Nodulation was significantly ($P \leq 0.05$) enhanced on bean plants even those that were treated with Bacillus alone. The seven isolates were then screened in a soil experiment in a glasshouse. Two Bacillus isolates caused an increase in nodulation, while the rest suppressed nodulation. Two isolates (K194 and K89) were found to have health promoting effects while the rest had growth promoting effects.

Shisanya C.A, Gitonga N. M (2007) Evaluation of nitrogen fixation using ^{15}N dilution methods and economy of a maize-tepary bean intercrop farming system in semi-arid SE-Kenya. *In: Bationo et al (Eds) Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities.* ISBN: 13978-4020-5759-5 (HB). pp. 389-400

Tepary bean has become popular among poor small-scale farmers in semi-arid Kenya, where it is intercropped with maize. This study aimed at (i) evaluating the N-economy of maize/tepary bean intercrop versus sole crop using natural abundance and ^{15}N enriched fertilizer methods and (ii) assessing the contribution of fixed N_2 by tepary bean to the total N balance in the intercrops and sole cropping systems assessed from harvested seed and residues. Experiments were carried out during the short rains of 2001/2002 and long rains of 2003 at Kenya Agriculture Research Institute (KARI) Kiboko, Kenya. Randomized block design was used with one block devoted to the ^{15}N natural abundance (-N), the other ^{15}N labelled fertilizer (+N), replicated 4 times. Above ground biomass and total N were determined in sole crops or intercrops (-N or + N). Tepary bean received 53-69% of its N supply from N_2-fixation with N_2-fixation slightly affected by intercropping or N fertilizer application. N_2-fixation of tepary in greenhouse experiment was lower (36-66%) than in the field study and more affected by N supply. Budgets for N were estimated for field intercrops based on above ground seed yields, return of crop residues, input of fixed N and fertilizer N. N_2-fixation was 59 Kg N/ha in plots receiving no N fertilizer, and 73 Kg N/ha in plots receiving N as urea. Corresponding fixation by sole tepary was high (87 and 82 Kg N/ha, respectively), but this advantage was outweighed by greater land use efficiency in intercrop than sole crop. Keywords: ^{15}N dilution methods, Kenya, intercropping, maize, tepary bean.

Theuri S. W. (2007) Effects of rhizobia inoculation and starter-nitrogen application on nodulation, biomass and grain yield of food legumes. Msc. Thesis, University of Nairobi, Kenya

A field experiment was conducted at the University of Nairobi's Faculty of Agriculture farm in 2004 long rains (LR) and short rains (SR) to determine the effect of rhizobia inoculation and starter-N dose on the performance of grain legumes. Common bean (*Phaseolus vulgaris* L.), lima bean (*Phaseolus lunatus* L.), Cowpea, (*Vigna unguiculata* L), green gram (*Vigna radiata* L.), pigeon pea (*Cajanus cajan* L.) and lablab (*Lablab purpereus* L.) were tested in the field experiment. The test crops were either uninoculated, inoculated with rhizobia, or supplied with 26kg N/ha. The treatments were laid out in a randomized complete block design (RCBD) in a split plot arrangement with three replicates. Nodule numbers, nodule biomass, shoot biomass, root biomass and grain yield were determined. Rhizobia inoculation had no significant effect on nodule numbers/plant in both seasons at 4 weeks after emergence (WAE) and 6 WAE. In most cases, common bean had significantly higher nodule numbers and nodule biomass than most of the other legumes while lima bean generally registered the fewest nodules. At 6 WAE, rhizobia inoculation improved nodule biomass in the short rains (SR) but not in the long rains (LR). Starter N doze had no significant effect on nodule biomass in both seasons. Inoculation and starter-N had no significant effect on shoot biomass accumulation and grain yield in both seasons. In the LR, lima bean produced the highest grain yield followed by common bean while the converse was the case in SR, Pigeon pea and green gram performed the poorest in the SR. Mean grain yield varied from 148 kg/ha to 1472 kg/ha in LR and from 214 to 4398 kg/ha in SR. It was concluded that inoculation and starter-N application was not necessary for the purpose of improving grain yield under the prevailing field experimental conditions. A follow- up experiment was conducted in a greenhouse to determine the abundance of indigenous soil rhizobia nodulating common bean (*Phaseolus vulgaris* L.) and cowpea (*Vigna unguiculata* L.) in soils sampled from Kabete (cultivated and uncultivated land), Machakos, Nyeri and Kajiado sites. The population size of indigenous rhizobia was determined using the most probable number technique. Cowpea and common bean were used as ''trap'' hosts for Bradyrhizobium spp and Rhizobium spp, respectively. Nodule numbers, nodule biomass, shoot biomass, plant tissue-N and the number of rhizobial bacteria cells/g dry soil were determined. The soil samples varied in chemical characteristics with the Nyeri site having a low pH. Indigenous rhizobia nodulating cowpea in the sites ranged from 78.5 to more than 900 bacterial cells per gram of dry soil. Common bean nodulating rhizobia had more than 900 bacterial cells per gram of dry soil at each of the sites. The Nyeri site had the lowest rhizobia population. In most sites, common bean produced significantly more nodules per plant than cowpea. A similar trend was observed with respect to nodule biomass, though this was only significant with Kabete soils. Inoculation with commercial inocula produced more nodule and shoot biomass than inoculation with soil inocula. It was concluded that indigenous rhizobia were widespread in Central Kenya.

Muriithi M. N. (2006) Influence of improved fallows systems and phosphorus fertilization on *arbuscular* mycorrhizal fungal symbiosis in maize. Msc. Thesis, Moi University, Eldoret, Kenya

Formation and functioning of *Arbuscular Mycorrhizal* Fungi (AMF) symbiosis is important in low input technology, which are considered appropriate technologies to replenish nutrients in soils in the tropics. Although improved fallows are promoted widely in western Kenya as a low input technology for soil fertility there is little information on extent of AMF colonization of subsequent crops and how that is influenced by phosphorus fertilization. This study was carried out to investigate the effect of improved fallows systems and P fertilization on AMF colonization

in the field grown maize, and to establish relationship between AMF colonization and mineral nutrition in maize as well as maize yield. The efficiency of AMF communities in the fallows systems were also tested on growth, dry matter production and nutrient concentration in maize under greenhouse. This study was carried out as a follow up of a six-year-old field trial established in 1997 in western Kenya. The trial comprised of four farming systems- Continuous maize (CM), Natural fallow (NF), *Crotalaria grahamiana* fallow (CG) and *Tithonia diversifolia* fallow (TD), arranged in a split plot design, with phosphorus (P) (50 Kg/ha) and without P fertilizer. Maize crops and fallow species (CG and TD) were grown rationally for three years, after which (2000), maize was planted continuously to test the residue effect of the fallows. In this study, maize was established during short rains (SR) 2002 and long rains (LR) seasons 2003 in the plots with CG, TD and CM systems, with and without P fertilization from TSP. Maize roots were sampled at two weeks interval for AMF colonization. The size of AMF spores communities was determined and different genera of AMF were identified based on spore morphology. Soil and above ground plant materials were also sampled for analysis of macronutrients and micronutrients to establish relationship between AMF colonization and nutrient uptake. Maize yield was estimated at the end of both seasons. The efficiency of AMF communities from fallow systems was also tested in the greenhouse using a sterilized uniform soil as a substrate and soil collected from the different treatments in the field as the soil inoculum. The experiment was set as complete randomized design with 13 different soil inoculums taken from different treatment (CM, CG and TD with or without P) in the field and 2 levels of P (0 and 50 Kg P/ha) replicated four times. Maize crop was used as test crop, and was grown for two months. Height, dry matter production and macro- and micro-nutrient concentration were measured. Data was subjected to analysis of variance (ANOVA) and regressions analysis using GENSTAT statistical package. In the greenhouse, AMF communities from TD and CG fallow increased ($p<0.05$) biomass production, P, K and Zn concentration of two-month-old maize plant with more P concentration ($p<0.05$) in maize inoculated by AMF communities from TD fallow than those from CM and CG fallows systems. In the field, fallow systems recorded high ($p<0.05$) nutrient uptake and maize grain yield compared to maize grown in the CM system with more P and N uptake and maize grain yield increases ($p<0.05$) recorded in maize in the TD fallow than maize in the CG fallow. Although fallow systems did not increase the AMF colonization and function significantly, maize cultivated after TD fallow tended to have higher AMF colonization during early period of maize growth. Early AMF colonization related positively ($r=$ 0.3 to 0.5) with nutrient uptake and maize yield, and was an important variable explaining nutrient uptake in maize. Similarly, phosphorus applications increased ($p<0.05$) maize production and nutrient uptake in all follow systems and promoted early AMF colonization significantly ($p<0.05$) in maize in the TD fallow indicating the need of small doses of P application in this soil to improve AMF colonization. Phosphorus application was also found to increase ($p<0.05$) Glomus species and reduce Scutellospora and Gigaspora species. The study suggests that improved fallow systems and P fertilization can affect AMF colonization of subsequent crops, which in return affects plant nutrition and productivity in the depleted soils of western Kenya.

Kiriiro F. K. (2005). Response of green grams to fertilizer nitrogen, chicken manure application and rhizobial inoculation. Msc. Thesis, University of Nairobi

A field experiment was conducted at the University of Nairobi, Kabete Field Station between April, 2000 and March 2001 to determine the effects of nitrogen source (organic, inorganic or combination) and rhizobium inoculation on growth, biological nitrogen (N) fixation (BNF) and yield of green grams (*Vigna radiata* (L.) Wilczek). Nitrogen was applied at a rate of 100 Kg N/ha as calcium nitrate ($Ca(NO_3)_2$), urea, chicken manure (CM), 50 Kg N/ha $Ca(NO_3)_2$ + 50 Kg N/ha CM and no N application. The grams were either inoculated or not inoculated. Wheat was grown as reference crop to determine BNF by difference method. The experiment was laid out in randomized complete block design with three replications. The results showed that total, leaf and stem dry matter, leaf area index (LAI), solar radiation interception, root nodulation, biological nitrogen fixation (BNF) and seed yield were significantly influenced by N sources. The numbers of leaves/plant, branches/plant, seeds/pod, harvest index (HI) and 1000-seed mass were not significantly affected by N sources or rhizobium inoculation. $Ca(NO_3)_2$ application increased total dry matter (TDM, g/m^2), photosynthetically active radiation (PAR) interception and LAI and seed yield relative to other N sources. Nodulation and BNF were significantly increased by rhizobium inoculation but were reduced by fertilizer N application. Nitrate N source gave the highest economic returns but was more costly to purchase. Chicken manure led to high economic losses due to high cost of buying the manure and low seed yield observed. The gross margin increased 6.5 times in plants that were inoculated with rhizobium without fertilizer N application, compared to non-inoculated. Farmers with limited financial resources could use Rhizobium while those not limited by finances may use nitrate N source to increase profits in green gram production.

Muthuri J. K. (2005). Effect of different soil fertility amendments on the nodulation and yield of two soybean varieties. Msc. Thesis, Kenyatta University, Kenya

Soybean (*Glycine max* (L.) Merrill) is referred to as the golden crop of the future. There is a concern in Kenya on its production due to the fact that the country remains a net importer of this vital food to the tune of 100,000 tons annually yet the country has the potential to produce that capacity locally. The major impediments in local production are singled out as: Expensive farm inputs in form of fertilizers and use of inferior soybean

varieties in terms of effective nodulation. The nodulation of soybean is influenced by inoculation, soil fertility, agro-ecological zones and soybean varieties. This study was carried out to achieve the following objectives, to investigate the effect of different soil fertility alteration on soybean nodulation and yield and to analyze symbiotic effectiveness between fast and slow growing rhizobia in nitrogen fixation with the soybean. Two soybean varieties (promiscuous and non-promiscuous) were planted in experimental plots at Kisii, KARI during the months of April to August 2008. There were five main treatments: Control, poultry manure, farmyard manure (FYM), di-ammonium phosphate (DAP) and inoculants strain USDA 1011. Sub-treatments were the two soybean varieties, the promiscuous variety was SB19 TGx 1740 2F while the non promiscuous was Gazelle. The experiment was carried out in a split plot design and replicated four times at Kisii, KARI Station. The greenhouse experiments were carried out to analyze the symbiotic effectiveness of fast and slow growing rhizobia isolated from Kisii while laboratory experiments were used to characterize the rhizobia isolated from the field. Nodulation status, plant biomass production, height of the plant and yield were used to generate data for the main field experiments. For greenhouse experiment, nodulation status, plant dry weight and acetylene reduction activities were used to generate the data. The transformed data was subjected to analysis of variance (ANOVA) and means were separated using Tukey's high significant difference (HSD). The effects due to soil amendments on nodulation status were significantly different at $P \leq 0.05$.There was no significant difference for grain weight for both varieties on different treatments. There was a significant difference in terms of nodule numbers and acetylene reduction assay for both soybean varieties when symbiotic effectiveness of the isolates was assessed. From the study it was concluded that the soybean treated with the inoculants had high nodulation and yield. The study also showed that FYM has slow mineralization. Fast growing rhizobia were more effective in nitrogen fixation in TGx variety than in Gazelle variety while slow growing rhizobia were more effective in Gazelle.

Karanja N.K., Mwendwa K.A., Okalebo J. R., Kahindi J.H.P (2004). Effect of Phosphate Rock Fertilization and *Arbuscular mycorrhizae* (AM) Inoculation on growth and Nodulation of Agroforestry Tree Seedlings. *West African Journal of Applied Ecology*, Vol. 6 Pp. 55-64

Phosphate rocks (PR) have been identified as cheap complements of easily soluble phosphate fertilizers for low pH soil. A-mycorrhizae improve plant uptake of P and other nutrients in acidic, low-P soils. Using two acid soils, Acrisols and andosols, two greenhouse studies were carried out to evaluate effect of minjingu Phosphate Rock (Minjingu PR) on growth of four agroforestry multipurpose trees: *Leucaena Leucocephala*, *Senna siamea*, *Grevillea robusta*, and *Eucalyptus grandis*. In the first experiment, one - month -old seedlings received Minjingu PR at) (PR0) 52 (PR1) and 77 (PR2) Kg P/ha in 2kg soil. In a second experiment, the minjingu PR rates of the first experiment were maintained while *G. robusta* and *L. leucocephala* were used as the test trees on the Acrisol only. *A -mycorrhizae* inoculum in the form of *A. tortilis* roots mixed soil was included in this study. There was a slower response to Minjingu PR fertilizer application in Andasols than in Acrisols. At 19 weeks after transplanting, PR2 had caused a significant ($P<=0.05$) height increase over PR0 in *L. leucocephala*. Addition of PR2 had a negative effect on the height of *C. siamea* whereas *E. grandis* did not respond to PR additions. Application of PR in Andosol, significantly reduced ($P<=0.05$) height and root collar diameter of *G. robusta* and *S. siamea* as compared to the control. In the second study, there were significant increases of up to 121% in height ($P<=0.001$) and root collar diameter ($P<=0.05$) and 4.5 times biomass over the control when *L. Leucocephala* was seedlings received alone and PR+mycorrhizae at 12 months after planting. Nodulation of *L. leucocephala* was significantly affected by P application and / or A-mycorrhizae inoculation but was variable within any similar treatments except for the controls, where no nodulation was observed. Species x Treatments interactions were significant, ($P<=0.05$) for shoot dry weight and ($P<=0.001$) for root dry weight. It is probably not necessary to add minjingu PR fertilizer to *G. robusta* in either soil and to *S. siamea* in the Andosols soils. PR and mycorrhizae inoculation have the potential to improve legume performance in these acidic soils.

Masinde J. K. (2003). The contribution of selected pasture legumes to soil fertility and wheat yield in a cereal based cropping system in the highlands of the rift valley province, Kenya. Msc. Thesis, Egerton University, Kenya

A two year study was conducted at two sites, Njoro and Mang'u both in Nakuru District to test the contribution of selected pasture forage legumes to soil fertility and wheat yields in a cereal based cropping system in the Kenya Highlands Rift Valley Province. In one experiment only *Vicia sativa* and *Crotalaria ochroleuca* nodulated with *Vicia sativa* having the highest biomass, tissue N content of 2.8% and C: N ratio of 13:1. Yield and possibly allelopathic effects of the previous year's weeds. Wheat grown after *Crotalaria ochroleuca* produced the highest biomass and grain yields, in the second experiment, *Vicia Villosa* had the highest nodule numbers and weight. Biomass yield was consistent in the two years and may have been affected by the poor rainfall of 1998/1999. *Trifolium decorum* among the annuals was superior in biomass in 1998/1999 at Mang'u while in 1999/2000 it was *Trifolium veppellianum*. In Njoro *Vicia villosa* had the highest biomass in 1999/2000. The perennial species yielded over seasons and sites. *Desmodium intortum* and *Desmodium uncinatum* did not flower at all > in the last experiment *Vicia* spp had the highest germination (87%) while *Trifolium steudneri* had the higher germination than tropical ones (*Trifolium steudneri* and *Trifolium quartinianum*). Mean germination time (mgt) for all the species ranged from 0.192 to 3.762

Shisanya C. A (2003) Yield and nitrogen fixation response by drought tolerant tepary bean (*Phaseolus* A. Gary var. Latifolius) in soil sole and maize intercrop systems in semi-arid. *Pakistan journal of agronomy Asian network for scientific information*. 293:126-137

Tepary bean (TB) a drought tolerant bean variety has become popular among poor small -scale farmers in semi-arid Kenya where it is predominantly intercropped with maize. Field experiments were conducted of effect of intercropping TB and maize on nitrogen fixation and crop yield in semi-arid Kenya over two cropping seasons. Experimental design was complete block design with eight treatments TB sole crop Not included with Rhizobium R3254 and without N fertilizer N TP sole crop not inoculated with R3254 with or without N TB sole crop inoculated with R3254 without N, TB with maize intercrop not inoculated with R3254 with or without N and maize sole crop with or without N. Each treatment was replicated 4 times. Significant differences (P= 0.05) were observed in total plant dry weight in treatment R3254 and both 21 and 42 days after em/ha intercropping TB and maize days after emergence (DAE).TB yield were significantly higher seed dry uninoculated intercrop. Inoculated TB treatments had significantly higher seed dry weight yields/ha Intercropping TB and maize suppresses the yield of the farmer under semi- arid conditions. Inoculating TB and Rhizobium strain R3254 was effective to cropping effective and significantly improved TB yields and intercrop. Soil N in sole TB plots above pre planting levels. Maize plots exhibited a decline in soil N. Total N concentration in plant tissues was significant enhanced in treatment R3254. There was a marked increase in soil P in all Treatment plots amendment.

Mwangi M. N. (2002). Soil invertebrate macro fauna population dynamics and their role in litter decomposition within a hedgerow intercropping in Embu, Kenya. Msc. Thesis, Kenyatta University, Kenya

Crop yields in Embu, Kenya, as in much of the developing world, are poor due to declining soil fertility caused by continuous cropping with few inputs. In low-input systems, soil biota regulates the transformation of organically bound nutrients into plant-available forms thereby enhancing food productivity. Management practice engaged may influence the nature of fauna population composition and structure and could lead to elimination/reduction of key groups and/or species of soil fauna and in some cases low abundances or biomass. A study was conducted during the long and the short rains of the year 2000 on-station at Embu in an ongoing experiment within hedgerows. The main experiment quantifies the abundance of soil invertebrate macro fauna at three soil depths (0-10, 10-20 and 20-30cm) and established their relationship to soil chemical and physical properties within seasons. The macro fauna populations were monitored of 25 cm x 25 cm x 30 cm. Soil cores and soil samples for physical and chemical analysis respectively were taken from 5 different locations (0-30cm depth within each plot at the start and at the end of each season. Simultaneously an experiment was conducted to investigate the role of soil macrofana in litter decomposition and the relationship between litter quality and rate decomposition. Two types of polyvinyl chloride litterbags with mesh size 7 and 1mm were used. The 7mm mesh size allowed macro fauna to enter while the 1mm excluded the macro fauna. Two types of litter *Calliandra calothyrsus* Meissner and *Leucaena leucocephela* Lam de Wit were placed in the litter bags in duplicate in selected treatments of the Embu trials, and were sampled for chemical concentrations at 1,2,4,8 and 16 weeks. Results from the study indicated that the composition and structure of soil invertebrate macro fauna varied with soil depths. Most faunal groups thrived well in the lower soil depths (20-30cm) than topsoil (0-10cm) layer/depths in hedgerows during the dry spell as opposed to during the wet conditions when the trend was reversed. Termites were the most abundant of the fauna observed. More fauna were recorded during the dry spell than when the conditions were moist. Hedgerow agro ecosystem treatments that involved organic inputs offered a desirable niche for the macro fauna as opposed to those that entailed addition of inorganic fertilizer *C. calothyrsus* litter supported higher macrofaunal population than that of *L. leucocephala*. The macro fauna abundance, biomass and diversity were correlated to soil nitrogen, phosphorus, potassium, pH compactness, but at varied levels. Soil invertebrate macro fauna enhanced the rate of decomposition of both litter types. *Leucaena leucocephala* decomposed and released nutrients faster than *C. calothyrsus* and the former had lower lignin and/or polyphenols to nitrogen ration than the latter. The study endorses the potential of soil invertebrate macro fauna as biological indicator organisms or ecosystems status.

Sande S. (2001). The Influence of soil fertility management practises on diversity and abundance of soil fauna in the Central Highlands of Kenya. Msc. Thesis, Kenyatta University, Kenya

The need for an increase in crop (particularly food) production to match the demand from an ever-increasing human population has led to intensive agriculture. This is usually associated with a high level of ecological disturbance. Soil fauna seem to play a key role in determining soil quality via mineralisation and the farmers already use presence of macro fauna as fertility indices yet their balance is likely to be upset by such disturbances. It is necessary to study their distribution in common farm management practises associated with intensive agriculture to determine which practises can be useful in increasing soil fertility and productivity sustainably. Presently, over 73% of the small holder farmers in Kiambu District, Central Kenya are using crop manure, animal waste and inorganic fertilizers to increase their farms' fertility and subsequent productivity. Disparity in these organic

amendment and soil erosion control practices had resulted in a scenario whereby patches of productive/fertile and less productive/degraded soils have developed and are conspicuously identifiable by majority of the farmers. This study was to find out if the organic resource management practises which farmers adopt in response to soil fertility decline, enhance the biodiversity and activity of soil fauna, some of which may serve as indicators of soil quality. Six small-scale farms were selected from members of Karura Catchment Committee in Kikuyu division of Kiambu District. A series of 20 x 20 x 20cm soil monoliths were dug, macro fauna hand-sorted, identified and counted. In addition, some key microfauna/microorganisms (Bacteria, Fungi and Actinomycetes) and mesofaunal groups (nematodes) were studied. This latter was done by plate dilution technique and the sieving /filtration respectively. Sampling was done as from May to December 2000. Results obtained pointed towards the act that farms had no soil erosion control or soil fertility control (termed unproductive by farmers) were less species rich but more species-even (S=38 and J=1.35323). Farms with both soil erosion control and organic amendments as a soil fertility control (termed productive by farmers) had a higher species richness of S=47 and less evenness of J=0.61614. The ratio of parasitic nematodes to non-parasitic nematodes was highest in the non-productive farms even though they had the least overall total count. Distribution of various microfauna groups differed in each farm with the lowest overall count being in the non-productive patches. Fungi density was highest in the degraded farms depicting a more acidic nature of the soils. Overall, these results pointed towards the fact that the practice involving organic amendments incorporation and a soil erosion control involving agroforestry led to increase in faunal species, abundance and activity, rendering the farms more productive.

Waithaka J. I. (1998) Soil fertility dynamics in smallholder farming systems in semi-arid Kenya. PhD thesis, University of Reading, UK.

After moisture stress, low soil fertility is the most important constraint limiting crop productivity in semi-arid Kenya. A formal diagnostic soil fertility appraisal was conducted between 20th and 30th September, 1995 in 50 smallholder farms in semi-arid areas of Embu District (now Mbeere) in Kenya using a standard questionnaire. The objective of the formal survey was to investigate the soil fertility management practices used by smallholder farmers and explore options and processes for sustainable improvement. In addition, soil sampling was done to a depth of 20 cm in three different fields namely; poor, good and virgin as identified by the farmers in each of the 50 farms visited. A total of 150 organic matter contents (loss on ignition) and soil pH (water). Nodulation assessment in cowpea *(Vigna unguiculata),* green grams *(Vigna radiata*) and field beans (*Phaseolus vulgaris*) was done on the farmers` crops in the poor fields. On-farm researcher managed trials to determine the effect of phosphorus (P) on cowpea biological nitrogen fixation (BNF) and productivity were also initiated and conducted for four consecutive cropping seasons from October, 1995 to July, 1997. One pot experiment on the same was also conducted. Phosphorus fertilizer was applied in the form of triple superphosphate at rates equivalent to 0, 20, 40 and 80 Kg P/ha. Millet and maize were used as the reference crops. The N Difference Method and ^{15}N Isotope Dilution Technique were used to estimate cowpea BNF. The survey results showed that most of the farming systems in the survey area do not utilise inorganic fertilizers as a source of plant nutrients. The only major external nutrient input comes from the fixation of N_2 by the grain legumes (as indicated by the good nodulation) and also to a lesser extent, manure from livestock grazed away from the farm holdings. Recycling of plant nutrients through use of manure and crop residues was also widespread. Organic matter contents were higher in virgin land compared to cultivated land. Extractable P levels were quite variable, ranging from 1-92 ppm. However, Mutuobare soils were on average high in extractable P (18 ppm) compared to Machanga soils (6 ppm). On-farm experimental results showed positive responses by cowpeas, maize and millet to P application through significant increases in dry matter yield and N and P uptakes. Cowpea BNF, nodulation, seed and residue yields were also markedly increased by P application. The responses were most significant after the application of P at 20 Kg/ha. Field observations indicated that P fertilizer hastened crop maturity and hence helping it escape drought. Significant interactions were also observed between fertilizer P and soil extractable P during the last three seasons of the on-farm experiments. Better responses to fertilizer P were observed when the Olsen P levels were less than 5 ppm and negative responses were common when the Olsen P levels were more than 10 ppm. BNF estimates with the N Difference method (4 Kg N/ha and 10 Kg N/ha with no P fertilizer and with 20 Kg P/ha applied, respectively) were less than for the ^{15}N Isotope Dilution Technique (5 Kg N/ha and 14 Kg N/ha with no P fertilizer and with 20 Kg P/ha applied, respectively) but comparable. The present study indicate that soil fertility management in the smallholder farming systems in semi-arid Kenya calls for an integrated approach which takes into account the range of input sources available to the farmers and the adverse economic circumstances facing them. The use of BNF by grain legumes coupled with small amounts of P fertiliser therefore offers a feasible option for improving the current soil fertility status.

Waithaka J. I. (1989). The influence of nitrogen source and rhizobium seed inoculation on growth, yield and quality of French beans [*Phaseolus vulgaris* (L)]. Msc. Thesis, University of Nairobi, Kenya.

Field studies were conducted between August, 1987 and January, 1988 at the Field Station, Faculty of Agriculture, University of Nairobi, Kabete, to show the effects of fertilizer nitrogen sources (Diammonium phosphate - DAP and Calcium ammonium nitrate - CAN) and Rhizobium seed inoculation on growth, yield and quality of French beans (*Phaseolus vulgaris*) Cvs, 'Monel' and 'Finbel'. Nitrogen fertilizers were applied at the rate of 200 Kg CAN or DAP/ha and a mixture of Rhizobium leguminosarum biovar phaseoli strains NUM 445+446 was used as the seed inoculants. A treatment where the seeds were not inoculated and no fertilizer applied was included as a control. The total dry matter production in the French bean plants was mainly due to accumulation of dry matter in the leaves and stems. The use of inoculated seeds and applying DAP at planting resulted in 'Monel' plants accumulating significantly higher total dry matter than those plants from inoculated seeds top dressed later with CAN, CAN top dressing alone or the control. The total dry matter production was increased by 85% compared to the control. Application of DAP at planting followed later with CAN top dressing resulted in a total dry matter production and cumulative leaf area that were significantly higher than that of 'Monel' plants from inoculated seeds top dressed later with CAN, inoculated seeds alone or the control. The total dry matter production and cumulative leaf area increase were 70.5% and 105.5% over the control, respectively. Similarly, using inoculated seeds and applying DAP at planting resulted in 'Finbel' plants accumulating significantly higher total dry matter and leaf area than those from inoculated seeds top dressed later with CAN, inoculated seed alone or the control. The total dry matter production and leaf area increase were 154.7% and 112.5% over the control, respectively. Application of DAP at planting followed later with CAN top dressing resulted in 'Finbel' plants with significantly higher cumulative leaf area than those from inoculated seeds alone or the control. The cumulative leaf area was increased by 107.3% compared to the control. The total, marketable pod yields and quality were not significantly increased by the N-sources and Rhizobium seed inoculation. Application of DAP alone at planting using inoculated seeds and applying DAP at planting followed later with CAN top dressing or top dressing plants from inoculated seeds with CAN resulted in 'Monel' plants producing significantly higher number of pods than using inoculated seeds alone. The effect of N-sources and Rhizobium seed inoculation on the nodulation of French beans was not significant. However, results indicated that using inoculated seeds and applying DAP at planting had a favourable effect on nodulation compared to CAN top dressing.

Ndukhu O.H. Dynamics of Nematodes as influenced by soil fertility management practices and *Bacillus Subtilis*

Continued land conversion leads to lose of soil fertility i.e. land degradation that ultimately results in loss of nematode biodiversity as indicated by the above results. Agricultural intensification such use of Prepac results in modification soil fauna environment leading to reduced nematode populations. On the other hand, application of compound fertilizers such as NPK promotes multiplication of nematodes as observed in this study. Addition of soil organic amendments like farmyard manure would lead to checked populations of nematodes due to competition for food and space with the introduced soil organisms. The potential Bacillus *subtilis* strains as bio control agent of root-knot nematode, Meloigongyne spp. and growth promotion in bean plants was demonstrated under field condition. These results show that Bacillus *subtillis* strains K194 and K158 can be incorporated in nematode manage package. Bean plants inoculated with the Bacillus strains had increased growth due to increased nodulation. Thus application of Bacillus spp. in root-knot management would therefore have an added advantage of enhancing nitrogen supply to the plants. Seed treatment is a more practical technique of applying Bacillus spp. locally available materials such as sugar and gum arabia should be used to boost the number of bacteria cells carried on individual seed. Use of locally available materials such as charcoal and filter mud as carriers of Bacillus spp. has proved to be a better alternative of applying the potential *Bacilluss* spp. Apart from providing nourishment, carrier materials also make Bacillus application easier. The efficacy of Bacillus *subtilis* strains as biocontrol agents of root-knot nematodes should be carried out under different field climatic condition. Studies to determine the effect of Bacillus *subtilis* on the other soil borne pathogens that infect beans should be initiated. More soil fertility managements should be incorporated in the study to determine their effects on nematode abundance and diversity.

Cropping Systems And Modeling

Overview

Cropping systems refers to crops and crop sequences and the management techniques used in field over a period of years. Cropping systems includes double cropping (also known as sequential cropping) –a practice of planting a second crop immediately following the harvest o f the first crop thus harvesting two crops in a year and taking advantage of nutrients left behind/fixed by the previous crop. Cropping systems also includes monocropping, intercropping, relay cropping, strip cropping and crop rotations. Most of the cropping systems make use of the benefits of legume-cereal associations. Different models have been used to test the optimal combination of crops that utilizes resources more efficiently to yield better returns. This section presents the results of various tests with cropping systems and modelling.

Source: Thompson K., Chidawanyika F., Kruszewska I., and Tirado R. (2015). Building resilience in East Africa agriculture in response to climate change. Greenpeace Research laboratories Technical Report: 05-2015

Matusso J. M. M. (2014) Effects of different maize (*zea mays l.*) – soybean *(glycine max (l.)* merrill) intercropping patterns on yields and its economics. Standard Global Journal of Scientific Research Vol 1(2): 039- 047

Field experiment was conducted for two seasons to evaluate the effects of different maize and soybean intercropping patterns on its yields and economics at Embu and Meru Counties, Kenya. The experiment was arranged in a randomized complete block design (RCBD) with four replications. The treatments were four maize (M)–soybean (S) intercropping patterns (conventional=1M:1S; MBILI-MBILI=2M:2S; 2M:4S; 2M:6S) and two sole crops of maize and soybean, respectively. The results showed that in both sites during the both seasons the MBILI treatment produced significantly higher stover and grain yields than all other treatments. At Embu site during the both seasons, the MBILI treatment was more profitable. At Kamujine site during the 2012 LR maize sole crop was the most profitable; whereas during 2012 SR the MBILI treatment was the most profitable.

Matusso J. M. M., Mugwe J. N., Mucheru-Muna M. (2014). Changes of soil inorganic n, soil organic c and n uptake by maize and soybean under different intercropping patterns in Embu West and Tigania east counties of Central Kenya. *Academic Research Journal of Agricultural Science and Research*. Vol. 2(2), pp. 22-33, April 2014; DOI:10.14662/ARJASR2014.011; ISSN: 2360-7874. Academic Research Journals; http://www.academicresearchjournals.org/ARJASR/Index.htm

In the central highlands of Kenya, low soil fertility is one of the major constraints causing decreased maize production and other staple food and income generating crops. The purpose of this study was therefore to determine the effects of maize-soybean intercropping patterns on soil inorganic N, soil organic C and N uptake by maize and soybean. The effects of conventional=1M:1S,MBILI-MBILI=2Maize:2Soybean; 2Maize:4Soybean, 2Maize:6Soybean and two sole crops of maize and soybean were investigated during two seasons (2012 Long Rains and 2012 Short Rains) at Embu and Meru Counties, using a randomized complete block design (RCBD) with four replications. At Embu, during 2012 LR, the MBILI and 2M: 4S treatments observed significantly the lowest $N0_3^-$ - N content (8.24 mg/kg and 9.15 mg/kg, respectively); whereas at Kamujine, the sole soybean treatment recorded statistically the highest $N0_3^-$ - N content (8.24 mg/kg). At Kamujine the sole soybean treatment recorded statistically the highest (12.84 mg/kg) soil Inorganic N. The N uptake by maize and soybean was significantly affected by the intercropping patterns and it was positively correlated with soil mineral N, at both sites during the sampling period. At Kamujine, the SOC was significantly affected by the intercropping and the conventional treatment recorded the highest value of 2.46%. Key words: maize-soybean, intercropping patterns, soil mineral-N, N-uptake, chemical soil properties, central highlands, Kenya.

Chomba S. K., Okalebo J. R., Imo M., Mutuo P. K. and Markus W. G. (2013). Predicting maize response to fertilizer application using growth curves in western Kenya. International Research Journal of Agricultural Science and Soil Science (ISSN: 2251-0044) Vol. 3(6) pp. 200-207, June, 2013; Available online http://www.interesjournals.org/IRJAS

To increase food security among smallholder farmers in western Kenya, which is one of the hunger hotspot in the country, evaluation of soil factors that determine yield of the major staple crops such as maize may enable development of site specific management regimes. In this study, we used Richards-Chapman plant growth function to examine the effect of N, P and K fertilization on maize growth and yield in nine randomly selected farms at Suari in Siaya district, western Kenya. Correlation analysis showed that maximum attainable growth rate is the most important predictor of maize grain yield (r2 =0.70; p= 0.035). The results also showed that combined N and P fertilizer application gave the highest maximum attainable maize stalk volume and growth rate. Applying N and P as single fertilizers had relatively similar growth responses, but lower than the N+P fertilizer application suggesting positive N+P interactions. These results indicate that maximum attainable stalk volume and growth rates are important indicators for measuring maize response to nutrient availability. The advantages of the multilevel nonlinear mixed effects model include its flexibility to model multiple sources of heterogeneity and complex patterns of correlation, and its higher power to make treatment comparisons.

Larsson M. (2012) Soil fertility status and *Striga hermonthica* infestation relationship due to management practices in Western Kenya. Msc. Thesis, SLU, Swedish University of Agricultural Sciences

Striga hermonthica, a parasitic weed, has long been believed to be correlated with the declining soil fertility status. However scientists have recently come to question this statement since some recent studies have shown contradictive results. To investigate whether soil fertility status and infestation of *Striga hermonthica* were correlated and the impact of it were caused by farmer management, 120 farmers in Western Kenya, where *Striga*

hermonthica infestation is prone, participated in this study. In three districts with two sub-locations each, farmers answered a structural questionnaire and identified two fields, one with high and one with low soil fertility. These fields later came to be the basis for this study and soil were therefore also sampled from them. Different soil variables such as: pH, ohlsen-P, texture, C, N, and seed bank of *Striga hermonthica,* were then analyzed. The *Striga* seed bank differed significantly between the districts, but there were no differences between the farms or the two fields (high and low soil fertility) on each farm. pH, C and N gave significant results for the amount of *Striga* seeds found in the soil. Soils with lower C:N ratio also contained fewer *Striga* seeds, while fields with high pH had more *Striga* seeds present. In Nyabeda, one of the sub-locations, trials were installed on the identified fields at 11 farms to measure actual *Striga* emergence in the field. Local and IR-maize were planted, both with and without fertilization. Variety was significant for both *Striga* emergence count and maize yield. Field status was also significant for *Striga* emergence. Fertilisation played no significant role in *Striga* emergence nor did it increase the yield. The local maize variety gave significantly higher yields than the IR-maize did. Furthermore IR-maize resulted in significantly higher emergence of *Striga*. *Striga* infestation seems to be correlated with soil fertility status, though the impact of farmer management has not been fully investigated due to the limited amount of time and data available. Further studies are needed to understand the impact of farmer management practices on *Striga* infestation and soil fertility.

Nambiro E., Chianu J., and Murage A. (2010). The association of agricultural information services and technical efficiency among maize producers in Kakamega, western Kenya. Contributed Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010.

Maize is the staple food for most Kenyan households, and grown in almost all the farming systems. Due to diminishing farm sizes in Kakamega District, crop productivity and the efficiency of farming systems are of great concern. This paper aims to provide empirical evidence on the links between efficiency in maize production and access to soil-related agricultural information services. Using cluster sampling, a total of 154 farmers in Kakamega District were interviewed. A 2–step estimation technique (Data Envelopment Analysis (DEA) and Tobit model) were used to evaluate the technical efficiencies among the farmers and the factors explaining the estimated efficiency scores. Data was disaggregated into farmers with and those without access to soil-related agricultural information services. The results shows that farmers with access to soil-related agricultural information services were more technically efficient (average technical efficiency of 90%) in maize production compared to those without access to information (technical efficiency at 70%). Given the significant role that access to soil related agricultural information services play on technical efficiency in maize production in the study area, the paper recommends improvements in farmers access to this important resources through: (i) the strengthening of the formal and informal agricultural extension services, (ii) a stronger linkage among agricultural research, agricultural extension, and farm level activities; and (iii) policy support for increased distribution of soil management inputs.

Njeru P. N., Mugwe J., Maina I., Mucheru-Muna M., Mugendi D., Lekasi J. K., Kimani S., Miriti J.M., Esilaba A. O., Muriithi F. (2013). Integrating scientific and farmers' perception towards evaluation of rain-fed agricultural technologies for sorghum and cowpea productivity in Central Kenya. *Academic journal of soil science and environmental management*. Vol. 4 (7), pp 123-131

Soil fertility degradation remains the major biophysical cause of declining per capita crop production on smallholder farms in Central Kenya Highlands. A study was conducted to compare farmers' perception and biophysical data on selected water harvesting and integrated soil fertility management technologies on sorghum (*Sorghum bicolor* (L) Moench) and cowpea (*Vigna unguiculata* L) production in Central highlands of Kenya. Three hundred and seventy one smallholder farmers were invited to evaluate thirty six plots laid out in Partially Balanced Incomplete Design method (PBIBD) replicated three times. The treatment which was ranked best overall rated "good" by the farmers practise with a mean score of (2.78) and yielding (3.5 t/ha) under sorghum alone plus external soil amendment of 40 kg P/ha+20 kg N/ha. This was closely followed tied ridges and contour furrows overall rated as "good" by the farmers under sorghum alone plus external soil amendment of 40 kg P/ha +20 kg N/ha + manure 2.5 t/ha and 40 kg P/ha + 40 kg N/ha + manure 5 t/ha both with a mean score of (2.7) and yielding (3.0 t/ha) and (2.9 t/ha) respectively. Generally, all experiment controls were overall scored as "poor" yielding as low as 0.3 t/ha to 0.6 t/ha. Therefore, integration minimal addition of organic and inorganic inputs on highly valued traditional crops with adequate rainfall under normal farmers practise in semi-arid lands could be considered as an alternative option contribution to food security in Central highland of Kenya.

Chumba R. K. B., Owuor B., Mwai G. N., Oghiambo G. D. (2012). Evaluation of yield advantage of maize Artemisia and maize + beans intercrops in a sub-humid ecozone of Maseno, Western Kenya. *East African Agricultural and Forestry Journal* Vol. 79 (1) 9-15

An experiment on intercropping systems at Maseno western Kenya sought to evaluate the yield potential of maize in different maize + Artemisia spacing regimes in comparison to a standard maize + beans system by identifying the most beneficial crop combination. The productivity of these systems was evaluated using land equivalent ratios (LER) Area - time equivalent ratio (ATER) and dominance analysis for Marginal Rate of Returns (MRR). There were 9 treatments laid out in a randomized complete block design (RCBD) with 3 replications. The treatment had a significant effect on both LER and AFTER ($P<0.05$) while maize yielded higher in maize + Artemisia (3 t/ha) intercrops. LER were comparatively higher than after values with yield advantages in intercrops provided to be economically more advantageous than other treatments. The identified biological yield advantages did not translate in to substantial economic efficiency but marginal analysis proved the sole crops to be inferior whereas the % MRR revealed that maize + Artemisia with optimum value of 1885 was the best spacing regime and more profitable than maize + beans intercrops at 518. Overall system productivity favoured maize + Artemisia with net field benefit of KES 76,900/ha than maize +bean (KES 42,600/ha) intercrops and hence farmers stand to gain better when they intercrop maize with Artemisia using a spacing of Artemisia 0.9 x 0.9 m; maize 0.9 m x 0.75 m than maize with beans system using maize 0.90 m x 0.75 m + 0.25 m beans line displacement of two rows in sub- humid areas.

Kihanda F. M. and Warren G. P. (2012). Management of soil fertility in a long term field trial of semi-arid Kenya Lessons Learned from Long-term soil Fertility Management Experiments in Africa. pp 85-103

The long-term experiment was initiated in 1989 on a P- deficit soil in semi -arid Kenya where sustainability of these cereal/legume intercropping was assessed by monitoring trends in grain yield were not identifiable because of season variations SOC and Olsen P increased for the first 7 years of manure application and then remained constant. The residual effect of manure applies for 4 years only lasted another 7-8 years when assessed by yield SOC and Olsen P mineral fertilizers the same annual rates of N and P as in 5 t/ha manure and initially gave the same yield as manure declining after nine years to about 80%. There was a wide agreement between observed and predicted dry matter yields soluble P but less for organic using the Agricultural production simulator (APSIM) model. Soil nitrate was highest at onset of the season and was highest where manure had been applied and was subject to loss through leaching or runoff.

Muchui M. N. (2012). Influence of fertilizers, harvest maturity, polyethylene bunch covers and postharvest treatment with 1-Methycyclopropene on physical, physiological and biochemical quality of tissue-cultured bananas (*Musa Spp.*) PhD Thesis, Jomo Kenyatta University College of Science and Technology, Kenya

This study aimed at determining the effect of inorganic fertilizers on yield and postharvest quality characteristics of tissue-cultured bananas in order to establish the limiting nutrients. The study also aimed at establishing the proper maturity indices and effect of pre-harvest polyethylene bunch covers alone and in combination with postharvest treatment with1-Methylcyclopropene on physical, physiological and biochemical characteristics of banana fruit at harvest and during ripening. The experimental site was in Maragua Ridge, Maragua District, Agro-Ecological Zone (AEZ) upper midland zone 3 (UM3). For the experiment on effect of inorganic fertilizers on yield and postharvest quality, nutrients under investigation were, nitrogen at 400 kg/ha, phosphorus at 50 kg/ha, and potassium at 600 kg/ha. Micronutrients were supplied as a combined treatment as follows: magnesium at 60 kg/ha, Zinc at 6 kg/ha, molybdenum at 0.5 kg/ha and boron at 1 kg/ha. The treatments included all above nutrients applied in such a way as to omit one nutrient, where all nutrients were applied and a control where no nutrients were applied. A randomized Complete Block Design (RCBD) with four replications was used. The other experiments consisted of studies carried out to establish clear harvest indices, the effect of pre-harvest bunch bagging on fruit quality and postharvest response to 1- MCP using a Completely Randomized Design (CRD) with three replications. Fruits were analyzed for selected postharvest quality parameters at harvest and during ripening. Data were examined for normality using R software and outliers by scatter plot using MS Excel software. Data were then subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS statistical program (SAS, 2001). The means were compared according to student Newman Keul's (SNK) test and Least Significance difference (LSD) ($\alpha=0.05$) to test for significant effects. Correlations among maturity indices were tested using MS Excel software. Application of inorganic fertilizers significantly ($p\leq0.05$) affected bunch weight, number of hands, number of fingers, grade, finger weight, finger length, pulp to peel ratio of green fruit, pulp and peel objective firmness, starch content, total soluble solids, vitamin C, pulp crude fibre, lightness (L*) of green peel, L* raw pulp, hue angle of green peel and raw and ripe pulp, pulp Ca, Mg and P content and peel P content. Green life and shelf life were not significantly ($p>0.05$) affected. Sensory evaluation of the fruits from all treatments showed significant (≤0.05) differences for preference, aroma and texture but not for sweetness. Phosphorus and micronutrients were found to limit postharvest quality of tissue-cultured bananas in Maragua Ridge region. Fruits harvested at 3/4 mature, Light full 3/4 full and full mature stages generally had similar postharvest qualities especially at the eating

ripe stage, except for green life where fruits harvested at the fully mature stage had significantly ($p \leq 0.05$) short green life for both banana cultivars (cv.) Grand Nain and Williams. Shelf life was not influenced by the stage of maturity at harvest for both banana cultivars. It may be concluded here that the optimum harvest maturity stage is three quarter, light full, ¾ full corresponding to 22, 24 and 26 weeks from flowering for cv. Grand Nain and 24 to 28 weeks for cv. Williams, as the fruits had acceptable grades and kept well while attaining optimum postharvest quality. Both banana cultivars showed a positive core relation(R) between Bunch age and finger grade, weight, length, pulp/peel ratio, total soluble solids (TSS) and total titrate-able acidity (TTA). Finger grade correlated very well with such postharvest qualities as TSS, and pulp/peel ratio at R=+0.85, +0.72, +0.98 for cv. Grand Nain and R=+0.75, +0.87, +0.86 for cv. Williams, respectively. The results indicated that the best maturity indices for both banana cultivars may be a combination of bunch age and grade as they correlated very well with postharvest characteristics such as TSS, pulp to peel ratios, TTA, green life and shelf life and are not destructive. Bunch covers did not influence significantly ($p>0.05$) the finger grade, finger length and bunch weight for banana cv. Williams. However, for cv. Grand Nain only grade was not significantly ($p>0.05$) affected by the bunch covers. Pulp/peel ratio for banana cv. Williams was not significantly affected while that cv. Grand Nain was affected ($p \leq 0.05$). Starch content, total soluble solids (TSS), pulp and peel moisture content, weight loss, chlorophyll content, peel and pulp firmness, peel and pulp color, lightness (L*) and hue angle at harvest and during ripening were not influenced by bunch covers for both cultivars. Total sugar content was similar in all treatments for cv. Williams but differed in cv. Grand Nain. Bunch covers did not influence green life and shelf life of both banana cultivars. Peak ethyl production differed for cv. Grand Nain in all treatments but not for cv. Williams while respiration was influenced slightly by bagging for cv. Grand Nain during ripening but not for cv. Williams. The covered fruits were more visually appealing, cleaner and had minimal bruises compared to the un-bagged fruits. However, few fingers from top hands of few bunches grown covered suffered sunburn irrespective of the bunch color. 1-MCP application delayed and reduced the ethylene peak, respiratory peak, starch degradation, TSS and TTA accumulation. Decrease in fruit firmness, green color loss and chlorophyll degradation were also delayed considerably by 1-MCP application. However, the un-bagged control fruits ripened faster than the bagged control fruits while bagged fruits treated with 1-MCP started to ripen earlier compared to un-bagged fruits treated with 1-MCP. De-greening of the peel and loss of firmness were also disrupted by 1-MCP irrespective of the growing condition. In this study 1-MCP was not effective in extending the green life of bananas.

Ng'etich, K. F. (2012). Enhancing farmers' agricultural productivity through improved field management practices in the central highlands of Kenya. Msc. Thesis, Kenyatta University, Kenya

Farmers in central highlands of Kenya have been experiencing declining crop yields in the recent past. Low water availability caused by low and unreliable rainfall, and poor water harvesting techniques coupled with low water harvesting techniques coupled with low soil fertility are key constraints to crop production in these regions. To increase crop yields, and reduce production risks, better use of available rainfall is required. The broad objective of the research was to enhance farmers' agricultural productivity through improved field management practices in the central Highlands of Kenya. The research was carried out in Maara, Meru South both in Tharaka Nithi County and Mbeere South district in Embu County. The study used both social logical and experimentation approaches. Long term rainfall and other meteorological data were utilized in the modelling exercise. A socio-economic survey was conducted to explore how farmers make crop production decisions and adapt their field practices in response to seasonal rainfall distribution patterns. Tillage and surface management, timing of split nitrogen application and temporal staggered planting trials were conducted to assess their effect on maize yields and also to collect data for Aqua Crop model parameterization, calibration and validation. The field trials were complimented with a runoff study. The rainfall analysis study established the most probable onset, cessation and the length of growing season. Rainfall analysis resulted in establishment of spatial rainfall onset an cessation dates of the study area. Based on farmer's survey, key findings were on how the farmers adapted and also cope with not only rainfall variability but also climate variability. From the staggered planting trial results, dry planting led to 28%, and 37 % higher grain yields in Kiamaogo and Machang'a respectively, compared to normal (wet) planting. Hence, it was observed that decision on the planting date, roughly going along with the start of the rains, is of utmost importance especially in low potential regions like Mbeere. Tillage methods and surface management study highlighted the impact of integrated approach in in-situ water conservation. For instance, even though there was significant ($p=0.05$) influence of minimum tillage on soil water conservation with time, Surface management strategies were more apparent within a short time and their influence on maize yields was significant. Split application of 70 N proved to be the best application method leading to 18% grain yield increase compared to single application. The finding also underscored the potential use of calibrated Aqua Crop model with high degree of reliability; R^2=0.87 to 0.96 for combined observed and estimated grain and stover yields in Machang'a and Kiamaogo. AquaCrop model was recommended for use in practical management, strategic planning, and estimation of yield production under varying climatic and agro-ecological conditions, tied ridging was very efficient technique in reducing sediment yield by 94% followed by mulching (73.5) compared to conventional practice (Bare surface). It was observed that conventional tillage accelerates soil loss as signified by high sediment yields irrespective of the rainfall pattern. The output of this study would be invaluable to extension service providers, governments, bureaucrats and people in regional natural resource management groups in planning, designing and evaluating effective and efficient soil

and water conservation strategies at local, regional and national scales. This would in turn result in positive spin-offs in farmers' adoption of soil and water conservation practices.

Dixit P. N., Cooper P. J. M., Dimes J. and Rao K. P. (2011). Adding value to field-based agronomic research through climate risk assessment: A case study of maize production in Kitale, Kenya. Experimental Agriculture (2011), volume 47 (2), pp. 317–338 C. Cambridge University Press 2011; doi:10.1017/S0014479710000773

In sub-Saharan Africa (SSA), rainfed agriculture is the dominant source of food production. Over the past 50 years much agronomic crop research has been undertaken, and the results of such work are used in formulating recommendations for farmers. However, since rainfall is highly variable across seasons the outcomes of such research will depend upon the rainfall characteristics of the seasons during which the work was undertaken. A major constraint that is faced by such research is the length of time for which studies could be continued, typically ranging between three and five years. This begs the question as to what extent the research was able to 'sample' the natural longer-term season-to-season rainfall variability. Without knowledge of the full implications of weather variability on the performance of innovations being recommended, farmers cannot be properly advised about the possible weather-induced risks that they may face over time. To overcome this constraint, crop growth simulation models such as the Agricultural Production Systems Simulator (APSIM) can be used as an integral part of field-based agronomic studies. When driven by long-term daily weather data (30+ years), such models can provide weather-induced risk estimates for a wide range of crop, soil and water management innovations for the major rainfed crops of SSA. Where access to long-term weather data is not possible, weather generators such as MarkSim can be used. This study demonstrates the value of such tools in climate risk analyses and assesses the value of the outputs in the context of a high potential maize production area in Kenya. MarkSim generated weather data is shown to provide a satisfactory approximation of recorded weather data at hand, and the output of 50 years of APSIM simulations demonstrate maize yield responses to plant population, weed control and nitrogen (N) fertilizer use that correspond well with results reported in the literature. Weather-induced risk is shown to have important effects on the rates of return ($ per $ invested) to N-fertilizer use which, across seasons and rates of N-application, ranged from 1.1 to 6.2. Similarly, rates of return to weed control and to planting at contrasting populations were also affected by seasonal variations in weather, but were always so high as to not constitute a risk for small-scale farmers. An analysis investigating the relative importance of temperature, radiation and water availability in contributing to weather-induced risk at different maize growth stages corresponded well with crop physiological studies reported in the literature.

Opala P. A. (2011). Management of organic inputs in east Africa: a review of the current knowledge of future challenges. *Archives of applied science research Journal* Vol. 3(1) 65-76

Organic inputs in Africa are used mainly as sources of crop nutrient but most of the ones available on the farms such as crop residues, animal manures and composts are of low quality and insufficient quantity. Proper management of such organic inputs to ensure sustained crop productivity poses a major challenge. Current research efforts aim to increase the understanding of the interactions between organic inputs, the soil and crop with developing predictive management guidelines. The factors influencing nitrogen mineralization in various plant residues have been identified and a decision support system (DSS) which makes practical recommendations for their appropriate use of nitrogen sources has subsequently been developed. This DSS has, however, not proved useful when applied to animal manures. To increase nutrient use efficiency, synchronization of nutrient release from the organic materials with crop demand has been attempted but attainment of perfect synchrony appears unlikely. Given that neither organic nor inorganic fertilizers alone can achieve sustainable crop productivity, focus has now shifted to the integrated soil fertility management paradigm that advocates for combined use of organic and inorganic sources of nutrients. Whereas the biophysical aspect of organic input management have been studied in detail, social and economic analyses are rare. Our knowledge of organic input systems, therefore, remains imprecise. This has made development of economically and socially acceptable guidelines for organic input management difficult. Adoption of the organic input technologies is consequently disappointingly low and biggest challenge is to have these technologies adopted by farmers.

Githunguri C.M., Esilaba A.O., Mutuku, L.M. (2010). Effect of Spacing on *Jatropha curcas* planted in semi-arid eastern Kenya. *In: Ouda et al (Eds) Proceedings of the 12th KARI Bienniaal Scientific Conference*. KARI Headquarters, Kaptagat Road, Nairobi, Kenya 8 – 12 November, 2010, pp 987-990

Jatropha carcus, which offers tremendous potential as cash crop in the semi-arid areas, is found in Western Kenya (Western and Nyanza provinces), Rift valley, and Coast and Eastern provinces. Its favoured niche in these sites is bush lands and along rivers. This makes it a reliable species for marginal lands, reducing competition for space

with food crops. A conservation effort by the Kenya Agricultural Research Institute has led to the preservation of 5 accessions, from Nyanza, Makueni, Kajiado and Marsabit in the National Gene Bank of Kenya. There is scanty literature on *Jatropha carcus* agronomy especially basic field operations like depth of planting holes and spacing. This study was conducted to evaluate *Jatropha carcus* performance under different spacing management and its optimum spacing at KARI Katumani Research Centre in semi-arid eastern Kenya. Seeds of *Jatropha carcus* provenance suitable for the semi-arid areas were obtained and a spacing trial established at KARI-Katumani Research Centre in April 2009. The 12 spacing included 2 x 2.5, 3 x 3, 4 x 2.5, 3 x 2.5, 2 x 3, 3 x 2, 4 x 2, 2 x 1.5, 3 x 1.5, 4 x 1.5, 2 x 2 and 4 x 3 meters. The plants were sampled for number of plants established, plant height, number of leaves and stress 3 & 5 months after planting, respectively. The 4m x 2m spacing had the highest plant height of 27.2cm, which was significantly different from other spacing. The other spacings were not significantly different from each other. The 3m x 3m and 4m x 2.5m spacing had the highest number of leaves, which were only significantly different from the 4m x 1.5m spacing. At 5 months after planting, the number of plants among 4m x 2.5m, 2m x 3m and 2m x 2m spacings were significantly different from the 2m x 2.5m spacing plants. The 4m x 3m spacing had the highest number of leaves, 19, which was significantly higher than other spacings. The other spacings were not significantly different from each other and the 4m x 3m spacing could have been different from the others due to some extreme experimental errors other than spacing. The 4m x 2.5 and 3m x2m spacings experienced the highest drought stress, which were only significantly higher than the 2m x 1.5m spacing.

Mahasi J.M., Vanluawe B., Mursory B., Mbehero R.C., Mukalama J. (2010) Increasing productivity of soybean in western Kenya through evaluation and farmer participatory variety selection. *In: Ouda et al (Eds) Proceedings of the 12th KARI Bienniaal Scientific Conference*. KARI Headquarters, Kaptagat Road, Nairobi, Kenya 8 – 12 November, 2010, pp 326-334

Soybean is an ideal crop for improved nutrition, food security sustainable crop production and suitable in livestock integration systems. However, its productivity in western Kenya is low and one of the main factors cited is lack of well-adapted varieties and consideration for preferred varieties for various end users during the breeding process. For intervention, 22 soybean lines with three checks were tested in three diverse environments (Lare in Nakuru, Menengai and Bureti) for two years so as to recommend superior lines for entry into the National Variety performance Trials (NPTs). The trial was planted in randomized complete block design with four replicates. Soybean recommended agronomic practices were followed to raise the crop in all sites. Data was recorded on days to 75% flowering, days to 75% physiological maturity, plant height and seed yield per plot. Only the yield data was subjected to ANOVA using SAS and the G X E iteration was found to be significant. Means were separated using LSD (P=0.05). The results facilitated the identification of candidate varieties for testing under NPT. These varieties were released in 2009 for commercial production in various agro ecological zones. To encourage adoption of the new varieties, a farmer participatory variety selection involving 8 Tropical Glycine crosses or TGx series, 7 KARI varieties and 3 Chinese lines were planted across the 5 project sites in baby trials (Migori, Mumias, Butere Busia and Teso). The plots sizes were 5m by 5m with 10cm between plants. The plots were managed using the recommended soybean production practices. Priority ranking of the genotypes was based on twenty-four criteria developed by farmers and researchers across sites. Graphs were developed in excel sheets. By gender, men preferred large size grain while females selected seeds based on cookability. TGx 1740 - 2F was the only variety, which excelled across locations and is better than existing varieties. Farmers also preferred early maturing varieties for drought escape and food security.

Midega C. A.O. , Khan Z. R., Amudavi D. M., Pittchar J., and Pickett J. A. (2010). Integrated management of Striga hermonthica and cereal stemborers in finger millet (*Eleusine coracana* (L.) Gaertn.) through intercropping with *Desmodium intortum*. International Journal of Pest Management. Vol. 56, No. 2, April–June 2010, 145–151

We evaluated the potential role of greenleaf desmodium, *Desmodium intortum* (Mill.) Urb., in the combined management of Striga hermonthica and cereal stemborers in finger millet (*Eleusine coracana* (L.) Gaertn.) in western Kenya between 2007 and 2008. Treatments comprised finger millet planted either as monocrop stands or intercropped with D. *intortum*. S. *hermonthica* counts were significantly lower in the intercrop than in the monocrop plots. Similarly, multi-season analyses showed that the proportions of stemborer-damaged plants were significantly lower in the intercrop than in the monocrop. These differences were associated with significantly higher grain yields in the intercrop than in the monocrop. Total labour and variable costs were significantly higher in the intercrop resulting from the additional seed cost and labour to plant, manage and harvest D. *intortum*. However, total revenue and gross margins were significantly higher in the intercrop due to the higher finger millet grain yields and additional product, D. *intortum* forage, part of which is consumed by farmers' own livestock or used for own plot extension, and the remaining amount is sold. Our results demonstrate that intercropping finger millet with D. *intortum* offers an effective means of control of both pests, leading to higher grain yields and economic returns.

Mwanarusi S., Itulya F., Aguyoh J., Mshenga P. and Owour G. (2010). Effects of cowpea leaf harvesting initiation time on yields and profitability of a dual-purpose sole cowpea and cowpea-maize intercrop. *Electronic journal of environmental, agriculture and food chemistry* Vol. 9 (6) 1134-1144

Harvesting of cowpea leaves for use as leaf vegetable has gained prominence in many parts of Africa and Asia. Little is known on effects of leaf harvesting on leaf and grain yields and profitability of cowpea-based cropping systems. This study sought to determine yields and initiation times. The study was conducted at Kenya National Dry Land Research centre-Machakos using a Randomized complete Block design with cowpea grown as a monocrop or intercropped with maize. Leaf harvesting was initiated at 2, 3 or 4 Weeks after Cowpeas Emergence (WAE) and a control where no leaf harvesting was done. Initiating leaf harvesting at 3 and 4 WAE resulted in highest leaf and grain yields, respectively among leaf harvested cowpea. Overall, cowpea grain yield were highest in control treatment. Leaf vegetable and grain yield were lower in intercrop than in monocrop treatments. Maize yields in intercrop systems were improved following harvesting of leaves of the companion cowpea. Initiating leaf harvesting at 3 and 4 WAE yielded highest returns in cowpea-maize intercrop and sole cowpea, respectively. Intercropping was o overall more profitable than sole cropping.

Shuma J. M., Weru S. and Muli, B. M. (2010). Improving productivity of maize, cassava and sweet potato in the coastal lowlands of Kenya through provision of high quality seed. *Proceedings of the 12th KARI Biennial Scientific Conference,* 8-12, November, (pp. 284-288)

Coastal Kenya is a food-deficient region not only due to erratic rains and poor sandy soils that limit crop production but also due to the common practice by farmers of using local or farm-saved seed for crop production. This leads to low returns from farms. To improve crop productivity, KARI-Mtwapa has since 2007 produced certified seeds of maize and clean planting materials of cassava and sweet potatoes and made them available to farmers through a delivery channel crafted for orphans Crops programme to all coastal districts in partnership with the Ministry of Agriculture. Maize was produced mainly at Bura while production of cassava and sweet potatoes was mainly done at the center. Field assessments indicated contribution of the programme to food production in the region was positive, reaching 7.7% in certain crops in one year. Generally, increase in food production where the seed was distributed was evident, ranging between 33% and 43% of the food produced. This has improved the livelihoods and food security of the local people in the region.

Thuanira D. M. (2010). Effects of Soil Fertility Management and *Trichoderma asperellum* on Severity of Wilt Disease of Passion Fruits. Msc. Thesis, Jomo Kenyatta University College of Science and Technology pp: 40-103, Kenya

Passion fruit is the third most important export fruit crop in Kenya after mango and avocado. Plant diseases are the main constraint to passion fruit production resulting in 40 to 100% yield losses. Passion fruit wilt disease caused by *Fusarium, oxysporum f. sp passiflorae* is of economic importance in Kenya. Management of this disease is difficult because the pathogen persists in soil for many years. Chemical controls are expensive and in most cases not effective. The most economical control method is the use of tolerant rootstocks, such as the yellow passion fruit, which however succumbs to the disease in some cases. This study was conducted to investigate effects of soil fertility management and application of *Trichoderma asperellum* on control of passion fruit wilt disease. In the first experiment, soils managed under organic, integrated and virgin systems were collected from farmers' fields and used to set up a bioassay in a greenhouse using the purple passion fruit seedlings. The soils were inoculated with a field isolate of *Fusarium oxysporum* f.sp. *passiflorae* (FoP) at 2.25*104 colony-forming units (CFU)/g. Split plot design with three replicates was used. Microbial populations of the antagonists *Trichoderma* spp. *Fluorescent pseudomonads* and actinomycetes were determined by serial dilution two months after transplanting and repeated once per month for eight months. Second experiment was done four weeks after the first experiment. In this experiment, the soils were inoculated with *T. aspereuum* at 5*107 CFU/ml and three weeks later with FoP at 2.25*104 CFU/g. Split-split plot design with three replicates was used. Disease severity, in both experiments, was assessed by the length of vascular discoloration and chlorosis at the end of experiment. Data was analysed using Analysis of Variance (ANOVA) and treatment means were separated using Student-Newmann-Keuls test. In the first experiment, disease seventy was not significantly different ($p \leq 0.05$) between organic and integrated managed soils but significantly lower ($p \leq 0.05$) in virgin soils. Organic soils had significantly higher ($p \leq 0.055$) population of antagonists than virgin and integrated soils. Organic soils were not more effective in controlling the disease than integrated soils probably because they did not have sufficient amount of organic matter that could sustain prolonged microbial activity. Virgin soils were more effective than organic integrated soils in controlling the disease probably because of higher microbial diversity that has been reported in virgin soils compared to arable soils. This has been reported in virgin soils compared to arable soils. This has been reported to enhance antagonism against soil borne pathogens. In second experiment, disease severity was significantly lower in *Trichderma* treated soils than non-Trichoderma treated soils with organic soils having the lowest severity. Reduced disease severity

in Trichoderma treated soils was a result of microbial antagonism byt T. asperellum against *F. oxysporum* f.sp. *passiflorae*. Organic matter improved efficacy of *T. asperellum*. The results propose an integrated and sustainable approach towards management of wilt disease of passion fruits by using bio-control agent *T. asperellum* and addition of organic matter.

Khan Z. R., Midega C.A.O., Wanyama J. M., Amudavi D. M., Hassanali A., Pittchar J., Pickett J.A.(2009). Integration of edible beans (*Phaseolus vulgaris* L.) into the push–pull technology developed for stemborer and Striga control in maize-based cropping systems. Crop Protection 28 (2009) 997–1006

Smallholder farming systems in eastern Africa are characterized by cereal/edible legume intercrops in fields severely constrained by parasitic weed, Striga hermonthica, cereal stemborers and declining soil fertility. The push–pull technology concurrently addresses these constraints. It involves intercropping maize with stemborer repellent fodder legume, Desmodium spp. (push), with an attractant crop, Napier grass, Pennisetum purpureum (pull), planted around this intercrop, thus making it difficult to interplant edible legumes. We assessed farmers' practice and perceptions on intercropping and willingness to integrate beans in their push–pull plots from a sample of 300 farmers in six districts in western Kenya. All the respondents traditionally intercropped maize with beans, planted either between the rows of maize, in the same holes with maize or in between maize plants within a row. The majority (92%) were willing to integrate beans in their push–pull plots.We, therefore, evaluated effects of integrating beans in the maize–desmodium intercrops. Treatments comprised a maize monocrop, maize–bean intercrop and three maize–desmodium intercrops, two of which were integrated with beans, either in the same holes with maize or in between maize plants in a row (bean integration plots). On-farm trials were similarly established among 56 farmers in four districts in western Kenya to assess the two integration methods. S. hermonthica counts and stemborer damage to maize were significantly lower and maize yields significantly higher in the maize–desmodium and bean integration plots than in the other systems. Overall, integration of beans in the maize–desmodium intercrops and the planting arrangement did not compromise the S. hermonthica and stemborer control efficacy of desmodium. Integration of beans significantly increased labour and total variable costs, with these being significantly higher in plots with both crops in different holes than in the same hole. Total revenue, gross benefits and benefit cost ratios did not significantly differ between the bean integration and maize–desmodium intercrops. Furthermore, these parameters were for most part not affected by the planting arrangements, both on-station and on-farm. These results show that integration of beans in the maize–desmodium and indeed push– pull technology while guaranteeing an additional crop, a protein source, to the farmers does not compromise the observed benefits of the technology but yields same economic benefits. Where labour is easily available, farmers are, however, advised to plant maize and beans in separate holes to avoid the risk of competition for moisture and nutrients where these might be limiting.

Mwanarusi S. (2009). Influence of Timing of Leaf Harvest Initiation, Leaf Harvesting Frequency and Cropping Regime on Nitrogen Dynamics, Biomass Production and Yield of Cowpea (*Vigna unguiculata* (L) Walp). PhD Thesis, Egerton University, Kenya

Cowpea is an important legume in tropical agriculture and primarily grown for its protein rich grain. Although supply of cowpea leaf vegetable is secondary to grain production, the vegetable is gaining prominence as an alternative to common leaf vegetables. Two main systems are commonly used in the production of cowpea as a leaf vegetable: uprooting the entire plant at 3-5 true leaf stage, or dual purpose production, where sequential leaf harvest are made, followed by grain production at the end of the season. There is, however, little documentation of effects of leaf harvesting initiation time and frequency on nitrogen fixation, biomass production and leaf vegetable and grain yields of cowpea, and the overall productivity per unit land area under different cowpea-based cropping systems. The main objective of this study was to determine biomass production, nitrogen fixation and leaf vegetable and grain yield responses of dual purpose cowpea to leaf harvesting initiation time and frequency. The study comprised of a greenhouse pot experiment and field experiment. The greenhouse part was conducted at Michigan State University using a Completely Randomized Design, with four replications. Two dual purpose cowpea cultivators, Kathoka and Ex-Luanda were used. Leaf harvesting was initiated at 2, 4 or 5 weeks after emergence (WAE) Thereafter leaf harvesting was done at 7 or 14 day intervals with a control treatment, where no leaf harvesting was done at 7 or 14 day intervals with a control treatment, where no leaf harvesting was done. The field experiment was conducted at Katumani National Dry Land Research Center, Machakos District, Kenya, Using a randomized Complete Block Design, with three replications over a span of four seasons. The most popular dual purpose cowpea cultivator in the area ('K80') was grown as a monocrop or intercropped with maize. Leaf harvesting was initiated at 2, 3 or 4 WAE. Leaf harvesting frequencies used were similar to those of the greenhouse experiment. Early leaf harvest initiation at 2 WAE resulted in lowest nitrogen fixation, biomass and grain yields were higher when leaf harvesting was initiated at 4 WAE or done at 14 days interval. No leaf harvesting (control) gave the highest nitrogen fixation, biomass production, and grain yields. Amount of nitrogen

fixed and biomass, leaf vegetable and grain yields were generally lower in intercrop than in monocrop cowpea. However, land equivalent ratios (LERs) in intercrop treatments were increased when leaf harvesting was done to the cowpea intercrop by 78% for 2 WAE and 104 for 4WAE leaf harvesting initiation times, and by 89% to 93% when leaf harvesting intervals was increased from 7 to 14 days. These data provided information that can enable producers to optimize productivity of dual-purpose cowpea-based cropping systems according to their specific yield goals.

Marenya P., Barrett B. C. (2008). Soil quality and fertilizer use rates among smallholder farmers in Western Kenya. *Agricultural Economics Journal* Vol., (40): 561-572

Studies of fertilizer use in sub-Saharan Africa have been dominated by analyses of economic and market factors having to do with infrastructure, institutions, and incentives that prevent or foster increased fertilizer demand, largely ignoring how soil fertility conditions farmer demand for fertilizer. We apply a switching regression model to data from 260 farm households in Western Kenya in order to allow the possibility of discontinues in fertilizer demand based on a soil carbon content content(SCC) threshold. We find that the usual factors reflecting liquidity and quasi-fixed inputs are important on high-SCC plots but not on those with poorer soils. External inputs become less effective on soils with low SCC, hence the discernible shift in behaviours across soil quality regimes. For many farmers, improved fertilizer market conditions alone may be insufficient to stimulate increased fertilizer use without contemplary improvements in the biophysical conditions that affect conditional factor demand.

Muthamia J. M. (2008). Determination of partial nutrient balances for improved soil fertility management in smallholder farms of Kirege location, central highlands of Kenya. Msc. Thesis, Kenyatta University, Kenya

Soil fertility decline is an acute problem facing smallholder farmers in central highlands of Kenya. Availability of organic and inorganic nutrient resources, their management under spatially variable soil fertility conditions has consequences on the soil resource base, cropping patterns and crop yields. Smallholder farms in the central highlands of Kenya exhibits a high degree of heterogeneity, which are influenced by a complex set of socio-economic and biophysical factors. The farms consist of multiple plots managed differently in terms of allocation of crops, nutrient inputs and labour resources, making within farm soil fertility gradients caused by management strategies a common feature. A monitoring study involving nutrient stocks, flows and balances was conducted in Kirege Location, central highlands of Kenya to explore soil heterogeneity with the aim of improving soil fertility management. Focus group discussion were conducted where criteria for wealth ranking farmers into different wealth status was developed. A rapid survey was conducted on a sample of 50 households randomly selected from the list of households in Kirege obtained from the local chief's office to characterize and classify the farms into three different types (rich, medium and poor). Nine case-study farms were randomly selected for detailed resource flow mapping (3 from each of the 3 farms types). The farms were visited to record movement of nutrients stock materials using a monitoring protocol covering household, crops, livestock, soil and socio-economic aspects of the farm. Soil in the plots identified in resource flow mapping at different distances from the homesteads were sampled at the end of 2006/2007 short rains cropping season (March 2007). The sampling depth was 0-20 cm to capture the level of nutrient soil organic carbon in the topsoil. The soil samples were analyzed to pH, C, N, P, K, Mg, and Ca at ICRAF laboratory using Infrared spectroscopy method. Resource flow mapping data was analyzed using IMPACT program version 2.0. Results revealed use of nutrient resources varied for different field types and was strongly influenced by distance from the homestead. Home fields received more nutrient inputs compared to outfields. In wealthy farms, home fields received 109.1 kg N/ha, 72.9 kg P/ha and 379 kg K/ha, compared to 42 kg N/ha, 32.1 kg P/ha and 55 kg K /ha in the outfields. In poor farms, home fields received 56.8 kg N/ha, 32.8 kg P/ha and 106 kg K/ha compared to 8.1 kg N/ha, 4.6 kg K/ha and 16 kg K/ha for the outfields. Variations in resource allocation were also observed with regard to farmers' level of resource endowment. Wealthy farmers used a mean of 74.5 N kg/ha, 50.9 kg P/ha and 244 kg K/ha, compared to 27.3 kg N/ha, 16.2 kg P/ha and 50.7 kg K/ha and 244 kg K/ha compared to 27.3 kg N/ha, 16.2 kg P/ha and 50.7 kg K/ha for poor farms. Partial nutrient balances and stocks were higher in home fields and in wealthy farmers' farms as compared to outfields and poor farmers' farms. Due to nutrient heterogeneity in smallholder farms, there is a need for a more targeted approach to soil fertility intervention that differentiates between farm fields, agro-ecological zone and resource endowment status.

Tittonell P., Vanlauwe B., Corbeels M. and Giller K. E. (2008). Yield gaps, nutrient use efficiencies and response to fertilizers by maize across heterogeneous smallholder farms of western Kenya. Plant Soil (2008) 313:19–37; DOI 10.1007/s11104-008-9676-3

The need to promote fertilizer use by African smallholder farmers to counteract the current decline in per capita food production is widely recognized. But soil heterogeneity results in variable responses of crops to fertilizers within single farms. We used existing databases on maize production under farmer (F-M) and researcher management (R-M) to analyze the effect of soil heterogeneity on the different components of nutrient use efficiency by maize

growing on smallholder farms in western Kenya: nutrient availability, capture and conversion efficiencies and crop biomass partitioning. Subsequently, we used the simple model QUEFTS to calculate nutrient recovery efficiencies from the R-M plots and to calculate attainable yields with and without fertilizers based on measured soil properties across heterogeneous farms. The yield gap of maize between F-M and R-M varied from 0.5 to 3 t grain/ha/season across field types and localities. Poor fields under R-M yielded better than F-M, even without fertilizers. Such differences, of up to 1.1 t/ha greater yields under R-M conditions are attributable to improved agronomic management and germplasm. The relative response of maize to N–P–K fertilisers tended to decrease with increasing soil quality (soil C and extractable P), from a maximum of 4.4-fold to –0.5- fold relative to the control. Soil heterogeneity affected resource use efficiencies mainly through effects on the efficiency of resource capture. Apparent recovery efficiencies varied between 0 and 70% for N, 0 and 15% for P, and 0 to 52% for K. Resource conversion efficiencies were less variable across fields and localities, with average values of 97 kg DM/kg N, 558 kg DM/kg P and 111 kg DM/kg K taken up. Using measured soil chemical properties QUEFTS over-estimated observed yields under F-M, indicating that variable crop performance within and across farms cannot be ascribed solely to soil nutrient availability. For the R-M plots QUEFTS predicted positive crop responses to application of 30 kg P/ha and 30 kg P/ ha + 90 kg N/ha for a wide range of soil qualities, indicating that there is room to improve current crop productivity through fertilizer use. To ensure their efficient use in sub-Saharan Africa mineral fertilizers should be: (1) targeted to specific niches of soil fertility within heterogeneous farms; and (2) go hand-in-hand with the implementation of agronomic measures to improve their capture and utilization.

Vanlauwe B., Kanampiu F., Odhiambo G.D., De Groote H., Wadhams L. J. and Khan Z. R. (2008). Integrated management of *Striga hermonthica*, stem borers, and declining soil fertility in Western Kenya. *Field Crops Research*, Vol. 107, 102-115.

Striga hermonthica, stem borers (Delile) Benth, stem borers, and declining soil fertility are serious threats to sustainable food production in the Lake Victoria zone of Kenya. To address these constraints, promising integrated crop management technologies were evaluated, using a multi-locational design in four sub-locations in Siaya and Vihiga district (Western Kenya) for six cropping season. Technologies evaluated consisted of the traditional Maize (*Zea mays* L.)- Bean (*Phaseolus vulgaris L.)* intercrops maize – *Desmodium* (*Desmodium Uncinatum* (Jacq.) DC.) push-pull intercrop, *Crotalaria* (*Crotalaria ochroleuca* G.Don) - maize rotation and soybean (*Glycine max* (L.) Merr) – maize rotation. Within each of these systems, imazapyr-coated herbicide-resistant maize (IR- maize) and fertilizer were super-imposed as sub-plot factors. The push-pull system was observed to significantly reduce *striga* emergence and stem borer damage from the second season onwards. IR maize reduced and delayed *striga* emergence from the first cropping season. Differences in *striga* emergence and stem borer damage between the other systems were not significantly different. After five cropping seasons the *striga* seedback was significantly higher in the maize-bean intercrop system than in the push-pull system under both maize varieties while the rotational systems had intermediate values not different from the day zero. Under IR-maize, the Striga seedback was significantly lower than under local maize for all cropping systems. Maize yields varied between seasons, districts, and cropping systems. Yields in the push–pull system were higher than in the maize-bean intercrop after two seasons and in the absence of mid-season drought stress. Both maize and soybean responded significantly to fertilizer application for both districts and for most seasons. The various interventions did not substantially affect various soil fertility-related parameters after five seasons. In the short term, IR-maize integrated in a push–pull system is the most promising option to reduce Striga while the rotational systems may need a longer timeframe to reduce the Striga seedback. Finally, farmer-led evaluation of the various technologies will determine which of those is really most acceptable under the prevailing farming conditions.

Fermount A. M., Obiero H. M., Van Asten P. J. A., Buguma Y. and Okwuosa (2007). Improved cassava varieties increase the risk of soil nutrients mining: an ex-ante analysis for western Kenya and Uganda. *In Bationo et al (Eds), Advances in integrated soil fertility management in sub-Sahara Africa: challenges and opportunities*. pp 511-519

Cassava production in Uganda and western Kenya has been hit hard by the cassava mosaic disease (CMD) epidemic in response, CMD resistant cassava varieties are currently released on a wide scale. The new varieties yield up to three times more than the local varieties these high yield levels will put major pressure on soil nutrients stock. Using a local variety an average farmer will harvest about 10 t/ha fresh roots thereby removing 26 N 3 Kg P and 19 kg/ha Using a good CMD resistant variety about 10 kg/ha the same farmer can harvest a 30 t /ha thereby removing 83 kg N 10 kg of N and 47/ha. If stems are used for planting material and or firewood then removal increases to 216 kg of N 22 kg of P and 102 kg of K/ha of CMD resistant varieties. Soils in western Kenya and Uganda are predominantly Ferrasoils acrisols and Nitisols old weather soils with small nutrient stocks. Without the use of fertilizers the rapid depletion of soil nutrients stocks seems unavailable with the new varieties. This will eventually result in to yield decline of cassava and rotational crops. The question arises when rotational crops are suitable for cultivating crops with high nutrients demand. However production levels of bananas the other

important food crop in Uganda have been sustained for half a century on several parts of the country despite K requirements (142 kg/ha /farmer) of good yield bananas fields maintain varieties have already triggered its promotion as a cash crop provided that there is a good industrial market outlet, farmers can be motivated to use targeted organic & inorganic fertilizer to prevent soil fertility depletion

Kihara J., Kimetu J. M., Vanlauwe B., Bationo A., Waswa B. and Mukalama J. (2007). Optimizing crop productivity in legume-cereal rotations through nitrogen and phosphorus management in western Kenya. *In: Bationo et al (Eds) Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities.* 493-501

Combined application of organic resources and mineral inputs is integral to sustainable soil fertility management but in-situ production of adequate organic matter is often limited by P availability. An experiment was set up at Nyabeda in Western Kenya aimed at (1) quantifying the contribution of herbaceous and grain legumes to nitrogen supply in a cereal-legume rotation system and (2) quantifying the impact of targeting phosphorus (P) to certain phases of the rotation on overall maize grain yield. In this split-split plot experiment, *Mucuna pruriens* was used as the herbaceous legume while soybean was used as grain legume. Results obtained in the two seasons of the study indicated that the use of either mucuna or soybean as previous crop significantly increased maize grain yield with or without the addition of nitrogen fertilizer. More than 5 tons /ha of maize grain yield was realized in season two following the addition of phosphorus fertilizer at both season one and season two compared to about 3 tons /ha of maize grain yields obtained when no P was added. It could be concluded that this region, the addition of P fertilizer is an integral management option to ensure optimal utilization of the nitrogen fixed by the legume crop. Using P during the legume season may be sufficient to supply P requirements to the succeeding cereal crop. Also applying P to the mucuna or soybean legume crop was not any different from applying it both to the legume and cereal crops indicating that farmers can save labour and cash by applying P only to the legume. The good performance of maize planted after mucuna was an indication that mucuna could be used by farmers in the region as an N source (Nitrogen Fertilizer Equivalency (NFE)>100 kg N /ha) thus reducing cost of buying N fertilizers. Although soybean showed a lower NFE of 40 kg N /ha, it had higher economic benefits and could thus be more acceptable to the farmers. These findings can be confirmed by using more than two cereals and legume rotation cycles.

Kimetu J. M., Mugendi D. N., Bationo A., Palm C. A., Mutuo, Kihara P. K., Nadwa J. S., Giller K. (2007). Partial balance of nitrogen in a maize cropping system in humic nitisol of Central Kenya. *In Bationo et al (Eds), Advances in integrated soil fertility management in sub-saharan Africa: challenges and opportunities* pp 521-530

The application of nitrogen in a soil under agricultural production is subject to several pathways including de-nitrification, leaching and recovery by an annual crop. This is as well influenced by the management practices .Nitrogen source and soil conditions. The main objective of this study was to investigate the loss of nitrogen N through nitrous oxide (N_2O) emission and mineral N leaching and uptake by annual crop as influenced by the N source. The study was carried out at Kabete in Central Kenya Measurement were taken during the second season after Two seasons of repeated application of N as urea and *Tithonia diversfolia* (Tithonia) leaves. Results obtained indicated that nitrous oxide (N_2O) emissions at 4 weeks after planting were as high as 12.3 μ N m^2 /h or Tithonia treatment and 2.9 μα N m^2 /h for urea treatment. Tithonia green biomass treatment was found to emit N_2O at relatively higher rate compared to urea treatment. This was only evident during the fourth week after treatment application. Soil mineral N content at the end of the season increased down the profile. This was evident in the three treatments (Urea, Tithonia and control) investigated in the study. Urea treatment exhibited significantly.

Kimiti J. M., Esilaba A. O., Vanluawe B., Bationo A. (2007). Participatory diagnosis in the eastern drylands of Kenya: are farmers aware of their soil fertility status? *In: Bationo et al (Eds) Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities.* 961-967

A participatory diagnosis (PD) was carried out in Makueni District, eastern Kenya, with a view of identifying farmer awareness on soil fertility status as to identify gaps for research on soil fertility improvement. The results indicate that farmers are aware of soil types, soil characteristics, soil fertility status and soil distribution of different soil types in their villages. In addition, the farmers are aware of declining soil fertility, which they attributed to soil erosion, continuous cropping, poor methods of cultivation and inadequate farm inputs. The farmers use farmyard manure to improve soil fertility and are aware of the quality of different manures used in their farms. The types of farmyard manures as ranked by farmers in decreasing quality are poultry manure> goat manure > cattle manure. However it was revealed that cattle manure is commonly used because it is readily available though not adequate. Crop residues, especially those of grain legumes, are also used for soil fertility improvement. In this paper the results of farmer participation research meetings with emphasis on soil fertility management in eastern Kenya are discussed.

Odera M. M., Kimani S. K., Esilaba A. O., Kayaire J. M., Mwangi E. and Gachanja E. (2007). Factors determining integrated soil fertility management in Central Kenya highlands: Participatory Learning and Action Research (PLAR) model analysis. *In Bationo et al (Eds), Advances in integrated soil fertility management in Sub-Sahara Africa: Challenges and opportunities* pp. 1019-1025

This paper presents the results of a participatory learning and action research (PLAR) model analysis of factors determining integrated soil fertility management among subsistence smallholders in central highlands of Kenya. The data was collected during three days PLAR model guided focus group discussions in Mukanduini village of Central division Kirinyaga district in Kenya. The objectives of the study were: 1) to guide farmers through participatory identification and ranking of key socio-economic and bio-physical factors that influence integrated soil fertility management (ISFM), and 20 to guide farmers through participatory identification and ranking of probable solutions to identified problems. The PLAR model analysis of the study was able to categorize the farmers in the village into three groups on the basis of existing ISFM on their farm holdings, and on wealth status. The key community-level factors constraining ISFM were: rainfall/moisture, low crop yields, poor markets, and low livestock yields. The farm-level factors constraining ISFM were identified to be: lack of proper soil water conservation methods, lack of adequate soil nutrient amelioration, improper soil residue management, and poor tillage systems. Suggested solutions included increased use of inorganic fertilizers, optimal quantities of inorganic inputs. proper management and use of crop residues incorporation of agro-forestry species in cropping system, practicing crop rotation, installation of soil and water conservation measures, deep tillage, and planting crops like cassava and sweet potato, which give reasonable crops yields in poor soils.

Onduru D. D., Chris Du Preez C. (2007). Spatial and Temporal Aspects of Agricultural Sustainability in the Semi-Arid Tropics: A Case Study in Mbeere District, Eastern Kenya. *Tropical Science,* (3), 134-148

A study was conducted in the semi-arid Mbeere district, Eastern Kenya, to determine spatial and temporal variability of crop yields and climatic factors and their impacts on sustainability of semi-arid agriculture. Spatial aspects were assessed by conducting a survey of on-farm crop yields and using a computer model (QUEFTS) to predict maize yields from soil chemical indices. Temporal aspects were studied using time -series data (rainfall, temperature and crop yields). The study did not find a significant correlation between farmers' actual yields and QUEFTS predications, and soil nutrients were thus not the only factors influencing maize yields in the study area. Other yield -reducing factors (climate and management) not accounted for in the QUEFTS model played a role. Grain yields of staple food crops were highly variable, Fluctuating in time and space, and suboptimal. Particular aspects of rainfall (e.g. the short rains, for cowpeas and beans) were more important than mean annual rainfall in determining crop yields, and factors other than rainfall and soil fertility apparently played a role. The observed low grain yields, large yield gaps and high rainfall variability challenge the sustainability of these farming systems.

Saha H. M. (2007). Improving resource use under maize-green manure legume systems in Coastal lowlands Kenya. PhD Thesis, Jomo Kenyatta University of Science and Technology, Kenya

The potential of the maize-mucuna intercropping system for increasing maize yields in coastal lowland Kenya has been demonstrated but little effort has been made to minimize its depressive effect on maize yields, while ensuring adequate legume dry matter (DM) production. The effectiveness of this system over sole cropping of maize or rotating mucuna with maize has not been evaluated. A study was therefore conducted in coastal Kenya to determine the effect of strategic modifications of the system to avert the yield depression associated with intercropping, and also on its effectiveness. Factorials of two densities for intercropped mucuna and three times of intercropping the legume with maize were evaluated between the 2002 LR and 2004 LR cropping season, inclusive. Sole cropped maize (control) and mucuna-maize rotation treatments were also evaluated. Data was collected from three replicates. The yields were analyzed using SAS to correlate mucuna and DM yield and maize grain, Stover and DM yields. Intercropped mucuna planted two weeks after planting maize produced 72-74% (3.9-4.1 t DM /ha) of the legume monocrop yield (5.5 t DM/ha), irrespective of the legume density. A four-week delay in under-sowing mucuna to maize increased the grain and stover yields of intercropped maize by 26-42% (0.58-1.07 t/ha-1) and 24-47% (0.43-0.47 t/ha), respectively. A similar delay also reduced the loss in maize grain and stover yields due to intercropping from 30-41% (1.11-1.55 t/ha) to 1-25% (0.04-0.97 t/ha) and from 15-42% (0.63-1.30 t/ha) to 0-28% (0-0.87 t/ha), respectively. Maize-mucuna intercropping systems in which the legume was planted same time with maize or two weeks later had consistently high land equivalent ratio (LER≥1.5), indicating high resource use efficiency. Economically, intercropping systems in which mucuna was planted at a density of 20, 000 plants /ha were more beneficial (net benefit ranging from Kshs. 24,645 to 26,012/ ha) than those systems with the legume planted at 40, 000 plants /ha (net benefit ranging from 15, 654 to 22, 758 /ha), and were nearly as beneficial as sole cropped maize (with net benefit of Kshs. 24,548). However, agronomic data showed that the low mucuna density would lead to poor ground cover and increased biomass production of Cyprus weed. It is therefore recommended that intercropped mucuna be under-sown two weeks

after planting maize since this would ensure minimum reduction in the yields of each of the two crops (<30%). Although a low mucuna plant density was found to have greater economic benefit than high density (40, 000 plants /ha), the latter would be more appropriate and is therefore recommended since it would ensure adequate ground cover and weed suppression. From the results of the study, it can be recommended that maize be grown under continuous maize-mucuna intercropping system since this system improved fertilizer-N use efficiency and gave annual cumulative maize grain yields that were over 75% of those from continuously sole cropped maize.

Tittonel P., Shepherd K. D., Vanlauwe B. and Giller K. E. (2007). Unravelling the effects of soil and crop management on maize productivity in smallholder agricultural systems of Western Kenya-An application of classification and regression tree analysis. *Agriculture Ecosystems and Environment Journal* Vol. 123: 137-150

To guide soil fertility investment programs in sub-Saharan Africa, better understanding is needed of the relative importance of soil and water management factors in determining small holder crop yields and yield variability. Spatial variability in crop yields within farms is strongly influenced by variations in both current crop management (e.g. planting dates, fertilizer dates) and soil fertility. Variability in soil fertility is in turn strongly influenced by farmers past soil and crop management. The aim of this study was to investigate the relative importance of soil fertility and crop management factors in determining the yield variability and the gap between farmers' maize yields and potential yields in western Kenya. Soil fertility status was assessed on 522 farmers' fields on 60 farms and paired with data maize-yield and agronomic management for a sub-sample 159 fields. Soil samples were analyzed by wet chemistry methods (1/3 of the samples) and also by near infrared diffuse reflectance spectroscopy (all samples). Spectral predictions models for different soil indicators were developed to estimate soil properties of the 2/3 of the samples not analyzed by wet chemistry. Because of the complexity of the data set, classification and regression trees (CART) were used to relate crop yields to soil and management factors .Maize grain yields for fields of different soil fertility status as classified by farmers were poor, 0.5-1.1; medium, 1-1.8, high, 1.4-2.5 t /ha. The CART analysis showed resource use intensity, planting date, and time for planting were the principal variables determining yield, but at low resource intensity, total soil N and soil Olsen P became important yield determining factors. Only a small group of plots with high average grain yields (2.5 t/ha; n=8) was associated with the use of nutrient inputs and good plant stands, whereas the largest group with low average yields (1.2 t/ha; n=90) was associated with soil Olsen P values less than 4 mg/kg. This classification could be useful as a basis of targeting agronomic advice and inputs to farmers. The results suggest that soil fertility variability patterns on smallholder farms are reinforced by farmers investing more resources on already fertile fields than infertile fields. CART proved useful tool for simplifying analysis and providing robust models linking yield to heterogeneous crop management and soil variables.

Kiraithe C. K. (2006). The influence of conventional and MBILI (maize-legume) intercropping system on yield. Nutrient uptake and rooting characteristics of intercrops in western Kenya. Msc. Thesis, Moi University, Kenya.

There were significant differences of legume yields depending on cereal proximity and nutrient level across all sites ($p<0.001$). Bungoma 2003 (long rains) had the highest groundnut grain yields, ranging from 430 to 893 kg /ha for the MBILI control and MBILI fertilized plots, respectively while the ground nuts within conventional fertilized plots ranged between 255 to 659 kg /ha respectively. Maize yields were relatively high in Siaya 2003 (long rains) than in other sites and seasons with MBILI at 150 kg DAP/ha (27 kg N/ha 30 kg P/ha) within maize groundnut intercrop giving the highest yield 4218 kg/ha. The N and P uptake in the legume and maize in all the sites were significantly ($p<0.001$) affected by nutrient level and row arrangement. Root density was higher and roots grew deeper in the MBILI system than in the conventional system Thus roots in the MBILI system were able to access N at deeper layers and therefore reduce dependency on N fixed leading to a greater overall resource capture significant difference of root density between the plough layer and subsequent depth was noted within the two intercropping system ($p<0.001$). This study indicated that application of 27 kg N/ha and 30 kg P/ha significantly ($p<0.001$) increased maize, bean and groundnut grain yields. Thus response showed that 1 high crop yield can be obtained through soil nutrient relationship and intercropping with suitable legumes because of their ability to fix appreciable amounts of nitrogen 2. Superiority of MBILI can be explained in terms of the higher root density and its ability to root deeper and is therefore able to forage for nutrients and water in deeper soil horizons. A steady increase in nutrient uptake was observed in fertilized MBILI, It is recommended that this practice be popularized among smallholder farmers moreover to plant maize and legume intercrops following this system so as to reduce on labour cost, In addition more research work is needed to establish the levels of nutrients down the soil profile and their acquisition by the MBILI deep rooting.

Njoka N., Njarui M., Abdulrazak S. and Mureithi J. G. (2006). Effects of intercropping herbaceous legumes with Napier grass on dry matter yield and nutritive value of the feedstuffs in semi-arid region in semi-arid region in Eastern Kenya. *Agricultura Tropica ET Subtropica Journal* Vol. 39 (4)

Semi-arid region is faced with inadequate quantity and low quality of livestock feeds. Research was conducted in the semi-arid region of eastern Kenya to investigate the contribution of two legumes, seca (*Stlylosanthes scabracv. Seca*) and Sirato (*Macroptilium atropurpureuem cv. Sirato*) to seasonal total fodder productivity and nutritive value when intercropped with napier grass(*Pennisetum purpurem cv. Bana*) The treatments consisted of napier grass planted as pure stand and intercropped with legumes. During the production phase, the grass and legumes were harvested for dry matter yield after every 8 weeks for a period of four wet seasons and two dry seasons between April 2002 and September 2004. Overall total herbage yield of the mixtures was higher than those of sole fodder grass with the grass constituting the major component of the yield. Seca was more productive and had a relatively stable yield than Siratro. It accounted for higher proportion of total DM yield of 15-34% in Napier compared to Siratro which had less than 5% except in the drier season when yield failed. Total DM yield was highest during the short rains of year 2002 and declined thereafter in subsequent seasons and was lowest during the dry seasons. It was observed that crude protein of Napier grass was significantly ($P<0.05$) enhanced by inclusion of the legume in the intercrop (CP 9.64-9.96% o DM) compared to sole Napier grass (CP 8.14% of DM). Napier grass intercropped with Seca was more degradable than sole Napier grass. It can be concluded that seca formed a better association with fodder grass than Sirato and is recommended for intercropping in the semi-arid region of eastern Kenya.

Onyango R. M., Kamadi M., Wanyonyi M., Barkuwot J., Ombakho, G. A. (2006). The Effect of spatial arrangements on yield of maize and associated leguminous crop. KARI-Kitale Annual report 53-56

The most commonly intercropped legume in north rift region is common bean *Phaseolus vulgaris*. Having beans in the maize cropping system has on average no effect on grain yield because it does not exert serious competition on it for moisture or nutrients. It was therefore recommended that farmers adopt the pattern with the highest bean population so as to maximize their yields. This was either through the improved production technology where one row is planted between maize rows or the modified improved production technology where one row is planted between maize rows with intra row spacing of 15 centimeters 2 plants per hill. Due to farmer circumstances and experience many farmers have still not adopted these packages. They continue with their current practice of planting in the same hole alternately in the same row one been row between two maize rows but at a lower population combination of the above patterns and random bean planting. Besides not using the recommended arrangements few farmers use fertilizer or control pests and diseases in beans. Low bean yields have been further aggregated by continuous production of maize and beans on the same piece land leading to bean diseases. It was therefore due to the above facts that the spatial arrangement issue was revisited in an attempt to convince farmers on not only how to maximize bean yields in a maize cropping system but also to identify other legumes other than common beans that can fit in the system. Apart from common beans other legumes like soybean-Nyala *glycine max* and cowpea *Vugna unguiculata* were introduced as alternative to common bean to see whether they can do better and also be able to break the disease cycle that comes as a result of continuous cropping of the same crop every year.

Onyango R. M., Mwangi T., Kamindi M., Wanyonyi M., Barkutwo J., Ombakho G. A. (2006). On farm verification of spatial arrangement of maize and common beans. KARI-Kitale Annual report pp 56-58

Due to sub- division of agricultural land over the years they have been forced by circumstances to intercrop their land. The most common type of farming system is that of maize and a leguminous crop. It is not usual to find maize intercropped with the common beans. A recommendation package for such a system is available and over the years surveys have indicated very low yields of bean crop. The low yields of bean crop are invariable due to the shading of beans by the much teller maize plants as well as the non adoption of research developed technologies. Research in the early eighties show that increasing the intra row spacing of maize (from 30 cm- 90 cm) and increased the number of maize plants per hill from one to three did not have any effect on maize yields. These arrangements would however allow more light to reach the shorter bean plants to the extent that their yields may increase. It is therefore important to verify the earlier results with farmers on a wider agro- ecological zone for enhanced adoption so that future food shortages are addressed.

Tittonel P., Vanlauwe B., Ridder N., Giller, K. E. (2006). Heterogeneity of crop productivity and resource use efficiency within smaller holder Kenyan farms: Soil fertility gradients or management intensity gradients. *Agricultural systems Journal* Vol. 94: 376-390

The decrease in crop yields at increasing distances from the homesteads within smaller holder farms of sub-Saharan Africa (SSA) is normally ascribed to the existence of within farm soil gradients. Field observations also suggest that a large part of such variability is concomitantly caused by poor agronomy. To understand the interaction between

soil fertility (S factors) and management decision (M factors) affecting crop variability, we combined field research conducted in western Kenya(Vihiga, Kakamega, and Teso districts; rainfall: 1600,1800 and 1200mm, respectively) with explorations using the simple dynamic soil model for dynamic simulation of nutrient balances, previously tested for the region. Field measurements indicated within farm differences in average maize grain yields of 48% (2.7 vs. 1.4 t /ha) in Teso, between fields that were close and far from the homesteads, respectively. Extreme values ranged widely e.g. between 4.9 and 0.3/ha for all the farms surveyed in Vihiga, where the average farm size was 0.6ha. Maize grain yields tended to increase with increase with increasing contents of soil C, total N, extractable P and exchangeable bases. However, the negative relationship between S factors and distance from the homestead was not as strong as expected, and yield variability was better explained by multiple regression models considering M factors such as planting dates, plant density, resource use and weed infestation(40-60% across sites). Then we analyzed the variation in resource (cash, labour, N) use efficiency within farms of different resource endowments with the aid of the simulation model. N balances at the plot scale varied from ca. +20 to -18 kg/ha, from -9 to 20 kg/ha and from -16 to -18 kg/ha for the different fields of high, medium, and low resource endowment case study farms, respectively. Labor productivities ranged between ca. 10 and 38 kg grain man/day across field and farm types. The results indicate the need of considering within farm heterogeneity when designing soil fertility management interventions. Resource use efficiency was strongly affected by soil quality. As farmers invest more effort and resources in the more productive and less risky fields, the interactions between S and M factors leads to farm driven resource use efficiency gradients within smallholder farms.

Tittonell P., Vanlauwe B., Leffelaar P. A., Shepherd K. D. and Giller K. E. (2005). Exploring diversity in soil fertility management of smallholder farms in western Kenya II. Within-farm variability in resource allocation, nutrient flows and soil fertility status. ***Agriculture, Ecosystems and Environment*** **Volume 110, pp 166-184**

Strong gradients of decreasing soil fertility are found with increasing distance from the homestead within smallholder African farms, due to differential resource allocation. As nutrient use efficiency varies strongly along these gradients, such heterogeneity must be considered when designing soil management strategies, aimed at improved overall resource use efficiency at farm scale. Here, we quantify the magnitude and study the origin of farmer-induced, within-farm soil fertility gradients as affected by biophysical and socio-economic conditions, and investigate farmers` perceptions of such heterogeneity. Farm transects, participatory resource flow mapping, farmers` classification of land qualities, and soil sampling for both chemical and spectral reflectance analyses were performed across 60 farms in three sub locations (Emuhaya, Shinyalu, Aduleka) representing the variability found in the highlands of western Kenya. Differences between the various field types of a farm were observed for input use (e.g. -0.7 to 104 Kg N /ha), food production (e.g. 0.g -2.9 t DM/ha), partial C (e.g. -570 to 1480 Kg /ha) and N (e.g. -92 to 57 Kg /ha) balances and general soil fertility status, despite strong differences across sub-locations. Concentration of nutrients in the home fields compared with the remote fields were verified for extractable P (e.g. 2.1 to 19.8 mg /Kg) and secondarily for exchangeable K (e.g. 0.14 to 0.54 cmol (+)/Kg), on average, whereas differences for soil C and N were only important when considering each individual farm separately. Farmers managed their fields according to their perceived land quality, varying the timing and intensity of management practices along soil gradients. Fields classified by them as poor were planted later (up to 33.6 days of delay), with sparser crops (ca. 30% less plants /m) and had higher weed infestation levels than those classified as fertile, leading to important differences in maize yield (e.g. 0.9 versus 2.4 t /ha). The internal heterogeneity in resource allocation varied also between farms of different social classes, according to the objectives and factor constraints. Additionally, the interaction of sub-location-specific socio-economic (population, markets) and biophysical factors (soils cape variability) determined the patterns of resource allocation to different activities. Such interactions need to be considered for the characterization of farming system to facilitate targeting research and development interventions to address the problem o poor soil fertility.

Kimurto P. K., Kinyua M. G., Ogola J. B. O., Macharia J. M. and Njau P. N. (2004). Physiological Traits Associated with Drought Tolerance in Bread Wheat (Triticum Aestivum L.) under Tropical Conditions. ***Proceedings of the 12th Regional Wheat Workshop for Eastern, Central and Southern Africa*** **Nakuru, Kenya, pp: 96-108**

Although it is generally accepted that drought tolerance is critical agronomic trait, efficient and predictable improvement in drought tolerance in bread wheat (*Triticum aestivum* L.) has not yet been achieved. Evaluating the responses of physiological traits associated with drought responses of bread wheat varieties grown in marginal rainfall areas. This study assessed the drought response of bread wheat using physiological traits associated with drought tolerance that may be used for selection. Two experiments (under the rain shelter and in the field) were carried out, each for two seasons (2001/2002). The rain shelter experiment simulated rains at three watering regimes: low (210 mm), medium (240 mm) and high (270 mm). **Significant genotypic variation conductance, transpiration rates and CO_2 assimilation**. Under dry conditions, these were identified as key control points in determining the drought resistant tolerant genotypes. These traits could also be responsible for sustained survival and facilitated recovery after re-watering. Thus their use as selection criterion in breeding for drought tolerance is promising. In these respects, the genotypes R960, KM14, R963, and R965 were the most promising candidates

with superior physiological traits and high grain yield. All of the genotypes were compared with the commercial checks Duma and Chozi. A need exist to determine the heritability of these traits to realize their potential usefulness in a breeding program.

Woomer P. L., Lang'at M. and Tungani J. O. (2004). Innovative maize legume intercropping results in above and below ground competitive advantages for understorey legumes. *West African Journal of Applied Ecology*, Vol. 6

Maize-bean intercropping (*Zea mays* with *Phaseolus vulgaris*) offers advantages to small holder farmers in terms of crop diversity and risk avoidance, but continued reliance upon this practice has resulted in poor yields and widespread pests and diseases of bean in the small hold growing areas of western Kenya. We are attempting to modify intercropping in a manner that will allow for legume maize-legume intercrop rotation as a means of disrupting pest cycles and improving the opportunities for symbiotic nitrogen fixation. The system, known as MBILI, based upon staggering every other maize row by 25 cm, and growing legumes in the resultantly wider inter-row, holding constant population of maize (444,444 plants /ha) and legume (88,888 plants /ha). This adjustment allows for intercropping legumes other than bean, particularly green gram (Vigna aureus) and groundnut (*Arachis hypogaea*), both of which have higher light requirements and greater capacity for symbiotic N-fixation than beans. MBILI was compared to conventional intercropping during a series of on-farm experiments conducted over four growing seasons (2000 and 2001) in Western Kenya. MBILI resulted in greater Land Equivalency Ratios than conventional intercropping, 2.0 vs. 1.7($P<0.001$), (2000 short rains, calculated from crop value). Combined results from the 2000 and 2001 short rains were Ksh 48,752 crop /ha for MBILI and Ksh 28,661 crop/ha for conventional intercropping, at otherwise same management. MBILI with groundnut increased crop value during three growing seasons between 2000 and 2001 to Ksh 62, 072 crop^{-}/ha compared to conventional maize-bean intercropping (Ksh 41,810), again under the same pair wise management. Some of these benefits are attributable to 54% greater light penetration to the legume under storey observed with MBILI (+20, 934 LUX) averaged throughout the day), an obvious above ground advantage. MBILI also resulted in greater Fertilizer Use Efficiency (FUE), particularly by maize because side-dressing applications may be more strategically placed. FUE of maize was increased by 46% (+7 kg maize kg N and P) when conventional and MBILI yields are compared (short rains 2000 and long rains 2002). Furthermore, unexpected benefits to MBILI were observed during cropping seasons experiencing mid-and late season drought, where overall maize yield under MBILI was 25% greater (+370 kg/ha), suggesting advantageous root distribution (2000 and 2001 short rains). Clearly, the benefits from MBILI include more than readily "meets the eye".

Tittonell P. (2003). Soil fertility gradients in smallholder farms of western Kenya. Their origin, magnitude and importance. Msc. Thesis, Wageningen University

Soil fertility depletion in smallholder farms is the main biophysical process explaining the decline in per capita food production in Africa. Such a process, which is the result of continual export of produce and lack of external inputs into the farm, is not homogeneously distributed in space. Variability in soil fertility arises from differences in underlying geology and geo-morphology, and due to a number of mechanisms within the farming systems. Such is the case of the net flow of resources, which is not equal for the various fields belonging to a single farm household, creating areas of carbon and nutrient accumulation and depletion. Additionally, those nutrient flows vary strongly between farmers of different social status. The biophysical processes involved in the inherent productivity of the soils and in the mechanisms of response to interventions are subjected to this spatial heterogeneity in soil quality, defined here as soil fertility gradients. Therefore, the existence of such gradients within smallholder farms must be considered when designing integrated soil fertility management strategies. This thesis was developed with the overall goal of identifying and defining spatial-temporal niches for targeting soil fertility strategies, and with the objectives of (i) quantifying the magnitude of the soil fertility gradients, (ii) documenting the factors driving farmers decision making processes that lead to their establishment, (iii) assessing their impact on crop productivity and (iv) studying the potential of simulation models as an approach to evaluate the effect of alternative management practices. Additional objectives, which were necessary to characterize the system under study, responded also to the information needs for the development of NUANCES, the framework project into which this thesis was carried out. Potential answers to the research questions were formulated into the hypotheses that are summarized as follows. The soil fertility gradients are originating from the inherent productivity plus the effect of the differential management practices that farmers consequently apply. The magnitude of such gradients, strongly affected by (site-specific) biophysical and socio-economic conditions, is sufficiently large to affect the basic soil and plant processes that dictate the efficiency of resource use and capture within the system. Their importance should be recognized (exactly as farmers do) and they should be targeted when designing soil fertility management strategies. The various sources of variability affecting soil fertility and operating at different scales were categorized as Site-specific factors, Wealth, Inherent biophysical properties and Management factors. The methodological approach combined different techniques to study these. Three sites

(Emuhaia, Shinyalu and Aludeka) were selected in western Kenya to represent the regional variability in terms of the SWIM factors. Background information and expert knowledge, transect walks and soil scape delineation, and 'first-approach' interviews were used to describe and categorize the socioeconomic and biophysical variability at different scales. A farm typology was developed according to household wealth, objectives and factor constraints. The concept of farm developmental cycle and the importance of off-farm income were also considered in the farm stratification. Interviews, farmers' rankings and resource flow maps, complemented with partial nutrient balances, conducted at case-study farms were used to identify resource allocation patterns. Allometric models were developed to estimate on-farm maize yields from non-destructive plant measurements. All aspects of crop husbandry (i.e. the 'management' factors) were recorded for the (geo-referenced) points where the plant measurements were taken. The biophysical characterization of the fields included slope and area measurements, soil profile observations and soil sampling for analysis by standard methods and by spectral reflectance. Ten soil fertility indicators plus a spectral soil fertility index were used in combination with a number of indexes representing the various management factors to build multiple linear regression models to explain maize yield variability. A dynamic simulation model combining well-known and relatively data-undemanding sub-models to calculate nitrogen balances at plot scale was developed in a FST (Fortran Simulator Translator) format. The model was parameterized with the field data and simulation scenarios were developed from the resource flow map information. The model was run to study the synergistic effect of soil fertility and management factors and to illustrate the importance of the soil fertility gradients in determining the efficiency of resource use when different management strategies are applied. Widely different resource allocation patterns at farm scale were identified when the between-farm variability was categorized by adding household objectives and factor constraints to the wealth ranking criteria. The type and magnitude of the off-farm income (labour: income ratios) had an important impact on the nutrient flows to and from the farm. Five farm types were identified. The small and wealthy type 1 farms, largely dependent on off-farm income, tended to remove their land and labour limitations by hiring in those factors and to increase their production by intensification (i.e. input use). The large, wealthy and market-oriented type 2 farms had the highest variability in land quality and production activities, acquiring labour and inputs from the market. The relatively large, self-subsistence and labour-limited type 3 farms had the largest grain production under a low-input situation, selling their surpluses on the market, and often alternative (seasonal) enterprises were observed in those farms (e.g. oxen services, buying and retailing grains at farm gate). The land-limited type 4 and type 5 farms differed in their factor allocation strategy. Type 4 farms had basically a similar strategy as that of type 3, but were not self-sufficient in grain production. The poorest type 5 farms sold most of their labour to the wealthier farm types. The resource flow maps conducted at case-study farms of those types revealed differences in food production, fertiliser use and crop residue management between farm types and between field types within a farm. Particularly for the poorer types (4, 5 and to some extent 3) areas of depletion and accumulation of C and N were revealed by the partial nutrient balances. The home gardens sustained an important proportion of the food production and some cash crops in those farm types. A notoriously different intensity of resource use was observed for the different land quality classes (i.e. 'fertile', 'average' and 'poor') identified by farmers in all farm types. Despite the district surveys and the interviews indicated that most farmers used fertilisers, the partial nutrient balances were negative, indicating that the amounts used are not sufficient to compensate the amounts of nutrients removed from the fields and exported from the farm. Differences in soil fertility between sites were mainly explained by inherent properties, such as soil texture, which determined to a large extent the C and related total N and P contents, and the effective cation exchange capacity of the soils. At farm scale, certain nutrients such as P and K showed important differences between field types, due to concentration of resources and use of ash inputs in the fields near the homestead. Indicators such as soil C and pH varied strongly at farm and at individual field scales, though such differences were not reflected by their average values (n = 20 farms per site). Most soil fertility indicators varied between the land quality classes ranked by farmers. The nutrient status of most soils sampled was below the critical limits given in literature, which was confirmed by the negative values of the soil fertility index (SFI) obtained by spectral reflectance. However, the SFI explained a disappointingly small amount of the maize yield variability. Instead, the intensity of resource use, particularly in the densely populated areas, explained ca. 50% of that variability. Other *management* factors explained between 40 and 60% of the yield variation. They differed between farmers' land quality classes, and were associated to some extent with the various soil fertility indicators and with the distance from the homestead. Up to 85% of the maize yield variability was explained by the combination of soil fertility and management factors. Their relative importance as explanatory variables differed from site to site, depending on the socio-economic and biophysical backgrounds. Nevertheless, these results indicated that management factors are inextricably related to (farmer perceived) land quality in general, and to soil fertility in particular. The interrelationships and their synergistic effects of the various SWIM factors could be also illustrated with use of the simulation model. The N balance proved an interesting overall resource use efficiency indicator that can be temporally aggregated to reveal trends in N depletion and accumulation when adopting a certain management strategy. Variations in the resource use

efficiency indicators revealed widely different results for the various fields of a farm when 'blanket' management strategies were simulated, indicating that the magnitude and complexity of the soil fertility gradients should be considered when designing such strategies. The interaction of factors and the processes leading to the establishment and maintenance of the soil fertility gradients were summarized in a conceptual 'resource allocation cycle'. The implication of such a cycle for the characterization of farm system previous to the development of farm models, and the importance of considering the soil fertility gradients in that respect, were exemplified with the results of this thesis. Conclusions were drawn from the adaptation of the original methodology, which helped in increasing the understanding of the managerial aspects of the household that affect the origin and magnitude of the soil fertility gradients. From the assessments of the variability in crop performance and in resource allocation it was concluded that it is impossible to unravel the effects of soil fertility and management, and that their relative importance vary from site to site, strongly influenced by population density, access to markets and to off-farm income. In line with these observations, it was further concluded that in densely populated areas the intensity of input use overrides the inherent properties in determining the origin and magnitude of the soil fertility gradients. In contrast, in sparsely populated areas and with higher variability in soil types the resource allocation pattern emerges from the perceived land quality, normally operating in the direction of increasing the magnitude of the soil fertility gradients.

Woomer P. L. and Tungani J. O. (2003). Light availability within an innovative maize-legume intercropping system in Western Kenya. *African crop science conference proceedings* Vol. 6 42-46

An experiment was conducted in western Kenya to characterize the penetration of solar radiation into the canopy of different maize-bean intercropping systems. The conventional system consisted of alternating 37.5 cm rows of maize and beans. A staggered system contained the same plant population but was planted as paired maize and beans rows. Rows were oriented either east-west or north-south. The experiment was oriented as a 2 x 2 factorial in a completely Randomized design. All treatments received 31 kg N and 20 kg P /ha as mineral fertilizer. Solar radiation was measured at maize tussling at positions above the maize canopy, above the bean under storey and above the soil. Crops were harvested at maturity and yields compared to light penetration patters. Maize yields were affected by neither row arrangement nor orientation and averaged 4.9 t /ha. Bean yields were significantly greater in the staggered row arrangement (+320 kg /ha, $p= 0.021$) but not row direction. Light to penetration to the beans was affected by row arrangement ($p<0.001$) and demonstrated an interaction between row arrangement and time of day ($p<0.001$). Staggering the row arrangement resulted in 20% more light to the under storey legume, an increase of 11500 LUX when averaged throughout the day. The net returns increased by Ksh 5356/ha (US$ 69) in the MBILI compared to the conventional intercropping. These findings suggest that staggered intercrop arrangements offer advantage over the conventional one and that part of that improvement is related to light penetration to under storey legume.

Gesare M. (2002). Effect of intercropping legume with maize on soil fertility and maize yield. *Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects*, June, 2000, Mombasa, Kenya. 193-197

Farmers in Nyamonyo and Nyatieko villages in Kisii District experience low crop yields due to low soil fertility. An experiment was carried out between 1997 and 1998 to determine the effect of intercropping maize with legumes and later incorporating the legume residues into the soil on soil fertility and maize yield. Treatments were laid out in a randomized complete block design with ten farmers serving as replicates in the two sites. The legumes intercropped with maize were soybean, common bean, dolichos, groundnuts and yellow grams. These treatments were intercropped in two maize crop plots, where in one plot legume residues were removed after harvest while the other had the residues incorporated into the soil. Two year results showed that maize intercropped with soybean gave average yield of 3630 kg /ha followed by maize intercropped with yellow gram with 3440 kg /ha at Nyatieko site. At Nyamonyo site maize intercropped with dolichos gave higher average yield of 3350 kg /ha.

Smithson P. C. and Giller K. E. (2002). Appropriate farm management practices for alleviating N and P deficiencies in low-nutrient soils of the tropics. *Plant and Soil* 245: 169–180, 2002.

Tropical upland regions have both the world's highest population growth rates and a preponderance of soils less suitable for agriculture. Nitrogen deficiency is almost universal, while acid infertility and the related problem of P deficiency affect more than 40% of tropical soils. Nutrient depletion, as opposed to inherent infertility, affects large areas due to continuous cropping with few inputs. Nitrogen management requires a continual supply of N that can be achieved through fertilization, green manuring, legume rotations or leguminous tree-shrub fallows. Rotations and fallows usually require foregoing one or more staple crop harvests, which is not feasible for smallholder farmers in land-limited areas. In such areas there are few options for farmers except mineral N

fertilizers. Phosphorus availability can be built up in soils, but to achieve this, external inputs of inorganic P are essential. Use of P-efficient crops, or mobilisation of soil organic P by various means, are temporary solutions since they involve only off take with no addition. Phosphorus additions may be either as soluble processed fertilizers or indigenous phosphate rocks (PRs). Most tropical PR deposits are unreactive and require processing before use. Some lower-cost options include partial acidulation, blending with soluble P sources or microbial solubilization. The relevance of microbial solubilization in particular requires testing at larger scale. There are no magic solutions to soil nutrient deficiencies or toxicities; to maintain productivity mineral fertilizers are necessary. They should be used in judicious amounts and coupled with improved organic matter management.

Cheruiyot E. K., Mumera L. M., Nakhone L. N. and Mwonga S. M. (2001). Rotational effects of grain legumes on maize performance in the rift valley highlands of Kenya. African Crop Science Journal, Vol. 9. No. 4, pp. 667-676, 2001. ISSN 1021-97301200

High fertilizer costs and declining soil fertility are among the key factors contributing to low crop yields in Kenya. The contribution of five legumes grown in the short-rains season to soil nitrogen status and performance of succeeding maize (*Zea mays* L.) was studied in an experiment at Njoro and Rongai within the Rift Valley Highlands of Kenya, from 1997 to 1999. Treatments included a weedy fallow, five grain legumes and maize (H513) grown during short-rains season followed by maize in the April-August long-rains season. The legumes were chickpea (*Cicer arietinum* L.), field bean (*Phaseolus vulgaris* L.), soybean [*Glycine max* (L.) Merril], garden pea (*Pisum sativum* L.), dolichos [*Lablab purpureus* (L.) Sweet]. The crop residues and vegetation of the weedy fallow were incorporated in the soil during seedbed preparation for the long rains season. The maize test crop was supplied with three levels of nitrogen, 0,30, and 60 kg/ha as main factor whilst fallow management options were allocated as sub-factors in a split-plot treatment arrangement of a randomized complete block design replicated three times. Results show improved soil N status following legumes, with dolichos giving highest available N. Grain yield in maize succeeding legumes was 2468% higher than maize succeeding weed fallow. In the absence of N fertilizer input, maize succeeding dolichos gave 20-40% higher yield than maize after weed fallow treated with recommended 60 kg N/ha fertilizer rate. The study has demonstrated that the use of grain legumes, particularly dolichos in rotation with maize, is a viable and preferable option to weedy fallows and maize-maize sequences.

Gemma S., Buresh R. J. and Gregory P. J. (2000). Land use affects the distribution of soil inorganic nitrogen in smallholder production systems in Kenya. *Biol Fertil Soils* Vol. 31: 348-355

We hypothesized that the integration of trees and shrubs in agricultural landscapes can reduce NO_3^- leaching and increase utilization of subsoil N. A field survey was conducted on 14 farms on acid in the sub humid highlands of Kenya, where there is little use of fertilizers, to determine the effect of vegetation types (VT) on soil NH_4^+ and NO_3^- to 4 m depth. The VT included maize (*Zea mays*) with poor growth and good growth, *Markhamia lutea* trees scattered in maize, natural weed fallow, banana (*Musa spp*.) hedge grow, and eucalyptus woodlot. The effect of VT on NH_4^+ was small (<1 mg N/kg) NO_3-N concentrations at 0.5-4m dpth were low beneath hedge grow and wood lot (0.2 mg/kg) intermediate beneath weed fallow (0.2-0.7 mg/kg) banana (0.5 -1.0 mg/kg) and Markhamia (0.5-1.6 mg/kg) and high beneath both poor (1.0-2.1 mg/kg) and good (1.9-3.1mg/kg) maize. Subsoil NO_3^- (0.5-4m) was agronomicaly significant after maize harvest with 37 kg N/ha/m depth beneath poor maize. In contrast, subsoil NO_3^- was only 2 kg N/ha/m depth beneath woodlot and hedge grow. These results demonstrate that the integration of perennial crops can tighten N cycling in agricultural land scopes.

Jeger A. D. E., Kariuki I., Matiri F. M., Odendo M., Wanyama, J. M. (1998). Monitoring nutrients flow and economic performance in African farming systems. (NUTMON) IV. Linking nutrients balances and economic performance in three districts in Kenya. *Agriculture, ecosystem and environment* Vol. 71:81-92

The national level agricultural production in Kenya is characterized, by a negative nutrient balance and a downward trend in food production per capita and can therefore be classified as unsustainable. However, little information is available concerning ecological and economic sustainability of the various production systems at farm level. A one year monthly monitoring activity was conducted in the season 1995/1996 in three districts with the participation of 26 households covering the major existing farming systems in these districts in which data were collected on agronomic and economic aspects of the farm management. The average N balance at the farm level is -17 kg/ha /yr with large variations among farms ranging from -240 kg/ha to + 135 kg/ha; the average K- balance is slightly negative, the P- balance slightly positive. Net farm income shows no relation with the nutrient balance. A high market orientation on the other hand correlates with crop and livestock activities import nutrient through fertilizers and or animal feeds but in sufficient to compensate the out flow though the marketed products leaching and erosion. The annual net income amounts to (US$ 1490/farm with large variation among farms. Average return s to family labour (US$ 2.2/day) and returns to land (US$ 91/ha) are comparable

or higher than unskilled wage rate and annual land rate respectively but 50% of the farm perform below these rate. Market oriented farm have an economic performance that is similar to substance oriented farms. Off farm income however is essential for large groups of small scale farms households to achieve economic viability without additional off-farm income 54% of the farms in the sample are estimated to below the poverty line. The replacement costs of mined nutrients amounts to 32% of the average net income. Nutrients mining levels than the major food crop maize and maize At crop level the cash crop tea and coffee realize higher gross margins and considerably lower nutrient mining levels than the major food crops maize and maize- beans . It is concluded that multi-disciplinary activity at farm level contribute to targeting and prioritization of development options aimed at optimization of soil nutrient management.

Shepherd K. D. and Soule M. J. (1998). Soil fertility management in west Kenya: dynamic simulation of productivity, profitability and sustainability at different resource endowment levels. *Agriculture Ecosystems and Environment* Vol. 71 131-145

A farm simulation model was designed to assess the long-term impact of existing soil management strategies, on farm productivity, profitability and sustainability. The model, which runs in time units of 1 year, links soil management practices, nutrient availability, plant and livestock productivity, and farm economics. A case study is presented of the application of the model to existing, mixed farm systems in Vihiga district, in the highlands of western Kenya. Three representative farm types were developed using participatory techniques to reflect differences in resource endowments and constraints faced by farmers. The model was used to assess the sustainability of the existing systems for three farm types as a basis for recommending improved practices for each. A summary model for calculating new sustainability indicators of soil productivity is presented. The low (LRE) and medium (MRE) resource endowment farms, which comprise about 90% of the farms in the area, have declining soil organic matter and low productivity and profitability. In contrast, the high resource endowment category of farms (HRE) has increasing soil organic matter, low soil nutrient losses and are productive and profitable. Crop nutrient yields were 17, 19, and 86 Kg N /ha year-1 on LRE, MRE and HRE farms, respectively. Soil C, N and P budgets were comprised of 7% of household income in LRE compared with 25% in MRE and 63% in HRE. It is concluded that low land and capital resources constrain the adoption of ecologically and economically sustainable soil management practices on the majority of farms in the area. Strategies are needed to (i) increase the value of farm output (ii) increase high quality nutrient inputs at low cash and labour costs to the farmer, and (iii) increase off-farm income

Gethi J. G. (1991). Effects of plant population and fertilizer residues on grain yield of simsim relayed with maize. *Proceedings of the 2nd KARI Annual Scientific Conference held at Panafric Hotel*, Nairobi, Kenya 5-7th September, 176-179

The growing of Simsim (*Sesamum indicum L.*) by the small holder farmers of Coast Province is usually in a relay system with other crops and mainly maize or cassava. It is also grown between coconuts and other tree crops. The study of the relationship between plant density and residues of fertilizers applied to the main crop on grain yield of simsim revealed that simsim benefits from the fertilizer and obtains high yields. The spacing used of 30 x 15 cm, 45 x 15 cm, 30 x 45 cm, 60 x 15 cm and broadcasting showed that in an intercrop system, the yields of simsim increase with a decrease in plant density. The pattern used of double or single row had no effect on the grain yield of simsim. The spacing of 30 x 45 cm was found to be superior in yields. The traditional method was also found to yield well even without fertilizers.

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Kamindi M., Onyango R. and Mose L. (1989). Evaluation of Herbicides for maize-bean Intercropping. Kenya Agricultural Research Institute (KARI), Kitale

Late and inadequate weed control results in significant yield reduction in maize/bean intercrops. The objective of this trial was to assess the effectiveness of different herbicides as compared to hand weeding. The effective herbicides would be recommended to farmers and will go a long way to casing the labour constraints which cause late and sometimes inadequate weeding in intercrops.

Ochieng J., Mwania N. and Kiiya W. (1989). Evaluation of bean cultivars for suitability in intercropping with maize. Kenya Agricultural Research Institute (KARI), Kitale, Annual report pp. 64-71

Maize-bean intercropping is a common practice by small-holder farmers. Those who interplant recommended maize varieties with a wide range of bean cultivars and have expressed differing views about the performance and other characteristics of these bean varieties when intercropped in different AEZs. The objective of this trial was to determine the growth, disease/pest resistance and yield of various improved bean varieties as compared to local (farmers') cultivars when sole-cropped or intercropped with maize in different AEZS.

Ochieng J. A. W. (1989). Inbred Line Screening Trial (I.L.S.T) Red Line Screening Trial (I.L.S.T.)., Kenya Agricultural Research Institute (KARI), Kitale Annual Report, pp 10-13.

The main objective of this trial was to determine the general combining ability for yield of new inbred lines derived from Kitale synthetic II (R11) cycle 8, Kitale synthetic II(S21) cycle 5, Ecuador 573 (R12) cycle 8 and Equador 573 (S22) cycle 5. This was done by evaluating top cross progenies of the inbred A. The trial was conducted as a (5 x 5) simple lattice of 25 entries at two location viz. Kitale and Chorlim, using standard agronomic practices and field plot techniques. There were significant (P>=0.05) differences between locations for yield, plant stand, ear height, maturity length and lodged plants. Differences among entries were spastically significant (P>0.01) for all characters except percent usable ears. There were no significant entries x location effect, except for yield, stand and percent bare tipped cars. Inbred lines: R11C8-22, R11C8-56, S21C5-65, 821C5-95, R12C8-14,R12C8-66,S12C8-65,S22C5-60 and S22CS -80 were identified as potentially useful lines based on general combining ability for grain yield as well as ear phenotypes of the top cross progenies. In particulate, the cross S21C5-65 X R12C3-93 should be a good single cross hybrid subject to the provision that it shows reasonably high stability in space and time from future evaluation, as it also had one of the lowest incidence of plant lodging, food husk cover and low ratings for leaf blight and rest scores.

Ochieng J. A. W. (1989). Elite Maturity Variety Trial (L.M.V.T.-1) Kenya Agricultural Research Institute (KARI), Kitale, Annual report pp 8-9

The objectives of this trial were to evaluate elite varieties for advancement into the late maturity maize N.P.T. The trial, comprising of 25 entries (including two commercial checks), was conducted as a (5 x 5) lattice in four replications at ten locations spread over the Rift valley and Western Kenya. Yields were highest at Chorlim (109Q/ha) and lowest at Kimilili (45Q/ha). Poor yields were recorded also at K.S.Co., farm at Endebess (69Q/ha) due to late planting, at Kakamega (61Q/ha) due to high incidence of ear rot and at Kipsogon (68Q/Ha) due to unknown reasons. Statistically significant (P>0.01) differences were found among locations as well as among varieties for all characters shown. Variety x location interactions were significant (P>0.05) for grain yield, percent prolificacy, maturity length, plant lodging incidence, and percent usable ears. The commercial checks, ranked in the order of higher yield were: H626 H614D>H625. Five new varieties were statistically at par with H626 in yield, but significantly (P>0.05) out yielded both H625 AND H614D by at least 7.4Q/Ha (10 percent). These were entry nos: - 15,16,17,19 and 22. Entry 16 was good also in terms of high percent prolificacy, low ear placement, early maturity, and low incidence of ear rots and low score for foliar diseases. Any one or all of the five new superior entries listed above may be entered into the 1990 N.P.T for late maturity varieties.

Gethi M., Khaemba B. (1985). The effect of intercropping cowpea (*Vigna unguiculata*) with maize (*Zea mays*) on the incidence and damage caused by the legume pod borer maruca testulalis geyer (*Lepidoptera, pyaralidae*) in Kenya. *East African Agricultural and Forestry Journal* pp 51

Intercropping cowpea and maize and insecticidal application had a significant effect on the distribution of *M.testulalis* larvae. There were significantly (p=0.5) fewer *Maruca larvae* in all intercropped and sprayed pure cowpea plots. The number of pods with damaged symptoms were also found to be significantly (p=0.5) more in all pure cowpea stands indicating that as the number of pods with damaged symptoms per plant. Similarly, the incidence of *Maruca larvae* and number of pods with damaged symptoms were predominantly higher at the edge of intercropped plots where it was relatively warmer than at the central portions of the plots where the shading effects of maize provided cooler and moist conditions.

Gethi M., Khaemba B. (1985). The effect of intercropping cowpea (*Vigna unguiculata*) with maize (*Zea, mays*) on the incidence and damage caused by the legume pod borer Maruca Testulalis Geyer (*Lepidorptera, Pyaralidae*) in Kenya. *East African Agricultural and Forestry Journal* Vol.51 (1)36-40

Cowpea *(Vigna unguiculata (L) Walp*) is an important grain legume in Kenya and serves as one major sources of protein for the majority of the population (Anon., 1978 b). About 67,000 ha were under cowpea production in 1977, out of which a total of 62,000 ha consisted of cowpea grown extensively in mixtures with other crops. About 85% of cowpea is grown in the marginal rainfall areas of Eastern province while 8% is produced in the Coast province and the rest in Nyanza and Western provinces. Cowpea yields in Kenya have ranged from 150 to 500 kg/ha, which is extremely low in view of the fact that yields as high as 1500 kg/ha can be obtained by protecting the crop from pest attack. Flower buds and flower-eating insect pests are the most important species causing considerable damage in all cowpea growing areas in Kenya. Among these species is the legume pod borer *Maruca testulalis* Geyer which is very destructive to the crop during the post flowering stage. In Kenya it is reported that *Maruca testulalis* was a major pest in hot, humid areas of Coast and Nyanza provinces. This paper reports the results of field studies conducted at the Coast Agricultural Research Station Kikambala to assess the effect of intercropping cowpea with maize on the infestation and damage by *Maruca testulalis*.

Allan A.Y., Laycock D. (1976). Maize yields in Western Kenya: Effects of plant numbers per hill and stage at thinning. *East African Agricultural and Forestry Journal* Vol. 42 (2) 141-148

The plant population per unit of area is a major factor which affects maize yields, and large numbers of experiments on populations have been carried out in many countries, particularly in the U.S.A. Reviews of the extensive literature have been prepared by Dungan, Lang and Pendleton (1958), and Downey (1971). In Kenya, Evans (1963), in a survey of maize experiments carried out by the Department of Agriculture, up to 1961, listed 14 spacing trials, the first of which had been done in 1915. On the basis of trials in the Kitale District of Western Kenya from1957-63. Moberly (1963) recommended that the optimum population for the local Kenya Flat White maize in this area was around 30,000 plants /ha. For the late-maturing hybrids which were released for commercial production from 1963 onwards, and which have the greatest yield potential in Western Kenya, Allan (1968) found that the highest yields were obtained over a broad range from 35-50,000 plants/ha, and confirmed that the most practical, standard recommendation for small farmers should be 35,864 plants/ha. (14,520/acre, obtainable with the convenient, parametric spacing of 3 feet by 1 foot). Following metrication, this recommendation became 90 x 30 cm, giving 37,037 plants/ha. Allan (1966) observed that the field germination of even high quality seed is generally not above 85%, and since the cost of planting extra seed is low compared with the potential benefit from obtaining a good stand, farmers were advised to plant at least 20% more seed than the actual number of plants desired. In fact, overplanting by 50% percent or even more is quite often recommended, to allow farmers to thin the stand down to the recommended population. Although practically all these population experiments were done on the basis of establishing one plant at each "hill" or "station" in the rows, a large proportion of the farmers in Kenya grow 2 or more plants in each hill, the hills then being spaced proportionally more widely apart in the rows. Practically all of the experiments in U.S.A on the effects of different hill-planting patterns which were reviewed by Dungan et al. (1958) indicated that there were no significant differences in yields due to planting 1, 2,3 or even 4 plants /hill, provided the populations were the same. Similar findings were obtained in trials in Zambia reviewed by Coxe (199), and in Rhodesia (Maize in Rhodesia, 1970). However, Fayemi (1963) and Chinwuba (1967) in Nigeria, Gonzales and Andes (1966) in the Philippines and Thakur (1968) in Bihar, India found that yields tended to decline when there were 2 or more plants per hill. Therefore, it was decided to carry out experiments on this practice in Western Kenya to determine its effects on yields and other parameters under the local conditions. At the same time, the effects of thinning out surplus plants at various stages were investigated, since thinning is frequently involved in the process of obtaining the recommended stand.

Martin H., Van der zande (1974). Some practical aspects of promoting fertilizer use and related essential agronomic improvements in small scale farming in Kenya. *13th meeting, of the E.A. specialist committee for soil fertility and crop nutrition* 9th -13th September, Nairobi

With over 500.000 acres of small scale hybrid maize planted maize planted, this crop has been taken as the basis for this paper on small scale farming inputs, with emphasis on correct fertilization and related improved agronomic measures. Without the foregoing, hybrid maize on its own is unlikely over to come up to expectations, and on anti-hybrid feeling with all its consequences might result. The problems related to a package deal of hybrid, correct fertilizer and good husbandry are emphasized as being basically input promotion scheme. Any such scheme requires a well-functioning country-wide system of stockists backed up by capable fully trained sales promotion representatives. Stockists in turn require an adequate margin of profit if availability of input supplies is to meet demand at the right spot. The present world economic crisis might well lift future fertilizer prices beyond the purchasing power of the average small scale farmers particularly if related to local producer commodity

prices. Unless something is done about local producer price and or a special fertilizer subsidy for small scale farmers. Past efforts to raise small scale farming to a high modern level of economic farming which have so far been encouragingly successful might well prove to have been wasted. The economy of the country can all afford any retrogression in small scale farming which has always been and should remain the backbone of the country's agricultural industry.

Weiss E. A. (1967). Soya bean trials on the Uasin Gishu (Western Kenya). *East African Agricultural and Forestry Journal*. 223-228

A series of experiments were carried out between 1961 and 1965 on the Turbo and soy estates of the East African Tanning Extract Company to ascertain the variety best suited to the area, time of planting, plant populations and fertilizer requirements. Two varieties grown locally Blyvoor and Voorster, proved the highest yielders. Planting in May, at a spacing of 36 in. x 2 in or 24 in. x 4 in., gave the highest yield. Fresh seed should be used. There was little response to fertilizer applications, either in the seedbed or as top-dressing. Weeds were economically controlled by several formulations with little effect on growth or yield. The effects of various insecticides, a defoliant and a growth regulator are described. In general, their use is not economic. The use of an inoculants, in this instance Nodulaid, is essential if soya beans have not been previously grown. It is unlikely, at present world prices and local yields, that large-scale plantings of soya bean will be economical as an alternative to wheat and maize on the plateau

Dougall , H. W. (1954). Fertilizer experiments on grassland in the Kenya highlands. *The East African agricultural journal* pp.19

It has become abundantly clear that the problem of successful key establishment can be aggravated to a market extent by weed competition. The presence of weed must be due; in part at least, topmost treatment of the land and it is important to appreciate that the proper growth of sown grasses and legumes should not be retarded in a struggle with weeds. It is considered that seed sowing should be given the best conditions possible, and a first essential would appear to be the preparation and subsequent maintenance of a clean seed bed of good tilth. In the experiments described. Sulphate of ammonia increased productivity and protein value of certain forms of natural pastures and established grass. It may be applied beneficially at intervals throughout a growing season, but this latter practice can be justified only in the circumstances of sufficient stock, adequate water supplies, fences, etc., or where ample facilities exist for conserving and utilizing the produce. The soluble phosphatic fertilizer could usually be ready.

Soil And Water Management

Overview

Effective management of soils and water is crucial for crop production systems in areas that are characterized by steep land scapes, water limitations and fragile soils. Water is crucial for nutrient absorption and transport through the plant systems, photosynthesis and soil microbial functions among others. Soil management entails managing soils to reduce soil and nutrient losses, compaction, acidification, and salinization among others. On the other hand soil water management includes all the activities that ensure optimum use of water while limiting losses through overland flow and evaporation. Water management is crucial especially with the changing climate which reduces the amount of water available for crop use especially in rainfed agriculture which is the most common way of supplying water to crops in Kenya. Examples of the most common soil and water management techniques include conservation tillage, water harvesting, soil cover and agroforestry. In this section we present the work carried out in various agro-ecological zone in Kenya to develop effective ways of managing soils and water.

Omondi J. O., Mungai N. W., Ouma J. P., Baijukya F. P. (2014). Effect of tillage on biological nitrogen fixation and yield of soybean (Glycine max L. Merril) varieties. Australian journal of crop science. AJCS 8(8):1140-1146 (2014); ISSN:1835-2707

Soil properties, plant characteristics, agronomic practices and environmental factors often influence biological nitrogen fixation of legumes. Tillage method used in a specific agro-ecological zone is among these factors thus, the aim of this study was to determine the effect of tillage and no tillage on biological nitrogen fixation and grain yields of three soybean varieties. The study was conducted at four agro-ecological zones of Western Kenya where treatments were replicated thrice using randomized complete block design in split plot arrangement. No tillage and conventional tillage were the main plots whereas, soybean varieties: Nyala, SB19 and SB20 were the sub-plots. Amount of N fixed was determined using 15N abundance method and quantity of nitrogen fixed under no tillage practice exceeded conventional tillage at all sites however, soybean varieties fixed same amount of N. Interaction effect of tillage method and variety on amount of N fixed was varying at every agro-ecological zone though, interaction between no tillage and Nyala fixed more nitrogen at LM 3 than at other agro-ecological zones. Soybean grain yield was similar between tillage methods and also among varieties in a combination of all sites. Practicing no tillage encourages biological nitrogen fixation and its longtime operation leads to yield increase as it improves most soil properties.

Anyanzwa H. (2013). Effects of cropping systems, nutrient levels and crop residue application on soil organic carbon content under minimum tillage experiment in Teso district Kenya. Msc. Thesis University of Eldoret, Kenya

Minimum tillage practise and the use of cropping systems that maximize crop residue addition to the soil has been efficient agricultural practices in maintaining or increasing soil carbon (SOC) which, though central to the sustainability of soil fertility on smallholder farm in the tropics, has significantly declined to very low levels. An on-farm experiment was carried out at Asinge ($0^0$36';$34^0$20'E and 1420 m above sea level) in Teso district to test the effects of cropping system, nitrogen levels and crop residue(maize stover) addition on the changes in soil matter and overall maize-soybean production in western Kenya. A 3×2×2 factorial experiment arranged in a split-split plot design with three cropping systems(maize-soybean rotation, maize-soybean intercropping and continuous maize) as main plots; nutrient N levels(0 and 60 kg N/ha) as subplots and crop residue management(with and without crop residue) as sub-subplots was initiated during the 2005 long rain season. Main plots of 12 m ×12 were split into subplots of 5.75 m ×12 m each (separated by 0.5 m paths) to accommodate different fertilizer N combinations and hence possible N response. Each subplot was split into sub-subplots of 5.75 m × 5.75 m with the inter sub-subplots spacing of 0.5 m to test with and without crop residue treatments. N fertilizer (urea) was applied at 0 and 60 kg N/ha with a blanket application of P fertilizer triple superphosphate (TSP) at 60 kg N/ha and also a blanket application of K fertilizer muriatic of potash (MOP) at 60 kg K20/ha to eliminate possible deficiencies for these two nutrients. Crop residue was applied at 0 and 2 t/ha. Maize and soybean were planted as test crops. Harvesting of crops was done at maturity to determine yields and nutrient uptakes. Soils and plant tissues were sampled after harvesting the crop each season for chemical analysis. Statistical analysis was done using Genstat Discovery Edition 3 for all data obtained to determine treatment effects. Results for 2005 LR, 2005 SR and 2006 LR indicated significant differences ($P<0.05$) and soil organic carbon and soil total nitrogen with treatments under crop residue application having high higher contents of both soil organic carbon and soil total nitrogen compared to non residue treatment. In all cropping system yields were significantly ($p<0.05$) as a result of fertilizer addition; higher yields were obtained in treatments receiving 0 kg N/ha. Rotation cropping system outperformed other cropping systems by having higher mean yields of 5.23 t/ha of maize in 2006 LR season with continuous and intercropping system having maize yields of 3.96 and 2.54 t/ha respectively. Economic analysis showed that treatments receiving fertilizer and crop residue in all cropping systems were profitable. However, all treatments under intercropping (maize+ soybean) gave gross margins of above Ksh.16,000 hence an attractive alternative and farmers would get better yields when soybean is integrated into the cropping system. There is need for minimum tillage research especially on the effects of cropping system and nutrient inputs on different soil types and climate, crop residue management (especially in crop/livestock systems) and equipment development to determine which of the practices is suitable in sustaining SOC and crop productivity in the nutrient depleted soils of western Kenya region.

Micheni A., Kanampiu F., Kitonyo O. (2013). Intensification of maize-legume cropping systems under conservation agriculture in eastern Kenya. *East African Agricultural and Forestry Journal* Volume 79: 73-79.

The effects of conservation agriculture (CA) practices in maize-legume cropping systems were investigated in the eastern region of Kenya during the 2010 short rains (November-December) season. Two beneficiary communities in two agro-ecological zones were therefore identified to host the 21 on-farm exploratory trials. Two best-bet CA treatments and conventional tillage practices were tested through on-farm trials against farmers' and conventional

practices. The treatments were laid out in a randomized complete block design where each experimental farm served as a replicate. The results showed that conventionally tilled plots gave high (P≤0.05) maize grain yield ranging between 0.23-2.67 t/ha compared with other tillage practices. The farmers' practice gave the least yield that ranged between 0.13-2.43 t/ha between farms and sites. However, bean yields were higher under furrows and ridges than other treatments. Full CA benefits usually accrue with time and therefore, long term experimental data should be collected and compared over time to provide conclusive results.

Njeru P. N. M., Mugwe J., Mucheru-Muna M., Maina L., Mwangi D. M., Amboga S., Miruka M., Lekasi J. K., Kimani S. K., Miriti J., Gitari J., Mahasi M. (2013). Intergrating scientific and farmers' evaluation of water harvesting and soil fertility technologies on sorghum productivity in Eastern Kenya. *East African Agricultural & Forestry Journal*. Vol. 79:43-150

Soil fertility degradation remains the major biophysical cause of declining per capita crop production on small holder farms in Kenya farmers perception and biophysical data on selected water harvesting and integrated soil fertility management technologies on sorghum (*Sorghum bicolour* (L) moench) and cow pea (*Vigna unguiculata* L) production in central highlands of Kenya. The treatments were three levels of water harvesting (tied ridges, contour furrows and conventional tillage) 3 cropping systems (sole sorghum and sorghum and cowpea intercrop and 6 levels of soil fertility amendment options (control 40 kg P/ha + 40 kg N/ha, 40 kg P/ha + 20 kg N/ha, 40 kg P/ha + 40 kg P/ha + manure 5 t/ha, 40 kg P/ha + 20 kg N/ha + manure 2.5 t/ha and manure 5 t/ha. One hundred seventeen smallholder farmers were invited to evaluate crops based on their performance and grain yields. Thirty plots laid out in partially balanced incomplete block design (PBIBD) replicated three times. The results show that treatments that were ranked top on the scale of good had external soil amendment of 40 kg P/ha +20 kg N/ha with (69.1%) respondent with grain yield of (3.5 t/ha). This was closely followed by tied ridges and contour furrows ranking ranging from 68.3% to 68.8% respondent under sorghum alone, plus external soil fertility amendment options. Generally the poorest ranked treatment and low yielding were experiment control. The results further showed that there was no significant difference between treatment scoring by gender (P>0.05) on the scale of food, fair and poor. Therefore integration minimal addition of organic and inorganic inputs on highly valued traditional with adequate rainfall under normal farmers practice in semi-arid lands could be considered as an alternative option contribution to food security in central highlands.

Okeye I. A. (2013). Effects of soil and water conservation technologies on sediment and maize yield in Tharaka-Nithi and Embu counties of Kenya. Msc. Thesis, Kenyatta University.

Decline in crop yields in Tharaka-Nithi and Embu counties is linked to poor agricultural activities and climate variability. Research has reported positive results from implementation of mulching, tied ridging, minimum tillage and intercropping. This study was set up to determine 1) determine the effect of soil and water conservation technologies on runoff 2) evaluate effect of technologies on sediment and nutrient loss 3) investigate effect of technologies on maize yield and, 4) analyze economic implications of the technologies. The study was conducted in Meru South and Mbeere South sub-counties for two consecutive cropping seasons; long rains 2011 and short rains 2011. A randomized complete block design was adopted in three replicates. Treatments were mulching, MBILI intercrop and convectional in both sites, minimum tillage in Meru South and tied ridges in Mbeer south. Convectional treatment was the control treatment. Key variables measured were runoff, sediment yield, nutrient concentration in sediment, grain yields, economic and weather data. Data was subjected to Analysis of variance Analysis using SAS 9.1.3. Mean separation was done using Fisher's LSD at 5% level of significance. Compared with control results showed that in Meru South, Mulching and MBILI intercrop reduced runoff by 26% (P=0.04) during short rains 2011; sediment yield was reduced by 41 and 12% under mulching and MBILI intercrop respectively, during long rains 2011(p=0.03) and by 71, 61 and 68% (p=0.01) under mulching, MBILI intercrop and minimum tillage respectively, by 29 and 35% respectively, during long rains 2011 (p=0.02). During short rains 2011, mulching, MBILI intercrop and minimum tillage reduced N concentration by 61, 33 and 46% respectively (p=0.01). Potassium concentration was reduced by 55, 40 and 44% under mulching, MBILI intercrop and minimum tillage respectively, during short rains 2011 (p=0.02). Organic carbon concentration was reduced by 54, 30 and 46% during long rains 2011 (p=0.01) and 54, 33 and 39% during the short rains 2011(p=0.01) under mulching, MBILI intercrop and minimum tillage respectively. Maize yield was increased by 5,40 and 7% under mulching, MBILI intercrop and minimum tillage respectively (p=0.001) during long rains 2011 net benefits under mulching, MBILI intercrop and minimum tillage respectively were increased by 11,75 and 165 respectively, during long rains 2011(p=0.001). Benefit cost ratio increased by 27, 77 and 54% during long rains 2011(p=0.004) and by 33, 44 and 89% during short rains 2011(p=0.02) under mulching, MBILI intercrop and minimum tillage respectively. In Mbeere South, runoff was reduced by 52% and 49% during long rains 2011 and by 51% and 30% during short rains 2011 under tied ridgings and mulching respectively. Mulching, MBILI intercrop and tied ridging reduced sediment yield by 78, 50 and 71% during long rains 2011(p=0.01) and by 53, 19 and 47% during long rains 2011 and by 33, 13 and 54% during short rains 2011 under mulching, MBILI intercrop and tied ridging respectively. Organic carbon concentration was reduced by 54, 22 and 50% under mulching, MBILI intercrop

and tied ridging respectively, during long rains 2011. Mulching reduced organic carbon concentration by 58% during short rains 2011. Total crop failure occurred during long rains 2011 due to erratic rainfall. During short rains 2011 tied ridging and mulching increased maize yield by 94 and 75% respectively. Tied ridging, mulching and MBILI intercrop increased net benefits by 228%, 205% and 127% (p=0.01) and BCR by 280%, 260% and 120% (p=0.004) respectively. The soil and water conservation technologies performed better than the control in all parameters evaluated.

Batjes, N.H. (2012). Projected Changes in soil organic carbon stocks upon adoption of recommended soil and water conservation practices in the upper Tana River catchment, Kenya. *Land Degradation and Development*. DOI:10.1002/ldr.2141

Large areas in the Upper Tana River catchment, Kenya, have been over-exploited, resulting in soil erosion, nutrient depletion and loss of soil organic matter (SOM). This study focuses on sections of the catchment earmarked as being most promising for implementing Green Water Credits, an incentive mechanism to help farmers invest in land and soil management activities that affect all fresh water resources as source. Such management practices can also help restore SOM levels towards their natural level. Opportunities to increase soil organic carbon (SOC) stocks, for two broadly defines land use types (croplands and plantation crops, with moderate input levels), are calculated using simple empirical model, using three scenarios for the proportion of suitable land and may be treated with these practices (low=40 per cent, medium = 60percent, high= 80 percent). For the medium scenario, corresponding to implementation on -348 000 ha in the basin, the eco-technology possible SOC gains are estimated at 4.8 to 9.3*106 tonnes (MG) CO_2 over the next 20 years. Assuming a conservative price of US$10 per tonne CO_2-equivalent on the carbon offset market; this would correspond to - US$ 48-93 million over a 20 year period of sustained green water management. this would imply a projected (potential) payment of some US$7-13/ha to farmers annually: this sum would be in addition to incentives that are being put in place for implementing green water management practices and also in addition to the benefits that farmers would realize from the impact on production of their practices themselves.

Gicheru P. T. and Kimigo J. (2012). Impact on soil quality of land-use change and continuous cultivation in Sasumua catchment, Kenya. *Pedologist* (2012) 326-331.

The effects after conversion from forest of 30 years of continuous land cultivation on soil quality were investigated by analyzing soil data from three studies carried out in the Sasumua catchment, Kenya during 1977, 1987, and 2007. Soil samples taken at depth of 0–30 cm were analyzed for (1977, 1987, and 2007) soil pH, electrical conductivity, cation exchange capacity, soil organic carbon (3.3%, 2.6%, 3.2%), total nitrogen 0.3%, 0.2%, 0.4%), exchangeable potassium (K^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}). Results of an analysis of variance for the 30-year period showed changes in soil reaction from pH 5.86 to 5.22 ($p < 0.005$), Mg^{2+} from 3.32 to 1.04 mg/kg ($p < 0.001$), and K^+ from 2.89 to 1.11 mg/kg ($p < 0.001$). Furthermore, Ca^{2+}decreased by 30% and TN increased by 21%. No change was observed in the level of SOC. Factors contributing to the decline of soil pH, Mg^{2+}, Ca^{2+}, and K^+ were re overgrazing, intensive cultivation of horticultural crops, and soil erosion by water. The application of farmyard manure to the land and the practice of agroforestry have helped to maintaining SOC-levels.

Kihara J., Mukalama J., Ayuke F. O., Njoroge S., Waswa B., Okeyo J., Koala S., Bationo A. (2012). Crop and soil response to tillage and crop residue application in a tropical ferralsol in sub-humid western Kenya. *In: Bationo A.* et al., (Eds). *Lessons learned from long-term soil fertility management experiments in Africa*. pp. 42-56. Springer

Conservation agriculture (CA) offers an opportunity to reverse prevailing land degradation and consequent loss of productivity often occasioned by intensive soil tillage in cropping systems in most parts of sub-Saharan Africa (SSA). A long term experiment was established in Nyabeda Western Kenya in 2003 to evaluate the effect of tillage and crop residue application on maize and soybean yields, and on soil properties. The experiment was set up as a split-split-split plot design with four replicates and involved a factorial combination of tillage system (reduced and conventional tillage), cropping system (continuous cereal, soybean-maize rotation and intercropping), crop residue - maize stover - management (plus and minus crop residue) and nitrogen N (N) application. Results showed that tillage influenced performance of maize although significant tillage effects were observed in only 5 out of the 15 seasons analyzed. Overall average maize grain yields were 2.9 t/ha in reduced tillage and 3.6 t/ha in conventional tillage systems. Application of crop residue increased seasonal maize grain yield in reduced tillage (340 kg/ha) and in conventional tillage (240 kg/ha), but the only significant crop residue (CR) effect was observed in season 10. Differences in maize yields between the two systems were attributed to phosphorus availability as it was demonstrated that application of crop residue in the reduced tillage resulted in better availability of P than without crop residue application. Under the rotation system, significant tillage effects were observed in 6 of the 15 seasons with greater maize yield in conventional than in reduced tillage system. Soybean yields under reduced tillage were comparable to those from conventional tillage with the good performance of soybean in

reduced tillage being related to the effect of its canopy on soil evaporation, and or to changes in microbial diversity and soil structure. For both the conventional and reduced tillage systems, legume benefits on succeeding maize observed with similar maize yields being observed between maize monocropping and maize rotated with soybean. Reduced tillage improved soil aggregation with greater aggregate mean weight diameters being observed in this system than in conventional tillage. Tests for biological activity showed that the application of crop residue increased termite abundance in both reduced and conventional tillage systems. The results from this study indicate the importance of long term trials in better understanding the beneficial effects of conservation agriculture on soil productivity.

Miriti J.M., Kironchi G., Esilaba A.O. , Heng L.K., Gachene C.K.K, Mwangi D.M. (2012). Yield and water use efficiencies of maize and cowpea as affected by tillage and cropping system in semi-arid eastern Kenya. *Agriculture Water Management* 115 (2012)148-155

Soil water conservation through tillage is widely accepted as one of the ways of improving crop yields in rain-fed agriculture. Field experiments were conducted between 2007 and 2009 to evaluate the effects of conservation tillage on the yields and crop water use efficiency of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) in eastern Kenya. Experimental treatments were a combination of three tillage practices and four cropping systems. Tillage practices were tied-ridges, sub-soiling-ripping and ox-ploughing. The cropping systems were single crop maize, single crop cowpea, intercropped maize–cowpea and single crop maize with manure. The treatments were arranged in split plots with tillage practices as the main plots and cropping systems as the sub-plots in a Randomized Complete Block Design (RCBD). The results showed that tied-ridge tillage had the greatest plant available water content while sub-soiling-ripping tillage had the least in all seasons. Averaged across seasons and cropping season, tillage did not have a significant effects on maize grain yield but it did have a significant effect on crop grain and dry matter water use efficiency (WUE). Nevertheless, maize grain yields and WUE values were generally greater under tied-ridge tillage than under sub-soiling-ripping and ox-plough tillage. The yields and WUE of cowpea under sub-soiling-ripping tillage were less than those of ox-plough tillage. When averaged across the seasons and tillage systems, the cropping system with the manure treatment increased ($P \leq 0.05$) maize grain yield, grain WUE and dry matter WUE by 36%, 30%, 26% respectively, compared to treatments without manure. Maize and cowpea when intercropped under ox-plough and ripping tillage systems did not have any yield advantage over the single crop.

Okwuosa E. A. (2012). Effect of land use system on soil carbon and selected soil properties in Mt. Elgon ecosystem, Kenya. Msc Thesis. University of Nairobi, Kenya

The aim of this study was to systematically quantify differences in soil organic carbon and key related soil properties in different land-use systems in Mt. Elgon Ecosystem, Kenya Results Show that soil organic carbon stocks varied significantly with depth (P<0.001) and among land use system (P<0.001) with primary and secondary forests having higher soil organic carbon storage. Mean values for soil organic carbon stocks in primary forests were 61.5 t/ha, 48.67 t/ha and 34.34 t/ha in the 0-10, 10-20 and 20-30 cm depths, respectively while for plantation forests were 43.23 t/ ha, 38.72 t/ha and 26.4 t/ha in the same depths. Carbon concentrations in 0-10cm soil depths in areas under by tea (49.05 t/ha) were similar to those in areas under plantation forest. Areas with maize crop had low soil organic carbon stock, viz.., namely 25.06 t/ha, 37.30 t/ha and 39.75 t/ha in three respective soil depths. the estimated depth-wise distribution of soil organic carbon stocks up to 30cm soil depth-wise distribution of soil organic stocks up to 30 cm soil depth in the Mt. Elgon study sites was 41, 36 and 32% in the 0-10, 10-20 and 20-30cm soil depths respectively. The total soil organic carbon stocks in the soil up to 30 cm depth was estimated to be 6,688.4 Gt of organic carbon distributed at 59, 19, 11, and 10% in Natural forests bamboo, plantation forest and tea plantations respectively. Land-use and soil depth had a significant effect (P<0.001) on the total nitrogen levels in the order of the primary forests> secondary forest> cultivated land-uses. Primary forest had 0.6, 0.4 and 0.3% N in the 0-10, 10-20 and 20-30cm soil depths, respectively. Cultivated land had the lowest amounts of nitrogen compared to forest land-uses. The study concludes that natural and plantation forests have higher potential for carbon storage when compared to cultivated land-use systems.

Paul B. K., Vanlauwe B., Ayuke F., Gassner A., Hoogmoed M., Hurrison T. T., Koala S., Ndawamwenye T., Six J., Pulleman M. M. (2012). Medium-term impact of tillage and residue management on soil aggregate stability, soil carbon and crop productivity. *Agriculture, Ecosystems & Environment*. Vol.: 164:14-22.

Conservation agriculture is widely promoted for soil conservation and crop productivity increases, although rigorous empirical evidence form sub Saharan Africa is still limited. This study aimed to quantify the medium-term impact of tillage 9 conventional and reduced and crop residue management (retention and removal) on soil and crop performance in a maize-soybean rotation. A replicated field trial was started in sub-humid western Kenya in 2003 and measurements were taken from 2005 to 2008. Conventional tillage negatively affected soil aggregate stability when compared to reduced tillage as indicated by lower mean weight diameter values upon wet sieving at 0- 15 cm ($p < 0.001$). This suggests increased susceptibility to slaking and soil erosion. Tillage and residue

management alone did not affect soil C contents after 11 cropping seasons but when residue was incorporated by tillage soil C was higher at 15-30 cm (p = 0.037) lack of treatment on the C content of different aggregate fraction. Soy-bean grain yields tended to be suppressed under reduced tillage without residue retention, especially in wet seasons (p = 0.070). Consequently, future research should establish for different climatic zones and soil types, t/ha critical minimum residue retention levels for soil conservation and crop productivity.

Rotich E. K. (2012). Manipulating cropping system, tillage method and crop residue management to reverse declining soil fertility. Msc. Thesis, Moi University Chepkoilel campus, Eldoret, Kenya.

An on-farm experiment was conducted at Nyabeda in Siaya District, Nyanza Province, and Western Kenya region to determine the effects of cropping systems, tillage system and crop residue management on soil organic matter and maize-legume production in the region. Soils were sampled before the onset of the trials to establish soil pH, organic carbon, nitrogen, and phosphorus status. A split plot experimental arrangement was set up with crop management system (monocropping and intercropping with soybeans) as main plots, tillage systems (conventional and conservation) as sub-plots and crop residue management (with and without crop residue) as su-sub plots during the 2003 short rains 2004 long rains and 2004 short rains seasons. At each planting, all plots received 60 kg of P_2O_5/ha and 60 kg of K_2O/ha. Crops were harvested at maturity to determine yields and nutrient uptakes. After harvesting the crop each season, soils and plant tissues were sampled for a chemical analysis. Results for the three seasons indicated slight increase in soil, pH, soil organic carbon and soil total nitrogen with treatments under soybean intercropping system higher than monocropping system. Crop management system contributed significantly ($p<0.05$) to grain %N, grain %P and stover %P. Intercropping system treatments with or without residues resulted in slightly lower maize total biomass yields than in monocropping system, though not statically different. Maize grain and stover yields also responded positively to conservation tillage and residue addition though the response was not statically significant. The highest grain yields under monocropping was 5.07 t/ha while the highest in intercropping was 3.91t/ha. Nutrient %N content of maize grain ranged between 1.04-2.08% and of maize stover ranged between 0.90-1.17%. Economic analysis showed that treatments under intercropping system with residue addition were more profitable in terms of combined returns from both soybeans and maize. However, all the treatments under intercropping gave the highest gross margins (GM) and marginal rate of returns (%MRR). The highest marginal rate of return in intercropping was 197% while in monocropping the highest was 157%. Intercropping maize legumes under conservation tillage with crop residue addition may therefore be an attractive option to farmers for adoption in order for them to reduce on input costs, improve soil conservation and enhance food security. There is need for long-term studies to show the effects of tillage, crop residue and cropping systems under the varying soil types in small-holder farms in Kenya where Soil Organic Matter (*SOM) are low.

Guto S. N., Pypers P., Vanluawe B., de Ridder N., Giller K. E. (2011). Tillage and vegetative barrier effects on soil conservation and short-term economic benefits in the central Kenya highlands. *Field Crops Research*. Vol. 122: 85-94.

Minimum tillage and vegetative barriers can conserve soil and water resources in the steep-sloping highlands of East Africa but there has been little adoption by smallholder farmers. Soil conservation efficiency and short-term economic benefits provided by tillage and vegetative barriers (leucaena and Napier) with no barriers. Maize and soybean yields were greater with than without vegetative barriers, except with Napier barriers when minimum tillage was practiced where strong root competition occurred. Cumulatively for the four cropping seasons, Napier barriers with regular tillage conserved most soil (72%) followed by Napier with minimum tillage (53%). The least soil (1%) was conserved for minimum tillage without barriers and leucaena barriers were intermediate in decreasing soil erosion. The highest positive marginal rate of returns (MRRs) were realized under leucaena barriers with regular tillage (2.09) followed by Napier with regular tillage (1.32). Minimum tillage without barriers was inefficient in soil conservation particularly when rainfall was intense and had poor MRRs. Leucaena barriers conserved less soil than Napier barriers but were more economically attractive, demonstrating a clear trade-off between soil erosion that is likely to impact crop yields in the long-term and short-term economic benefits. Napier barriers with regular tillage present a win-win scenario due to efficient soil conservation and attractive economic returns provided future prices of labour and Napier cuttings remain stable.

Kihara J., Martius C., Bationo A. and Vlek P. L. G. (2011). Effects of tillage and crop residue application on soybean nitrogen fixation in a tropical ferralsol. *Agriculture Vol. 1*. ISSN 2077-0472, DOI:10.3390/agriculture1010022. *PP: 1, 22-37*

This study was aimed at quantifying soybean (*Glycine max*) nitrogen fixation under reduced tillage (RT) and conventional tillage (CT) in a tropical Ferralsol of the sub-humid zone of western Kenya, using isotope N dilution method. Crop residue (CR) management was a superimposed treatment in soybean-maize rotation and intercropping systems. This study quantified N in abscised soybean leaves. Soybean-N derived from the atmosphere (% NDfA) ranged between 41-65%, it was higher ($P<0.05$) in RT (55.6%) than in CT (46.6%). Total fixed-N under 'RT + CR'

was more than in the other treatments by at least 55% in intercropping and 34% in rotation system. Nitrogen fixed in soybean above ground parts was 26-48 kg N/ha with intercropping 53-82 kg N/ha with rotation. Seasonal litter fall contained about 15 kg N/ha, with 54% NDfA. Annual nitrogen balances with soybean and maize grain removed were better in RT (-9 to -32 kg N/ha) than in CT (-40 to -60 kg N/ha). Application of P increased module weight (P<0.05) BY 3 to 16 times over the control. Soybean residues should be returned to the field after harvest to reduce soil N mining. We conclude that 'RT + CR' increases biological nitrogen fixation in soybean, over CT, and that phosphorus application is needed for better soybean nodulation in western Kenya.

Kihara J., Batiano A., Mugendi N., Martius C., Vlek G. (2011) Conservation tillage, local organic resources and nitrogen fertilizer combinations affect maize productivity, soil structure and nutrient balances in semi-arid Kenya. *Nutrient Cycling Agro-ecosystems* Vol. 90: 213-225

Smallholder land productivity in drylands can be increased by optimizing locally available resources, through nutrient enhancement and water conservation. In this study, we investigated the effect of tillage system, organic resource and chemical nitrogen fertilizer application on maize productivity in a sandy soil in eastern Kenya over four seasons. The objective were to (1) determine the effects of different tillage-organic resource combinations on soil structure and crop yield, (2) determine optimum organic-inorganic nutrient combinations for arid and semi-arid environments in Kenya and (3) assess partial nutrient budgets of different soil, water and nutrient management practices using nutrient inflows and outflows. This experiment, initiated in the short rainy season of 2005,was a split design with 7 treatments involving combinations of tillage (tied ridges, convectional tillage and no- till) and organic resource (1t/ha manure + 1 t/ha cop residue and ; 2 t/ha of manure (crop residue) in the main plots. Chemical nitrogen fertilizer at 0 and 60 kg N/ha was used in sub-plots. Although average yields in no-till was by 30-65% lower than in convectional and tied-ridges during the initial two seasons, it achieved 7-40% higher yields than these tillage systems by season 4. Combined application of 1 t/ha of crop residue and 1 t/ha of manure increased crop yield over sole application of manure at 2 t/ha by between 17 and 51% depending on the tillage system, for treatments without inorganic N fertilizer. Cumulative nutrients in harvested maize in the four seasons ranged from 77 to 196 kg/N ha, 12-27 kg P/ha and 102 to 191 kg K/ha representing 23 and 62% of applied N in treatments with and without mineral fertilizer N respectively, 10% of applied P and 35% of applied K. chemical nitrogen fertilizer application increased maize yields by 17-94%; the increases were significant in the first 3 seasons (p<0.05). Tillage had significant effect on soil macro-(>1mm) and micro-aggregates fractions (<250µm >53µm: p<0.05), with aggregation indices following the no order till>tied ridges>convectional tillage. Also, combining crop residue and manure increased large macro-aggregates by 1.4-4 g 100 g per soil above manure only treatments. We conclude that even with the modest organic resource application, and depending on the number of seasons use, conservation tillage systems such as tied ridges and no till can be effective in improving crop yield, nutrient uptake and soil structure and that farmers are better of applying 1 t/ha each of crop residue and manure rather than sole manure.

Anyanzwa H., Okalebo J. R., Othieno C. O., Bationo A., Waswa B. S., Kihara J. (2010). Effects of conservation tillage, crop residue and cropping systems on changes in soil organic matter and maize-legume production: A case study in Teso district. *Nutrient Cycling in Agroecosystems: Special issue*. pp 39-47.

The effects of conservation tillage, crop residue and cropping systems on the changes in soil organic matter (SOM) and overall maize-legume production were investigated in western Kenya. The experiment was a split-split plot design with three replicates with crop residue as main plots, cropping systems as sub-plots and nutrient levels as sub-sub plots. Nitrogen was applied in each treatment at two rates (0 and 60 kg N/ha). Phosphorus was applied at 60 kg P/ha in all plots except two intercropped plots. Inorganic fertilizer (N and P) showed significant effects on yields with plots receiving 60 kg P/ha + 60 kg N/ha giving higher yields of 5.23 t/ha compared to control plots whose yields were as low as 1.8 t/ha during the third season. Crop residues had an additive effect on crop production, soil organic carbon and soil total nitrogen. Crop rotation gave higher yields hence an attractive option to farmers. Long-term studies are needed to show the effects of crop residue, cropping systems and nutrient input on sustainability of SOM and crop productivity.

Macharia C. N., Njeru C. M., Gichangi A., Shiluli M. S., Ombakho G. A. (2010). Agronomic and financial implications of using farm-saved seed from naturally segregating certified maize hybrids by smallholder farmers. *East African Agriculture & Forestry Journal*. 76 (2): 121-129

Use of farm saved maize seed is wide spread in medium altitude ecosystems in western Kenya. The practise is contrary to current recommendations and is one of the causes of low maize yields in the area. In order to determine the agronomic and financial implications of using farm-saved seed versus certified hybrid maize, experiments were conducted on farmers' fields. First generation seed (CGI) of certified seed of two commercial hybrids (H513 and H614), a local maize variety respective first and second segregating generation (SG1 and SG2) of H513 and H614 seed were evaluated with and without inorganic fertilizer. Differences (P<0.05) in maize grain

yield were observed with the first generation certified hybrids consistently yielding more than their respective SG1 and SG2 generations. Fertilizer application on CG1, SG1 and SG2 of H513 and H614 resulted in higher ($P<0.05$) yield. The farmers' variety did not show response ($P>0.05$) to fertilization. Financial analysis showed that although certified seed with fertilizer yielded approximately one ton more grain per hectare than unfertilized local maize, the marginal rate of return on hybrid maize and fertilizer was only 15%. It is evident from this study that while the use of certified maize seed and inorganic fertilizer will significantly increase maize yield, the increase cannot economically absorb the additional costs of certified seed and fertilizers. Since using improved seed and fertilizer is not profitable to smallholder farmers, intervention at policy level may be necessary to increase use of these inputs to improve overall productivity, conserve farmland and improve food security.

Miriti J. M. (2010). Effects of tillage practices on soil physical properties and moisture conservation in a sandy loam soil in Makueni County. PhD thesis, Chapter 2. University of Nairobi, Kenya

Soil water conservation through tillage is widely accepted as one of the appropriate ways of addressing soil moisture constraints in rain-fed agriculture. A field experiment was conducted between 2007 and 2009 to evaluate the effects of tillage practices on soil water conservation in Makueni County in eastern Kenya. Experimental treatments were a combination of three tillage practices and four cropping systems. Tillage practices were tied-ridges (TR), sub-soiling and ripping (SR) and ox ploughing (OP). Cropping systems were maize sole crop + 5Mg/ha manure (SMM). The treatments were arranged in split plots with tillage practices as main plots and cropping systems as the sub-plots in a Randomized Complete Block Design (RCBD). Each treatment was replicated 4 times. Soil profile moisture content was measured in three blocks using the neutron probe gauge. The results showed that tillage significantly ($P<0.05$) influenced soil bulk density, soil surface (0-5cm) crust strength, surface roughness, saturated hydraulic conductivity (Ks) and infiltration rates between crop rows. SR significantly ($P<0.05$) influenced soil bulk density, and total porosity of the hardpan which was found to beat the 14-27cm soil layer. Average SR inter-row bulk density (1.51 M/gm^3) and crust strength (5.49kg/cm^2) were 7% and 15% higher than OP. Inter-row basic infiltration rates in OP (7.9 cm hr-1) were two fold greater than in SR (3.6 cm/h) and TR (3.3 cm/hr) tillage. Surface roughness in TR was twice more than that in OP and SR. Inter-row total porosity and Ks were lowest in TR and highest in OP tillage. There were however no significant tillage differences observed on bulk density, soil surface crust strength, Ks and infiltration rates within crop rows. Available water content (AWC) in the soil profile was consistently highest in TR and least in SR in all seasons. Ox-ploughing conserved more soil profile moisture than SR but significantly ($P\leq 0.05$) lower than TR. The inter-row mean soil surface (0-15cm) moisture over 3 seasons in SR (14.1%v/v) was significantly ($P\leq0.05$) lower than in OP (16.4%v/v) and TR (18.0%v/v). Soil profile moisture was significant ($P\leq0.05$) different among cropping system with SC reading the least and SM the highest. The soil depth moisture extraction for cowpea was 0-90cm compared to 0-70 cm of maize. The major conclusion from this study is the sub soiling and ripping the soil along crop planting line (without disturbing the soil between rows) in this soil had no significant moisture conservation advantages over the ox-plough tillage.

Miriti J. M. (2010). Effects of tillage and cropping systems on yield of maize and cowpea in semi-arid Makueni County. PhD thesis, Chapter 3. University of Nairobi, Kenya

Soil water conservation through tillage is widely accepted as one of the ways of improving crop yields in rain-fed agriculture. A field experiment was conducted for 6 seasons between 2007 and 2009 to evaluate the effects of conservation tillage on the growth yields of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) in Makueni County in eastern Kenya. Experimental treatments were a combination of three tillage practices and four cropping systems. Tillage practices were tied-ridges (TR), sub-soiling and ripping (SR) and ox ploughing (OP). Cropping systems were maize sole crop(SM), cowpea sole crop (SC), maize-cowpea intercrop (MC) and maize sole crop + 5 Mg/ha manure (SMM). The treatments were arranged in split plots with tillage practices as main plots and cropping systems as the sub-plots in a Randomized Complete Block Design (RCBD). The results showed that (TR) had the highest plant available water and SR had the lowest in all seasons. Highest average maize total dry matter (TDM), grain and Yield components (plant height, harvest index, number of ears per m^2) were observed in TR while they were similar in SR and OP. Manure application significantly increased ($P\leq0.05$) average maize grain yields by 33% (from 0.88 to 1.23 Mg/ha) compared to treatments without manure across the seasons. Intercropping significantly ($P\leq0.05$) reduced the 4-season mean grain yields by a third (32%) and the reduction varied between 9-50% depending on rainfall amounts and distribution within season. With respect to the intercrop cowpea grain production, TR out-yielded OP and SR tillage systems by 88% and 113%, respectively. Sole cowpea TDM yield and crop water productivity (CWP) under SR were less than in OP in all seasons implying SR was not suitable for cowpea production. In contrast with SC, SM yields were slightly higher in SR than in OP. Tillage differences in terms of CWP and fertilizer nitrogen use efficiency (FNUE) were not significant ($P\leq0.05$) but TR had the highest CWP values. Manure increased maize CWP and GWP by 32% (12-67% and 56% (15-135%), respectively and the greatest increase were observed in seasons with poor rainfall distribution.

Miriti J. M. (2010). Effects of Tillage and Cropping Systems on Yield and Economic Returns of Maize and Cowpea in Makueni County. PhD thesis, Chapter 4. University of Nairobi, Kenya

Crops yields and financial returns are important criteria for the adoption of conservation tillage by farmers. A study was carried out to compare the financial profitability of sub-soiling and ripping (SR) and tie-ridging (TR) tillage relative to conventional ox-plough (OP) in the production of the maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) under subsistence farming conditions in Makueni county in semi arid Eastern Kenya. The treatments arrangement was split-plot with tillage practices the main plots and cropping systems as the sub-plots in a Randomized Complete Block Design (RCBD) replicated in 4 blocks. Cropping systems were maize sole crop (SM), cowpea sole crop (SC), maize-cowpea intercrop (MC) and maize sole crop + 5 Mg/ha manure (SMM). The yields of maize and cowpea in every season were determined at harvest. Prevailing market prices for cowpea and maize grain, labour, inputs applied and other relevant socio-economic data were collected every season, to enable estimation of profitability and acceptability of the technologies. Tillage effects on the 4-season average maize grain yield was not significant for SM and maize with manure (SMM). Compared to OP, SR did not improve maize grain yield for SM, SMM and Intercrop maize (IM) attained in TR were 15%, 21%and 110% respectively higher than in OP. Maize grain production was increased by 33% (from 0.88 to 1.23 Mg/ha) ($P<0.05$) when manure was applied. Compared to sole maize, intercropping significantly ($P<0.05$) reduced the 4-season average grain yields by a third (32%). SR yielded 15% less cowpea grain production than OP. Tied ridging increased land preparation costs by 190% while it was reduced by 53% in the SR when compared to OP. Net returns from maize production ranged from a negative of 16023 to positive 13293 KES/ha and were positive in only two (SRS07 and SRS09) out of four season. Although sowing maize with manure improved maize yields and net returns, this was restricted to relatively wet season. Sole cowpea resulted in positive net incomes in OP tillage in all seasons. Compared with maize, sole cowpea production was more economically productive. Majority of the farmers' preferred growing maize to cowpea. Tied ridging was ranked the highest in terms of crop performance, but farmers preferred ox-ploughing tillage.

Muya E. M., Obanyi S., Sijali I. V., Wakiiru G., Ngutu M. (2010). Review of the effcts of amendment on the quality of saline-sodic soils of Kalacha irrigation scheme, Marsabit district, Kenya. *In: Ouda et al. (Eds) Proceedings of the 12th Biennial Conference of the Kenya Agricultural Research Institute*, Nairobi, Kenya, November 8th -11th 2010 pp. 1019-1033.

In Kalacha irrigation scheme, Marsabit district, agricultural production went down by over 80% between 1984 and 2005, because of loss of soil quality and productivity associated with increased salt and sodium concentrations. The soils in the area were found to have poor structure, very high pH, which is too alkaline for crop growth, low organic matter content, high electrical conductivity and high exchangeable sodium percentage (ESP). Therefore, this review was carried out to select the most promising intervention packages to improve the soil quality and productivity in the area, by reducing the toxicity associated with low soil organic carbon, high pH, and high salt and sodium levels. From the literature review, intervention strategies for this type of soil were found to be a stepwise processes, involving the establishment of the current status of soil quality in relation to their critical limits or environmental thresholds, identifying the most promising technological options, based on the current state, and determining the minimum time required by the soil to change under the envisaged reclamation programme. From the past research reviewed, the most promising plant species were found to be *Leucaena leucocephala, Tamarindas indica, Acacia tortalis,* kallar grass, alfalfa, barley, wheat, *Chloris gayana, Gliricidia sepsium, Sorghum versicular, Sueda monoica, Salvadora* and *Cenchrus ciliaris*. The most promising reclamation strategy was found to be the integrated system comprising vermicompost, improved tillage, green manure, nitrogen fixing bacteria and gypsum.

Nafuma L.S., Kitur B.K., Mahagayu C.M., Wanyera R., Kipkemoi P.A.L. (2010) Burning soil for finger millet (*Eleusine coracana*) production in Kenya: A case study in Bomet District. *In: Ouda et al (Eds) Proceedings of the 12th KARI Biennial Scientific Conference* Pp.110-114.

Farmers in Bomet district burn soil before growing finger millet. This has resulted in long-term soil degradation and low yield of other major crops like maize and beans. The objectives of the study were to determine the effect of heat on soil chemical properties, finger millet yields and to quantify the problem of land degradation due to soil burning in Bomet. Soils were heat treated in oven/muffle furnace and chemically characterized. Finger millet was planted in heat-treated soils, harvested and yields determined. Soils were sampled from farmers' burnt fields and analyzed. Results indicate the heating soil releases a lot of nutrients to the soil solution, causes the finger millet to mature early and increases finger millet yield. However, heating soil destroys soil organic matter significantly. Results also indicate that burning soil could cause long-term soil fertility problems in the district, yields. Keywords: Heating soil, finger millet, organic matter, soil fertility

Ngigi S. J., Kariuki K. A. (2010). Rainwater harvesting and management for improving agricultural productivity in arid and semi-arid areas in Kenya. In: Ouda *et al* (Eds) Proceedings of the 12th KARI Biennial Scientific Conference. November, 8-12, 2010. Pp. 1110-1113.

Kenya Rain water Association (KRA) has been working to implement rainwater harvesting and management systems (RHM) and complementary technologies across Kenya since 1994. A founder member of the Greater Horn of Africa Rainwater Partnership (GHARP), KRA works in arid and semi-arid lands (ASALs) with poor farmers and local community groups, to help provide access to a sustainable water supply; improve food security; and help develop their livelihoods. In terms of the agricultural product value chain (APVC), KRA's work focuses on the early part of the chain-production-as well as building the capacity of local communities. The paper discusses KRAs work in terms of rainwater harvesting (RWH) technologies; environmental conservation methods; the development of viable sustainable livelihoods; and community capacity building to ensure an enhanced skill-set useful for accessing markets. The paper argues that RHM is an essential part of the APVC in ASAL areas of Kenya and that it has power to improve crop yield and quality; enhance the natural environment; motivate other communities to replicate similar systems; and to provide farmers with a solid basis for successfully accessing markets.

Njiru E.N, Kironchi G. G. Mbuvi J.P. and Nguluu S. (2010). Anaysis of climate data and the associated risks to maize production in semi-arid eastern Kenya. *Proceedings of the 11th Biennial KARI Conference* pp 8-12.

Climate change is one of the most important constrains to agricultural production and food insecurity in marginal areas that rely on rain fed production systems. Climate for two analogue locations in semi arid eastern Kenya was analyzed using instat plus v3.4 statistical package with aim of determining changes and variability in seasonal and annual rainfall and temperatures, percentages of season with adequate rainfall for maize production variabilities of dry spell in October - December rainfall seasons, and accumulated rainfall and soil moisture content relations at different maize growth stages. Analysis gave declining trends in both seasonal and annual rainfall amounts at rate between 0.15 and 2.1 mm per annum and increase of 0.04ºC and 0.03ºC in mean maximum and minimum annual temperatures respectively. This is indicative of changes in climate and hence have the need for early exploration of necessary mitigation strategies by all stakeholders and policy makers. There were high chances 9>90% probability of dry spell in October and high percentage of season having less than 250 mm rainfall compared to those with more than 450 mm. Rainfall was low and poorly distributed over the crop growing season and soil moisture remained low even during periods of crop high water demand signifies the high risk involved on maize production and the need for introduction and popularization of alternative crops as well as water conservation measures during months of high rainfall. It also calls for specification of specific crops to be grown in the two seasons with different rainfall expectations.

Nzabi A., Makini F., Kidula N., Mutai E (2010) Effect of cover crops and conservation tillage in improving maize yields in semi-arid areas of South west Kenya. In: Ouda *et al* (Eds) Proceedings of the 12th KARI Bienniaal Scientific Conference. November, 8-12, 2010. Pp 442-447

Three quarter of the arable land in Migori and Homa Bay Districts is semi-arid. The rainfall is erratic with an average of 800-1200 mm per annum while evapo-transpiration is very high. Soil erosion is also rampant and soil fertility is very low. Striga weed (*striga hermonthica*) infestation is also very high. These factors have led general low crop yields especially maize (0.45 t/ha). Conversely, convectional ploughing (farmer practice) that farmers use cause hardpans resulting in poor water infiltration thus encouraging surface runoffs. An experiment was carried out in these districts in 2006-2007 with the objectives of accessing the effect of cover crop and conservation tillage in improving maize yields in the semi-arid areas of southwest districts in Kenya. The treatments were conservation tillage (ripping) + lablab, ripping + mucuna and conventional ploughing without cover crops which was on control. The farmer field school (FFS) approach was used. Mukoro in Migori district had 33 farms while Rangwe in Homa Bay District had 18 farms. The results indicated that there was a significant difference ($P<=0.05$) in yields between the treatments where ripping + lablab significantly out yielded both ripping + mucuna and farmers practice in most of the seasons in both sites. Similarly, ripping + mucuna significantly out-yielded farmers practice. Ripping + lablab gave overall mean maize yields of about 3 t/ha, ripping + mucuna 2.4 t/ha, while farmers practice gave 1.7 t/ha. From the results, it can be concluded that conservation tillage with cover crops give high maize yields in semi-arid areas. It is therefore, recommended to use combination in order to get high maize yields in semi-arid areas.

Okiyo T., Gudu S., Kiplagat O., Owuoche J. (2010). Effect of post anthesis moisture stress on performance of stay green sorghum hybrid in eastern province of Kenya. *In: Ouda et al. (Eds) Proccedings of the 12th Biennial Conference of the Kenya Agricultural Research Institute*, Nairobi, Kenya, November 8th -11th 2010 pp. 130-135.

Low soil moisture in crop production can be overcome by use of suitable crops. This study was set up to determine the response of four sorghum genotypes to post-anthesis moisture stress. Parent one, sirghum line with stay green drought tolerance was crossed with, an aluminium tolerant cultivar (Parent two). The parents, the first filial plant populations and KARI Mtama-4 were planted at Kiboko in 2008. The experiment was laid in RCBD with three replicates in a split-plot arrangement. Randomly selected main plots received supplemental irrigation after the first six weeks of emergence. Results indicated significant ($P \leq 0.05$ differences between treatments for leaf width ($P \leq 0.01$), for plant height and panicle weight, while significant ($P \leq 0.01$) differences among the genotypes were noted for stem girth, leaf width, plant height panicle weight and seed index. The F1 out-perfumed Parent one, Parent two and KARI Mtama-4 by 95.6%, 146.4% and 328.8% without water; and by 155.4%, 124.3% and 82.0% with water respectively for panicle weight. Parent one and F1 maintained green leaves both on watered and plots without water up to harvest while KARI Mtama-4 and Parent two had dry leaves and lodged stems on plots without water.

Omolo, P. O., Othieno C. O., Okalebo J.R., Kipsat, M. J. T (2010). Effects of tied-ridges for rainwater harvesting integrated with inorganic fertilizers on maize performance in semi-arid areas of Western Kenya. Proceedings of the 1st KARI mini conference, November 5-7, 2007. PP: 83-86

Soil moisture constraint is one of the most limiting factors to crop production in arid and semi-arid lands (ASALs). However, in Kenya, these areas are also deficient in major plant nutrients, particularly nitrogen (N) and phosphorus (P). Nutrient losses usually occur through soil erosion and continuous cropping with little or no nutrient replenishment. A study was conducted in Uranga division, Siaya District in the Kenya's lake Victoria basin and Chepararia, West Pokot District, North Rift to determine the effect of tied ridging, (improved soil moisture conservation) and different rates of N and P fertilizers (improved soil fertility) on the performance of maize, during the long rains seasons of 2004 and 2005. The experiment was laid out in a split plot design with fertilizer rates (four N rates; 0, 50, 100, 150 kg N/ha and two P rates; 0, 60, kg/ha) forming main plots and water harvesting technologies (tied and untied ridges) as sub plots. The treatments were administered in a factorial arrangement and replicated three times. The results indicated that tied ridges conserved moisture, which resulted in significant improvements on maize germination percentage, increased biomass and grain yields. Highly significant ($p<0.005$) yield improvements were recorded with combinations of N and P. The most economical combination was that of tied ridging in combination with 50 kg N/ha and 60 kg P/ha.

Omolo P.O. (2010). Effects of tied-ridging, nitrogen and phosphorus fertilizers application on maize production in semi-arid area of Siaya district. Msc. Thesis, Moi University, Kenya.

A study was conducted in Uranga Division, Siaya District in the Kenya's semi-arid Lake Victoria Basin for two seasons to determine the effects of tied-ridging (improved soil moisture conservation) and different rates of N and P fertilizers (improved soil fertility) on the performance of maize in 2004 during the short rain season and in 2005 during the long rain season. The experiment was laid out in a split-plot design with four N fertilizer rates/ha (0, 50, 100 and 150 kg) and two P fertilizer rates/ha (0 and 60 kg/ha) forming main plots and water harvesting technologies (tied and untied-ridges) as sub plots. The treatments were administered in a factorial arrangement (4 x 2 x 2) and replicated 3 times. Analysis of variance was done at 5% level of significance to determine the effects of treatments on grain and stover yields. The results indicated that tied ridges conserved moisture, which enhanced significant improvements on maize emergence percentage, increased significantly ($p<0.05$) biomass and grain yields were highly significant ($p<0.01$). Highly significant ($p<0.01$) yield improvements were recorded with combinations of N and P. The most economical combination was that of tied-ridging in combination with 50 kg N/ha and 60 kg P/ha.

Wanyama J.M., Mose L.O., Rono S.C., Masinde A.A.O., Serem A. (2010). Determinants of fertilizer use and soil conservation practices in maize based cropping system in Transnzoia district, Kenya. In: Ouda J. *et al.*, (Eds.). *Proceedings of the 12th Biennial Conference of the Kenya Agricultural Research Institute*, Nairobi, Kenya, November 8th -11th 2010 pp.1086-1095.

Despite the key role maize plays in food security and income generation in Kenya, its yield potential has not been fully achieved. Subsequently this has led to stagnation/decline in maize production. Despite the trend the human population continues to increase causing frequent food shortages among different wealth classes. This has been partly attributed to soil degradation due to poor conservation measure. Soil erosion and fertilizer application are major inputs in maize production therefore demands occasional review of their determinants and interventions. The purpose of this study was to assess the determinants of fertilizer and soil erosion control.

A survey was carried out in Trans Nzoia district where 415 respondents were randomly selected from three groups of farmers (small scale, medium scale and large scale farmers). The results revealed that soil erosion and fertilizer application is still a critical factor in maize production because of low adoption patterns for soil erosion technologies and low fertilizer rates. From logit and tobit models the results showed that change agent (extension) visit to farmers, proportion of under maize production, the sex of the household head and agricultural training significantly affected likelihood of farmers adopting fertilizers in maize production while, employment type of household head, fertilizer price and proportion of area under maize significantly influenced ($p<0.05$) the intensity of fertilizer application. Adoption of soil erosion technologies that significantly affected their adoption were the type of work and extension visit. The multiple factors influencing fertilizer use and soil erosion control demands involvement of many stakeholders. Low cost integrated soil erosion and fertilizer technologies for specific target farmers need to be designed and promoted.

Karuma A. N. (2009). Effects of legume cover crops and sub-soiling on soil properties and maize growth in Machakos district, Kenya. Msc. Thesis, University of Nairobi, Kenya.

Incorporating legume cover crops into the cropping systems and sub-soiling /ripping has been used as an alternative method of improving soil fertility, crop yields and minimizing soil erosion problems. The current study explored the use of legumes and sub soiling in Kalama division, Machakos District, Kenya. The area has an average annual rainfall of 600 mm which has 66% reliability. In order to achieve this objective, a survey and a field experiment were conducted to: identify the factors that influence the adoption of Conversation Agriculture (CA) technologies in Machakos District; determine the effect of legume cover crop, sub-soiling/ripping on soil properties and maize growth. The survey was conducted in mid-season of the long rains in the area (LR, 2008). This was in order to observe the land use trends, agronomic practices, farm resources and the soil fertility management practices practiced in the area. The target population consisted of the farmers who were instructed on or practiced conservation technologies introduced by the KARI/LRNP project in the district. The field experiments were carried out in a randomized complete block design in four farms during the 2008 long (LR) and short rain (SR) seasons. The first trial (LR, 2008) had three treatment groups (T1= maize + dolichos + sub soiling, T2 = maize + dolichos + no sub soiling, T3 = maize alone + no sub soiling). The second trial (SR, 2008) had four treatment groups (T1 = maize + dolichos + sub soiling; T4= maize with sub soiling). Socio-economic factors played a greater role in adoption of CA technologies with respect to gender, age, education and farmer's resources. Fifty seven percent of the respondents were female and more men were educated than female (65%). It was thus recommended that farmers be trained more on cover crops use as method of increasing soil fertility. Further there is a need to improve level of education with special focus on women in the area to enhance proper maximization of farms and improve food security. Results from the field experiments showed that rainfall amount and its distribution affected the growth of dolichos and maize. Early in the season, the dolichos had a higher ground cover than maize with a peak at 8 weeks after planting (WAP) and thereafter tended to decrease slowly due to moisture stress. A further increase in cover was noted at 14-16 WAP after some rainfall showers 12 WAP. The maize did not recover from the drought spell and was harvested at 17 WAP in SR, 2008. INLR, 2008, there was crop failure due to lack of adequate rainfall. There were significant differences in cover among the treatments at $P < 0.05$ in all the different WAPs. In reference to legume biomass, there were no significant differences among the treatments at $P<0.05$ but T1 had greater biomass than T2. Different treatments showed differences in maize heights and sub soiled plots gave a higher height of 2-10cm more than in the non-sub soiled plots as the WAPs progressed. Plots with dolichos (T1 and T2) gave higher maize dry matter yield than the maize alone plots (T3 and T4) in LR, 2008. In SR, 2008 compared to the initial characterization of the soils and this could be attributed to the dolichos in the field. The penetration resistance in all the plots ranged from 3.83 - 4.18 kg/cm^2 with T4 reporting the highest and T1 lowest penetration resistance.

Miriti J.M., Wakaba P.W. (2009). Effects of soil water conservation tillage and cropping systems on crop water productivity and farm incomes. Kenya Agricultural Research Institute, KARI-Muguga, *Annual report*. pp. 76-85

This study was an attempt to evaluate crop water productivity and economic implications of soil water conservation tillage practices (ripping and tie-ridging) on maize and cowpea production in arid and semi-arid areas of Makueni district. Results indicate tillage did not have significant influence on crop water productivity. Application of manure improved maize yields and water productivity over maize without manure. Growing maize and cowpea together increases crop water productivity in comparison with sole cowpea. Although rainfall distribution for all seasons is not provided in the report, water productivity depended more on rainfall distribution in the season than total rainfall. Seasons with well distributed rainfall had the highest crop water productivity values. Manual making of tie-ridging tillage increases land preparation labour cost by more than two times when compared with ox-ploughing (conventional tillage practice). Ripping and sub soiling on the other hand reduces labour cost compared to ploughing because of the minimized tillage. Marginal net returns for cowpea were positive in all seasons; indicating that cowpea is a profitable enterprise in the study area. The highest returns are realized when cowpea is grown under the conventional ox-plough tillage. Cost benefits ratio for sole maize was less than 1 in

majority in two out of three seasons, implying negative marginal returns. Application of manure improved water productivity and marginal returns for maize in seasons with favourable rainfall only. This study concludes maize in seasons with favourable rainfall only. This study concludes maize production particularly is not beneficial is the study area. Intercropping cowpea and maize in the same row has no economic benefits compared to sole crop particularly in ploughed and ripping tillage. Growing cowpea using the conventional ox-ploughing is the most economically viable cropping system for the area.

Maguta J. K. (2009). Conservation tillage in Kenya: the biophysical processes affecting its effectiveness. PhD thesis, Universitat zu Bonn.

Appropriate soil management is important for improved ecosystem functioning and high crop production. This study investigates how different tillage [reduced tillage (RT) and conventional tillage (CT)], crop residue (plus and minus crop residue) and cropping systems (soybean-maize intercropping, rotation and continuous maize) affected (1) soil aggregation, (2) composition and diversity of microbial populations, (3) crop residue (CR) disappearance and termite activity, (4), nitrogen fixation and (5) crop productivity in Kenya. The main experiment in Nyabeda (western Kenya) had been established in 2005. Soybean-maize intercropping improved macro aggregation and reduced micro aggregates and free silt and clay ($P<0.05$) compared with the other cropping systems. The proportion of soil large macro aggregates was 30% to 89% higher in RT than in CT, depending on depth. Addition of CR affected ($P<0.05$) soil aggregation mainly at the top 5cm; it increased the large macro aggregates (by up to 180%) in the soybean-maize intercropping systems. The composition of both bacteria and fungi communities was markedly different in the two tillage systems. With CR application, Simpson's indices of fungi were in the order intercropping > rotation > continuous maize. In addition, intercropping had highest bacteria diversity in the Nyabeda site. CR affected bacteria composition (e.g., in Matayos) and lowered diversity of soil fungi ($P<0.01$); fungi Simpson's index was 0.75 for plots without and 0.65 for plots with crop residue. Bacteria diversity was inversely related with aggregate mean weight diameter and with soil hot water-extractable carbon. CR disappearance was up to 85% of the initial residue in 3.5 months , and the relative contribution of macro- and meso-fauna to residue disappearance was 70-95% for surfaced placed and 30-70% for buried residues. Soil termite galleries (mainly sheetings) was more enriched in carbon (1.6%) than bulk farm soil (1.4%) and mound soil (1.2%; $p<0.01$); gallery soil and bulk farm soil had similar aggregates sizes but the values were lower (22-56% for >250<2000 um aggregates; $P<0.05$) than for mound soil. Soybean nitrogen derived from the atmosphere (%NDfA) ranged from 42-65%; it was higher ($P<0.05$) in RT (55.6%) than in CT (48.2%). Nitrogen fixed seasonally in soybean above ground plant parts was 26-48 kg N/ha with intercropping and 53-82 kg N/ha with rotation. Seasonal litter-fall contained about 15 kg N/ha. Total fixed N under RT plus CR was at least 55% and 34% higher than in the other treatments (RT minus CR, CT plus CR, and CT minus CR) in intercropping and rotation systems, respectively. Seasonal average maize grain yields were 3.2-4.1 t/ha in continuous maize, 3.0-3.9 t/ha in soybean-maize rotation, and 1.8-2.8 t/ha in the soybean intercropping system. Soybean grain yields were 0.92-0.99 t/ha in the soybean- maize intercropping, followed by rotation> continuous maize. Soybean yields were similar between CT and RT; maize yields were lower ($P<0.05$) in RT than CT. Overall net benefits for the 9 seasons were higher in CT than in RT. We conclude that (1) despite fast disappearance of CR, its application increases soil aggregation and influences microbial composition and diversity and nitrogen fixation; (2) for ferralsols of western Kenya, combining RT an CR is important for improved soil structural stability and, intercropping maize and legume (soybean) leads to better soil structure and also gives higher net benefits than conventional rotation and continuous maize systems; and (3) RT is appropriate for soybean production; maize yields are lower in RT than in CT due to surface crusting in the RT resulting from inadequate soil cover.

Nganyi E. W. (2009). Pigeon pea response to phosphorus fertilizer, temperature and soil moisture regimes during the growing season at Katumani and Kampi ya Mawe in Machakos and Makueni districts of Kenya. Msc. Thesis, University of Nairobi, Kenya

Pigeon pea (*Cajanus cajan*) is an important grain legume grown in the semi arid areas of the tropics used for food, feed and as a cash crop. Food insecurity is a persistent problem, especially in the marginal regions where the rapidly raising population cannot be supported by the rain-fed agriculture, especially in highly variable, erratic and changing climate as well as declining soil fertility. A sound strategy in the alleviation of these challenges is the expansion of production of crops that are suited to marginal environments such as pigeon pea. The broad objectives in this research were to establish the response of pigeon pea to basal phosphorus fertilizer application. The specific objectives were to characterize the soil fertility factors at the experimental site, to determine the variations of soil moisture over the growing season of pigeon pea, to assess the response of pigeon pea to basal fertilizer application and to test the suitability of the Agricultural Production System (APSIM) software as a monitoring and forecasting tool in the pigeon pea production. Two field rain-fed experiments were conducted between November 2006 and September 2007 at Kenya Agricultural Research Institute sites at Katumani and Kampi ya Mawe (in Machakos and Makueni districts respectively). The experimental design was a randomized complete block design laid out as split-plot and replicated four times. The whole plot treatment was fertilizer application and the sub-plot

treatment, five pigeon pea varieties which included one a local cultivar, Kionza as a local check. At the beginning of the experiment, soils were sampled for physical and chemical analyses. After every fortnight, crop phenology including height was recorded; soil moisture monitored using a neutron probe and weather data collected at nearby weather stations. At harvest, yield data was recorded and plant sampled for Nitrogen (N), Phosphorus (P) and Potassium (K) nutrient analyses. Results showed that in all varieties fertiliser application improved the ability of the crop to sequester soil moisture during dry spell but this did not influence the growth and development of the crop nor translate to better yields, seed quality or the shelling percentage for all the five varieties at Katumani; and for four varieties at Kampi ya Mawe; and only at Kampi ya Mawe. It also had significant effect on dry matter partitioning in N, P but not for K at that site. Although Katumani was more fertile and received more rainfall (1010 mm) during the cropping season, more than twice and better distributed than at Kampi ya Mawe (429 mm),only one variety (ICEAP 00040) performed better there (2044 kg/ha) by about twice. APSIM simulation predicted well the crop growth, development and yield in medium, but not in the long-duration varieties. It is recommended that factors that allow the local cultivar Kionza to respond to fertilizer application at only Kampi ya Mawe while not in the other varieties or site to be investigated. It should also be established if pigeon pea's phosphorus requirements have been adequately met and if not, what other factors could synergistically improve this crop's response. APSIM internal parameters need to be adjusted so that they can accurately predict the growth and phenological development of pigeon pea under field condition at the two experimental sites.

Rockstrɑm J., Kaumbutho P., Mwalley J., Nzabi A.W., Temesgen M., Mawenya L.,Barron J., Mutua J., Damgaard-Larsen S. (2009). Conservation farming strategies in East and Southern Africa: Yields and rain water productivity from on-farm action research. Soil & Tillage Research 103 (2009) 23–32.

Improved agricultural productivity using conservation farming (CF) systems based on non-inversion tillage methods, have predominantly originated from farming systems in sub-humid to humid regions where water is not a key limiting factor for crop growth. This paper presents evidence of increased yields and improved water productivity using conservation farming in semi-arid and dry sub-humid locations in Ethiopia, Kenya, Tanzania and Zambia. Results are based on on-farm farmer and research managed experiments during the period 1999–2003. Grain yield of maize (*Zea mays* L.) and tef (*Eragrostis Tef* (Zucc)) from conventional (inversion) tillage are compared with CF with and without fertilizer. Rain water productivity (WPrain) is assessed for the locations, treatments and seasons. Results indicate significantly higher yields ($p < 0.05$) for CF+ fertilizer treatments over conventional treatments in most locations, increasing from 1.2 to 2 t/ha with 20–120% for maize. For tef in Ethiopian locations, the yield gains nearly doubled from 0.5–0.7 to 1.1 t/ha for ''best bet'' CF+ fertilizer. WPrain improved for CF+ fertilizer treatments with WP gains of 4500–6500/m rainwater per t/maize grain yield in the lower yield range from 0 to 2.5 t/ha. This is explained by the large current unproductive water losses in the on-farm water balance. There was a tendency of improved WPrain in drier locations, which can be explained by the water harvesting effect obtained in the CF treatments. The experiences from East and Southern Africa presented in this paper indicate that for smallholder farmers in savannah agro-ecosystems, conservation farming first and foremost constitutes a water harvesting strategy. It is thus a non-inversion tillage strategy for in situ moisture conservation, rather than solely aimed at minimum tillage with mulch cover. Challenges for the future adoption of CF in sub-Saharan Africa include how to improve farmer awareness of CF benefits, and how to efficiently incorporate green manure/cover crops and manage weeds.

Wangechi, S. W. (2009). Effect of N-fertilizer and farmyard manure application, rhizobium inoculation and irrigation on performance of snap bean (*Phaseolus vulgaris* L) in Central Kenya. MSc. Thesis, University of Nairobi.

Improved management of soil fertility in low N soils is critical for increased land productivity and economic sustainability. Snap bean farmers in Kenya incur high costs on farm inputs, especially on chemical N fertilizers. Therefore, nutrient management practices that integrate the use of inorganic N fertilizer and organic manures are needed. A study was conducted at a farmer's field in Mwea, Central Kenya, to determine the effect of various combinations of farmyard manure and inorganic N fertilizer on growth and yield of snap bean. The study was carried out in two plantings (between April 2006 and July 2006 for the first planting and between September 2006 and December 2006 for the second planting) under furrow irrigation. The treatments tested were: four levels of inorganic N-fertilizer (0, 30, 60 and 90 kg N/ha) and four levels of farmyard manure (0, 4, 8 and 12 t/ha). The treatments were tested in a factorial experiment laid out in a randomized complete block design with three replications. A farmers practise consisting of 100 kg N/ha and 50 kg P_20_5/ha was included in each replications. The beans which were of variety Amy were planted in plots measuring 3 m by 3.5 m and furrows in between for irrigation. Furrow irrigation was done two times a week with 50 mm of water being applied each time. The data collected included: crop emergence, flowering and pot set percentages, plant heights, nodulation, shoot biomass, root biomass, pod yield and pod moisture content. The results showed that the application of 90 kg N/

ha significantly had higher emergence rates. The interaction between the N-fertilizer and organic manure levels was significant with the highest emergence percentage being recorded in plots supplied with 60 kg N/ha and 8 t/ha Farmyard Manure (FYM). Higher fertilizer rates at 90 kg N/ha had higher pod set percentage. N-fertilizer had a significant effect on plant heights with 60 kg N/ha having the tallest plants. Farmyard manure significantly improved the root dry weights of snap bean. The farmers practise treatment (100 kg N/ha and 50 kg P_20_5/ha) had the highest shoot dry weight. N-fertilizer application had a significant effect on total pod yield meaning that the fertilizer is necessary for a higher snap bean pod yield. The interaction between N-fertilizer and manure affected total pod yield significantly with the plots treated with 60 kg N/ha and 4 t/ha FYM registering the highest total pod yield. In terms of marketable yield, the interaction between N-fertilizer and manure had a significant effect with the highest "extra fine" yield exhibited by the plots supplied with 30 kg N/ha and 8 t/ha FYM while for the "fine" grade of snap bean, application of 60 kg N/ha and 4 t/ha FYM had the highest yield. N-fertilizer had a significant effect on unmarketable yield, with more N-fertilizer resulting in more "reject" yield of snap ban. Overall, combining FYM and N-fertilizer performed better in terms of pod yield than the farmer practise treatment (100 kg N/ha and 50 kg P_20_5/ha). Higher rates of fertilizer at 90 kg N/ha had more yields but also produced more "reject" yield.

Danga B. O. (2008). Effects of chickpea managed fallow on soil moisture and wheat yield and simulation of nitrogen and carbon turnover. PhD Thesis, Egerton University, Kenya

Monocropping and minimal use of residue contribute to low soil organic matter, fertility and productivity. The objectives were to evaluate the effect of chickpea rotation, residue incorporation and inorganic fertilizer N on soil water and N, and wheat yield and to predict long-term dynamics in soil mineral N and organic matter. The treatments arranged in a spit-split in a randomized complete block design, included fallow management treatments: 1) Chickpea green manure (GM) with its residues incorporated at blooming. 2) Mature chickpea (CHR) with its residues incorporated after grain harvest. 3) Bare fallow land (FS), ploughed and maintained weed free and 4) traditional weedy fallow (NT) as control, and inorganic N fertilizer applied at 0, 30 and 60 kg/ha N respectively as sub-plot treatments. Experiments were conducted for six and four consecutive seasons at the Njoro and Rongai sites respectively. The soil water content was the highest in the FS and NT during the fallow period, except in 2003 at Njoro when soil water potential was higher than 40 kPa at the 120cm depth. Available soil water at wheat planting varied with season, ranging from 0.088-0.103 m^3/m^3 in 2004 and from 0.123-0.147m^3/m^3 in 2005. The GM returned to soil between 3.3 to 83.6 kg/ha N while the CHR returned 1.60 to 49 kg/ha N. Inorganic N application increased wheat grain yield by 17 % (30 kg/ha) and 10.7% (60 kg/ha). Fallow chickpea treatment used more water to increase soil N that subsequently increased wheat yields compared to the bare and weedy fallows. The wheat grain yield increased by 24% and 39% for CHR and GM respectively compared to the NT control averaged for the 3 years. The GM improved the fallow with 30 kg/ha N fertilizer gave highest wheat yield. In a laboratory study the soils amended with CHR mineralized 47% CO2-C of added C compared to 55% for the GM. The GM mineralized approximately 64% of its N content. The 3-pools model improved the predictions over the 2 pools for both NIRS and hot water extract methods. The labile fraction decayed with a rate constant of 1.0/d the intermediate hemicellulose pool, 0.141/d for the GM and 0.034/d for CHR, and the recalcitrant pool 1.0×10^{-4}/d. Using chemical properties determined by the NIRS method in NCSOIL resulted in very close predictions of C and N dynamics in soil for both residues. Nitrification rates were much faster in the alkaline than acidic condition, whereas the source of the microorganisms population had a minor nitrofocation rate. Growing chickpea and incorporating its residues as green manure was recommended as a suitable short fallow management to enhance organic matter and N turnover in soil.

Miriti J. M., Esilaba A. O., Bationo A., Cheruiyot H., Kihumba J., Thuranira E. G. (2007). Tied-ridging and integrated nutrient management options for sustainable crop production in semi-arid eastern Kenya. *In: Bationo, A. (Ed.) Advances in integrated Soil Fertility Management in Sub-Saharan Africa: challenges and opportunities.* pp. 435-441. Springer 2007

A field experiment was conducted for two seasons at Emali, Makueni District in Eastern Kenya to compare the effect of tied ridging and integrated nutrient management practices on the yield of rainfed maize (*Zea mays* L.) and cowpeas (*Vigna unguiculata* L.). The main treatments were flat bed (FB, traditional farmers` practice) and tied ridging (TR) as main plots. The manure and fertilizers were farmyard manure (FYM, goat manure at 0 and 5 t/ha) in a factorial combination with nitrogen (N fertilizer at 0, 40, 80 and 120 kg N/ha) and P fertilizer at 40 kg P/ha as the subplots in a split-plot treatment arrangement of a randomized complete block design (RCBD). Results from maize yield data in the continuous maize cropping systems indicate that maize stover was significantly ($P \leq 0.05$) increased by the application of 5 t/ha of manure in both seasons. Tied ridges, manure and fertilizer did not affect grain yields in the first season. However, main grain yields obtained in plots with tied-ridges and manure were higher by 11% and 14% compared to plots without tied ridges and manure respectively. There was a significant interaction between manure and nitrogen which gave higher stover yields in the 2003 long rains season. Under the cowpea- maize intercropping system, tied ridges and manure application did not have a significant effect on

maize yields in both seasons. Application of nitrogen significantly (P≤0.05) increased maize stover by 29% and TDM yields by 50% in first and second season respectively when compared with treatments without nitrogen. Nitrogen application also increased cowpea stem and TDM yields by 57% and 45% respectively in the second season. Cowpea yields were not affected by tied-ridges in both seasons. There was significant effects of manure, nitrogen, manure * nitrogen and tied ridges * nitrogen interactions on cowpea stem and TDM in 2003 short rains season. In general, the combination of tied ridges with manure or nitrogen gave higher maize and cowpea yields than when these factors are applied alone. These preliminary results indicate that tied ridging in combination with integrated nutrient management has the potential to improve crop production in semi-arid eastern Kenya.

Mutegi J.K., Mugendi D.N., Verchot L.V., Kung`u J.B. (2008). Combining napier grass with leguminous shrubs in contour hedgerows controls soil erosion without competing with crops. *Agroforestry systems* Vol. 74:37-49

We established hedges/barriers of calliandra (*Calliandra calothyrsus* Meissner), leucaena (*Leucaena trichandra* (Zucc.) Urban)) and napier grass (*Pennisetum purpureum* Schumach) and combination hedges of either calliandra or leucaena with napier grass on slopes exceeding 5% to study the effect of vegetative barriers on productivity of arable steep-lands in central Kenya. Hedges/barriers were pruned regularly and biomass incorporated into the plots. Hedge plots were monitored for soil fertility, soil losses and maize crop yield changes. Inorganic-N concentration in the tree hedge plots was higher than in the control and napier barrier plots after 20 months. Napier grass barriers were the most effective in reducing erosion losses across the two seasons. The effectiveness of napier grass to significantly reduce soil erosion was detectable in one year old napier barriers. Soil loss from all the other one year old vegetative treatments was similar to sol loss from the control. Seventeen month old combination hedge plots recorded lower soil losses than tree hedges of the same age (P=0.012). Maize crop yields throughout the trial period were high and similar for leguminous and combination hedge plots, but lower in the napier grass and control plots. Overall, we observed that the combination hedges seemed to provide a win-win scenario of reduction in soil erosion combined with improvement of maize crop yields and soil fertility enhancement. We conclude that vegetative hedges have a potential for improving soil productivity in arable steep-lands of the central highlands of Kenya, and that in adoption of vegetative hedges for this purpose there are trade-offs between soil conservation, soil fertility and maize crop yields to be considered.

Gichangi M., Njiru N., Itabari K., Maina J., Karuku A. (2007). Assessment of improved soil fertility and water harvesting technologies through community based on-farm trials in ASALs of Kenya. *In: Bationo et al (Eds) Advances in integrated soil fertility management in Sub-Sahara Africa: Challenges and opportunities*. pp. 759-765

Low soil fertility and moisture deficits are major constraints to crop production in the semi-arid areas of Kenya. Farmers in these areas use Farmyard manure (FYM) as a cheaper alternative source of plant nutrients as opposed to more costly inorganic fertilizers. Community based on-farms trials were conducted in 4 hot and dry semi arid districts (Machakos, Kitui, Mwingi and Mbeere), and in two cool dry semi arid parts of Laikipia and Kiambu districts. The trials were aimed at evaluating the effect of improved soil fertility and water harvesting technologies (open furrows and tied ridges) on the yield of maize and beans over a period of 4 seasons. The study also aimed at identifying opportunities for improvement and modification of the technologies from farmers' observation and feedback. A number of technological options were offered to farmers for testing and treatments were replicated on between 20 -30 farms. The treatments were FYM 10 t/ha, FYM 20 t/ha, 20 kg N/ha + 20 kg P_2O_5/ha, FYM 10 t/ha +20 kg N/ha and FYM 10 t/ha + 20 kg N/ha+20 kg P_2O_5/ha for maize. For beans-based trials the treatments included FYM 5 t/ha, FYM 10 t/ha, 50 kg DAP/ha, 100kg DAP/ha and FYM 5 t/ha + 50 kg DAP/ha. The fertility treatments were also tested with or without water harvesting in a randomised complete block design (RCBD). In all the clusters, use manure or inorganic fertilizer included yield of maize and beans. Treatments that received FYM 10 t/ha + 20 kg N/ha produced the highest yields followed by treatments that received FYM 10 t/ha + 20 kg N/ha. The trend was similar for treatments that received 100 kg DAP/ ha and those that received FYM 5 t/ha + 50 kg DAP/ha for the bean trials. Higher net benefits were realised when organic and inorganic fertilizers were applied as compared to the control. Treatments that received both organic and inorganic fertilizers were applied as compared to the control. Treatments that received both organic and inorganic fertilizer (FYM 10 t/ha +20 kg N/ha + 20 kg P_20_5/ha) had the highest benefits of 19,166 (Kshs) for maize while for beans the highest net benefits 27,535 (Kshs) were obtained with FYM 5 t/ha + 50 kg DAP/ha. It is therefore recommended that farmers need to augment the limited quantities of farmyard manures available on smallholder farms with inorganic fertilizers and combining with appropriate water harvesting techniques for increasing the yields of maize and beans.

Kathumo V. M. (2007). Establishment of soil management zones based on spatial variability of soil properties for precision agriculture using GIS in Katumani, Machakos District of Kenya. Msc. Thesis, University of Nairobi, Kenya.

Analysis and interpretation of spatial variability of land/soil properties is a key-stone in precision agriculture. Spatial Variability is a problem in soil testing because mixing soil cores from high-and low-fertility areas creates a soil sample that does not represent either are because each point in a field is unique. Precision agriculture needs to be employed in solving this problem, which involves the use of Global Positioning System (GPS) and geographic Information Systems (GIS). However, reliable soil information required for precision farming planning is scarce, particularly in Kenya. Therefore a more detailed soil study of a part of Kenya Agricultural Research Institute (KARI) Katumani Research Centre was conducted with the principal objectives of (a) characterizing spatial variability of soil properties (b) determining relationships between spatial variability of soil fertility and their determining factors and (C) evaluating Grid-point versus Grid-cell soil sampling schemes for precision farming. Spatial variability and soil management zone maps were presented each at scale 1:6,000 and the results of soil properties and their determining factors relationships were presented in bar charts, GPS was used to geo-reference the sampled locations, which were based on the grid point and grid-cell soil sampling schemes. Physical and chemical properties of the soil samples were analyzed using the standard procedures. Spatial analyst extension of Arc view GIS software was used for the GIS analysis. Genstat was used for statistical analysis, Where one-way analysis of variance to test the significance of the studied factors. Spatial analysis by calculating variogram statistics was used to test spatial variability of soil properties. Generally soil fertility data showed variability where, soil phosphorus and percentage clay content were highly variable with 888 and115 general variances respectively. Total nitrogen was the least variable with general variance of 0.0022. Present land use, vegetation cover and soil texture were the major factors influencing soil phosphorus, total nitrogen and soil pH distributions in the study area respectively. This is because they were all significant at $P<0.05$. Micro-relief had no effect on soil fertility within the study area by depicting unusual relationship with exception of phosphorus, which did not show significance at $P<0.05$. Organic matter was influenced by vegetation cover and not by slope due to its unusual relationship, although was significant at $P<0.05$. Phosphorus was high in cultivated area than in grazing area. This was probably due to application of phosphatic fertilizers. Soil reaction (pH) was found to be low in loamy sand than in the sandy clay, due to high rate of leaching of basic nutrients and low organic matter hence low buffering capacity in loamy sand soils. Generally, the study area had respectively acid soils due to the presence of gneiss parent material. Vegetation cover played a major role in the distribution of soil nitrogen in the area hence high levels were found in areas with thick herbs and shrubs. By observation, gird-point sampling scheme was a better strategy for characterizing spatial variability of soil properties in the area than the Grid-cell sampling scheme. This is because variability was precisely defined within very short distances than in Grid-cell sampling scheme, which generalized variability in each cell. This was also supported statistically where grid-point sampling scheme gave higher general variances for all land/soil properties than Grid-cell sampling scheme. Soil management decisions would therefore be based on the developed soil management zones for precision agriculture where inputs should be matched with the site potential to maximize crop yields while minimizing excess usage of crop inputs.

Mburu D. M. (2007). Assessment of land use change, soil conservation technologies and performance of maize and beans in a semi arid environment: the Longonot case study. PhD Thesis, Chapter 1, Jomo Kenyatta University of Agriculture & Technology

Assessment of four soil conservation treatments (terrace, hedgerow, grass strip and tied ridging) including a control was carried out in Longonot for two years in 2003-2004 to evaluate suitable conservation technologies for the area. Short maturity maize variety (DH02) was used as the test crop to evaluate the treatment effects on maize yield as a result of improved soil moisture storage. Maize was harvested for two long rain seasons (April - October 2003 and 2004) while two short rain seasons(October 2002 - March 2003 and October 2003 - March 2004) were total crop failure due to very low seasonal amount of rainfall (201mm and 189 mm respectively). Ridges had the highest maize yield of 3000 kg/ha and 700 kg/ha in 2003 and 2004 long rain seasons respectively. There were no significant differences ($p<= 0.05$) among other treatments due to low amount of rainfall. The other conservation treatments (terrace, hedgerow and grass strip) had almost similar yields with an average maize yield of 1700 kg/ha and 450 kg/ha in 2003 and 2004 long rain seasons respectively. Ridging is a promising soil conservation technology in the area that can increase soil moisture storage for increased food production.

Mburu D. M. (2007). Assessment of maize and bean yield, water use efficiency and response to nitrogen fertilizer under semi arid environment: the Longonot case study. PhD Thesis, Chapter 5, Jomo Kenyatta University of Agriculture & Technology

Selected maize and bean varieties were planted for two years at Longonot to evaluate their performance under the semi-arid environment. Three of the maize varieties, Cargil 4141, Pannar 67 and pioneer planted, were imported into the country, while two varieties, H513, DH02 were locally produced. The three bean varieties, GLP 585, GLP 1004 and Pinto with local common names; Wairimu, Mwezi moja, and Mwitemania respectively were locally

produced. Nitrogen fertilizer was applied as urea at the rate of 36 kg N/ha in maize and 18 kg N/ha in beans. The fertilizer was split applied in two equal quantities at around 20 and 40 days after emergence for both maize and beans when there was rainfall. The experimental design was randomized complete block design laid as split plot and replicated three times. Fertilizer was applied in the main plots and maize and bean varieties were subplots. The data collected on biomass accumulation, phenological changes and final crop yield were analyzed using Genstat version 6.1. There was no significant difference ($p<=0.05$) in maize and bean yield amongst the varieties, but there was significant difference in yield between seasons. The yield differences were as a result of the amount and distribution of rainfall between the seasons.

Miriti J. M., Esilaba A. O., Wakaba P., Bationo A., Cheruiyot H. K., Kathuku A. N. (2007). Water harvesting and integrated nutrient management options for maize-cowpea production in semi-arid eastern Kenya. Kenya Agricultural Research Institute, Muguga, *Annual Report*, pp 75-77.

Field experiments were conducted for four years at Emali, Makueni District in Kenya to compare the effect of tied ridging and integrated nutrient management practices on the yield of rain-fed maize (*Zea mays* L.) and cowpeas (*Vigna unguiculata* L.). The main treatments were tied ridging and flat bed as main plots. The manure and fertilizers were goat manure at 0 and 5 t/ha, in a factorial combination with nitrogen (N) fertilizer at 0, 40, 80 and 120 kg N/ha and phosphorus (P) fertilizer at 0 and 40 kg P_2O_5/ha and crop management as subplots. The use of tie ridging alone did not result in better yields when compared with flat bed tillage. Maize grain and stover yields were significantly increased by 27% and 37% respectively when manure was applied. Combining tied ridges with manure and inorganic fertilizers resulted in more crop yields being achieved than when either was used separately. Application of N fertilizer in crop rotation of maize and cowpeas lowered maize grain yields and increased haulms yields when compared with the control treatments. In general, water harvesting using tie-ridging enhanced crop response to manure, N and P application.

Miriti J. M., Esilaba A. O., Bationo A., Cheruiyot H., Kihumba J., Thuranira E. G. (2007). Tied-ridging and integrated nutrient management options for sustainable crop production in semi-arid eastern Kenya. In: Bationo, A. *et al.,* (Eds.) *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities* pp 435-441. Springer.

A field experiment was conducted for two seasons at Emali, Makueni District in Eastern Kenya to compare the effect of tied ridging and integrated nutrient management practices on the yield of rainfed maize (*Zea mays* L.) and cowpeas (*Vigna unguiculata* L.). The main treatments were flat bed (FB, traditional farmers' practice) and tied ridging (TR) as main plots. The manure and fertilizers were farmyard manure (FYM, goat manure at 0 and 5 t/ha) in a factorial combination with nitrogen (N fertilizer 0, 40, 80, and 120 kg N/ha) and P fertilizer at 0 and 40 kg P/ha as the subplots in a split-plot treatment arrangement of a randomized complete block design (RCBD). Results from maize yield data in the continuous maize cropping systems indicate that maize stover was significantly ($P<0.05$) increased by the application of 5 t/ha of manure in both seasons. Tied ridges, manure and fertilizer did not affect grain yields in the first season. However, mean grain yields obtained in plots with tied-ridges and manure were higher by 11% and 14% compared to plots without tied-ridges and manure respectively. There was a significant interaction between manure and nitrogen which gave higher stover yields in the 2003 long rains season. Under the cowpeas-maize intercropping systems, tied ridges and manure application did not have a significant effect on maize yields in both seasons. Application of nitrogen significantly ($P\leq0.05$) increased maize stover by 29% and TDM yields by 50% in the first and second season respectively when compared with treatments without nitrogen. Nitrogen application also increased cowpea stem and TDM yields by 57% and 45% respectively in the second season. Cowpea yields were not affected by tied-ridges in both seasons. There was significant effects of manure nitrogen.manure*nitrogen and tied ridging*nitrogen interactions on cowpea stem and TDM in 2003 short rains season. In general, the combination of tie-ridges with manure or nitrogen gave higher maize and cowpea yields than when these factors are applied alone. These preliminary results indicate that tied ridging in combination with integrated nutrient management has the potential to improve crop production in semi-arid eastern Kenya.

Okoth P. F., Ng`ang`a J. K., Kimani P. K. (2007). Consequences of field management and soil erosion on the sustainability of large scale coffee farming in Kiambu. In: Bationo A. (Ed.) *Advances in integrated Soil Fertility Management in Sub-Saharan Africa: challenges and opportunities*. Springer pp. 299-309.

Uncontrolled soil erosion and land degradation affect production systems and are a threat to the sustainability of most agricultural systems. This paper introduces a new management concept; the integrated land use management concept (ILUM), as a means of mitigating against erosion. Large scale coffee estates in Kiambu district, Kenya, were selected for soil erosion investigations through the use of aerial photographs and satellite images. Aerial photographs (1:10,000) were used to delineate using satellite images. Samples collected from the plots indicated pH values of extremely acid to slightly acidic soils with deficiencies of Ca, Mg and K. the erosion status varied from slight to severe with the bulk of the fields under moderate to critical erosion severity conditions. A direct

relationship between management and nutrient status of the fields, soil erosion status and slope steepness was observed. Liming of the extremely acidic soils at 500 g/tree, and the use of SSP and DSP fertilizers is recommended instead of acidifying fertilizers. Mulching is recommended for steep slopes (8-13% and 13-18% slopes). Large fields should be subdivided and Kikuyu grass (*Pennisetum clandestinum*) introduced between the fields as a conservation measure for erosion management and control.

Mutuo P. K., Shepherd D. K., Albrecht A. and Cadisch G. (2006). Pediction of carbon mineralization rates from different soil physical fractions using diffuse reflectance spectroscopy. *Soil Biology and Biochemistry* 38 (7): 1658–1664.

Soil carbon (C) mineralization rate is a key indicator of soil functional capacity but it is time consuming to measure using conventional laboratory incubation methods. Recent studies have demonstrated the ability of visible-near infrared spectroscopy (NIRS) for rapid non-destructive determination of soil organic carbon (SOC) and nitrogen (N) concentration. We investigated whether NIRS (350–2500 nm) can predict C mineralization rates in physically fractionated soil aggregates (bulk soil and 6 size fractions, n= 108) and free organic matter (2 size fractions, n = 27) in aerobically incubated samples from a clayey soil (Ferralsol) and a sandy soil (Arenosol). Incubation reference values were calibrated to first derivative reflectance spectra using partial least-squares regression. Prediction accuracy was assessed by comparing laboratory reference values with NIRS values predicted using full hold-out-one cross-validation. Cross-validated prediction for C respired (500 days) in soil aggregate fractions had an R^2 of 0.82 while that of C mineralized (300 days) in organic matter fractions was 0.71. Major soil aggregate fractions could be perfectly spectrally discriminated using a 50% random holdout validation sample. NIRS is a promising technique for rapid characterization of potential C mineralization in soils and aggregate fractions. Further work should test the robustness of NIRS prediction of mineralization rates of aggregate fractions across a wide range of soils and spectral mixture models for predicting mass fractions of aggregate size classes.

Omuto C. T. (2006). Large-area soil physical degradation assessment using GIS, remote sensing, and infrared spectroscopy in arid and semi arid Kenya. Msc. Thesis, University of Nairobi, Kenya

Soil physical condition controls several important soil functions such as support for biomass production, water cycling, filtering pollutants, and land surface energy balance. However, physical degradation undermines this ability. Currently, there is lack of rapid and repeatable methods that can facilitate timely large-area assessment for the effective monitoring and control of soil degradation. This study tested the combined applications of point-measurements of physical properties, soil diffuse spectral reflectance (DSR), and remote sensing to spatially assess the degradation in large watershed (4500 km^2) in semi arid areas in eastern Kenya. Indicators of the degradation were determined from 540 point-measurements of infiltration and water retention and field observation of the visible signs of soil physical degradation. The physical properties included steady-state infiltration rates, sorptivity, water-holding capacity, pore distribution index, bulk density, and air-entry potential. The parameters describing these properties were derived using non linear mixed effects (NLME) approach, which was also used to test for the effects of other covariates such as land use and geographic features. A screening protocol was then developed that took evidence of degradation from visible assessments in the field, estimated soil physical properties, and rapid soil test based on soil DSR to predict the degradation cases, Over 90% sensitivity and specificity was achieved with a mixed effect logistic model based on one third holdout sample. The screening results showed that soil DSR was powerful tool for detecting early warning indicators of degradation that were not readily discernable from field observations. In addition to the point-estimates of likelihood of physical degradation, time integrated remote sensing indicators were also tested for power of prediction of the trends of the degradation in the study area. The standardized deviations of land surface temperature (LST) and Normalized Difference Vegetation Index (NDVI) from time-series Landsat scenes were used to study the thermal and vegetation conditions of the degradation at sampled points. These indices effectively predicted the likelihood of the degradation of the held-out samples with 80% accuracy of ground reference data and were used to map the degradation in the whole study area. The approach developed in this study showed promising opportunity for spatial prediction of physical degradation at high spatial resolution over large areas and could be a useful tool for guiding policy decisions on sustainable land management especially in the tropics where land use policies lack scientific support.

Shishekanu M. N. (2006). The influence of tillage implements and practices on soil and moisture conservation of a crusting soil. MSc Thesis, University of Nairobi, Kenya.

Soil crusting and hard-setting conditions limit agricultural productivity of most semi-arid lands of Kenya. Hydrologicl conditions of these soils are negatively influenced by the development and occurrence of soil crusting and hard-setting under the influence of bad tillage implement practices and adverse seasonal rainfall characteristics. The occurrence of soil crusting and hard setting conditions decrease rainwater infiltration and inversely increase the surface runoff. The reduced rainwater infiltration and high surface runoff induces agricultural soil drought due to reduced water tramittance and consequent storage into the soil profile. The objectives of this study was to

investigate the influence of tillage implements and practices on soil and moisture conservation on a crusting and hard setting (sandy clay loam) Luvisol of the semi-arid Kenya. The experiment was conducted under extreme field conditions of bare land (no test crop) to eliminate any influence of crop cover, over the pertinent hydrological and soil properties. This study took two rainy seasons (short and long rains) with field investigations covering rainfall characteristics, soil surface roughness, shear strength, penetration resistance, bulk density, soil loss, wet soil aggregate stability, surface runoff and soil moisture, Investigations were conducted on 12 micro-plots of two square metres laid out in a split-plot in a Randomized Complete Block Design, complemented by a differential tillage depth treatment laid on a Randomized Complete Block Design. The main experimental treatments consisted of farmyard manure (FYM) at 0 and 10 t/ha for soil amendment. In the 10 (10) farmyard manure per hectare were applied throughout for soil amendment. The experimental treatments were two tillage implement practices (minimum tillage-Modified Reversible Maresha Prototype- MRMP, and conventional Rumpstand -RS and two farmyard manure applications. FYM (0 and 10 t/ha). A complimentary tillage depth treatment was introduced during the long rainy season aimed at providing understanding of the effect of tillage depth on soil moisture conservation. The conventional tillage implement was used at 12cm and 17cm tillage depth with 10 tonnes per hectare uniform manure application. The tillage implement practices and manure showed a significant influence on surface runoff infiltration, soil loss and moisture conservation. The hydrological response of all treatments were influenced by soil crusting and hard setting. The seasonal rainfall characteristics (amounts, frequency duration and intensities) and the treatment effects on the soil surface roughness and aggregate stability impacted on the hydrological response. The minimum tillage implement practice reduced soil loss by 19% surface runoff by 40% and enhanced water infiltration throughout the study. During the second rainy season the minimum tillage steadily enhanced soil moisture conservation due to the furrow depression storage created by the oriented surface roughness of the MRMP. The conventional tillage implement practice initially reduced soil loss, surface runoff and reduced water infiltration. The treatment response to ten tonnes of manure reduced soil loss by 40% surface runoff by 39% and enhanced water infiltration throughout the study period. The tillage implement practice and manure interaction treatment reduced soil loss by 48%, surface runoff by 68% in the MM and 18% in the RS and enhanced water infiltration throughout the study period. The soil moisture conservation response to ten tonnes for manure reduced soil loss by 40%, surface runoff by 39% and enhanced water infiltration throughout the study period. This study has shown that minimum tillage and manure application have a greater impact on soil loss, surface runoff and soil moisture conservation in a crusting and hard setting soils of the semi arid. Rainfall intensities of above 75mm per hour has show to influence total soil loss of 66% and runoff water of 40%. During the second rainy season the minimum tillage steadily enhanced soil moisture conservation due to the furrow depression storage created by the oriented surface roughness of the MM. The results obtained showed some significant changes in the hydrological related properties and soil management treatments. The tillage oriented surface roughness, soil aggregation, soil and runoff loses and moisture; changed with rainfall events and soil management practices. FYM and MRMP tillage practices compared to their control of no-manure and RS reduced runoff by 39% and 40% and soil loss by 40% and 36% respectively. Soil moisture conservation was however, not improved until about mid- season (short rains). Deep tillage (RS17) on the other hand showed a 60% improvement at a 17cm soil depth over the 12cm tillage depth (RS12) and was highly significant at 5% probability level. This study has shown that tillage implement (MRMP) practice and incorporation of farm yard manure (FYM) on a crusting and hard-setting soil is a potential soil and water conservation tool that provides protection even when erosive forces are severe. It has also revealed that, application of un-decomposed manure and MRMP, do not immediately improve moisture retention. Deep tillage that incorporates FYM beyond 12cm depth can enhance improvement in soil moisture conservation.

Kamoni P. T. (2005). Effects of soil water, nitrogen and phosphorus on maize growth and yield in semi-arid environment. PhD thesis, The University of Nairobi, Kenya.

A field study was carried out for three seasons from Nov. 1999 to Feb 2001 to investigate the influence of irrigation to growth. Light and nitrogen use in maize under semi-arid conditions in Machakos, Kenya. The study also accessed the potential and applicability of the world food study (WOFOST) model in predicting maize growth and yield in the same area. The work spanned three seasons namely short rains 1999 (SR1999, Nov 1999 - March 2000); long rains (LR 2000, April to August 2000) and SR 2000 (Nov 2000 to March 2001) the rainfall received in the three seasons was 350, 143, and 534 mm respectively. The experimental design was randomised complete block design laid out as split plot with water regime as main plots (irrigated rain-fed) nitrogen N (0, 50,100 kg N/ha) and phosphorus P (0, 25 kg P_2O_5) factorially combined as sub plots. Data collected included leaf area index (LAI) photosynthetically active radiation, (PAR) interception maize yield total dry matter (TDM) accumulation nitrogen uptake and soil moisture. Irrigation significantly increased TDM (at physiological maturity) by about 2 to 10 fold during the study period. Grain yields were lost during the dry season (LR 2000) (151 kg/ha) and highest (6,027 kg/ha) in wettest season (SR 2000). Irrigation significantly increased leaf area index (LAI) by about 2 fold (maximum LAI 1, 3, 2.8 for rain fed and irrigated respectively) in the dry season but had no effect in the wetter season. PAR interception increased by the same factor as LAI (maximum PAR interception 33%, 64% for rainfed and irrigated respectively in the dry season). Maize light extinction coefficient was lower (0.03) under moderate and low water supply (rainfed SR 1999 and LR 2000) and higher (0.37) under high water supply

(irrigated LR 2000 and SR 2000). The total plant N uptake was highest (175 kg/ha) in wettest season SR 2000) and lowest (14 kg/ha in the driest season. Irrigation increased N uptake by a factor of 2 and 10 in the moderately wet season and dry season respectively. Cumulative evapo-transpiration was higher with irrigation in the season with moderate rainfall (SR 1999) by about 2 fold and 5 fold in the dry season (LR 2000). Soil water extraction was higher in the fertilized maize (at 30 and 45 cm) compared to the unfertilized maize in the three seasons. Nitrogen application improved TDM grain yield LAI, PAR interception and N uptake in the season that water was not limiting (wet season or under irrigation) in the three seasons light use efficiency ranged from 2.2 and 2.5 g/MJ with N application and high water supply and 1.04 g/MJ under low water supply (rainfed). WOFOST model exaggerated grain yield by 10 to 20% because of over estimation of the partitioning coefficient. The product of the various variables (LAI, soil profile, moisture leaves, stems dry matter, TDM and grain yield) were closer to measured values under wet (178 to 534 mm rainfall) or irrigated conditions but were highly over estimated (30-75.6%) under dry conditions. The validation showed that reasonable estimation (80-90%) of grain yield leaves stems and total dry matter can be made under adequate water supply. The optimal N application was 50 kg/ha above which there was no improvement in maize growth and yield. Supplementary irrigation can increase maize yield even at low fertilizer input level in semi-arid Kenya.

Kibe A. M., Singh S. and Kalra N. (2005). Consumptive use of water and water use efficiency by wheat (*triticum aestivum*) in relation to irrigation and nitrogen. In: Kinyua et al (Eds) *Proceedings of the 12th Regional Wheat Workshop for Eastern, Central and Southern Africa*, Nakuru, Kenya, 22–26 November 2004. KARI and CIMMYT. Pp. 21-34

A field experiment was carried out on a sandy loam soil to study the use relationships to yields of a late sown wheat cultivator, HD-2285 under limited and adequate water and nitrogen regimes . The experiment was laid out in a split - plot design with four irrigation levels (I0 no post - sowing irrigation; I1 one irrigation at CRI; I2, two irrigations, each at CRI, and flowering; I3, four irrigations each given at CRI, jointing , flowering and dough stages) in main plots and a combination of three N levels, viz. N0, N50 and N100 and two zinc levels, Z0 and Z5 in sub-plots, (subscript numbers signifying N and Zn qualities in Kg/ha), in three replicates. the Consumptive use of water (UC) by wheat increased with every additional level to a maximum of 328.4 mm and 301.7 mm. Water use efficiency (WUE) was maximum (1.38 kg grain/m^3 water use) with two irrigation treatments given at the crown root initiation (CRI) and flowering stages. This did not correspond with the above ground biomass and grain yield production, which were highest under four irrigation treatments (I3). The Moisture use rate increased with increase in irrigation water to a maximum of 2.74 and 2.51 mm/day in the first and second seasons, respectively. Moisture extraction was maximum (59.4% - 65.8%) from the 0-30 cm soil layer. water use efficiency increased markedly with increase in nitrogen application attaining a maximum (1.42 and 1.52 kg grain/m^3 water use) under 100 kg N/ha application. Maximum WUE did not correspond to the highest grain yield. The rate of increase in both grain yield and WUE started to decline as ET further increased beyond 270 mm.

Musembi K. B. (2005). Effects of planting density and weeding regimes on forage and grain yield of maize. Msc. Thesis, University of Nairobi, Kenya

Maize is a major food and forage crop in Kenya and planting density and weeding regime influence yield. The effects of weeding regimes and maize planting density on maize forage grain yield and quality were evaluated during the 2001/2002 short rains and long rains of 2002 at Kenya Agricultural Research Institute, Muguga in Central Kenya. Weeding regimes were weed free (WI), weedy (W2), herbicide (W3) and hand weeding twice (W4). Maize densities were 9(D1) and 18 plants m-2 (D2) intercropped with beans. Maize was thinned at 98 DAE at tasseling stage and assessed for forage yield and quality. Stover and edible weeds biomass yield and quality were also assessed. Soil moisture content down the profile, PAR interception, weed density, maize height and rate of tasseling was determined gradually over the season. Maize yield and bean biomass was also determined. The collected data was analysed using GENSTAT software and their means separated with LSD at P =0.05.Percent interception of photosynthetically active radiation (PAR) was significantly higher in D1 than in D2 after thinning in both seasons. Interception of PAR was significantly higher in W2 compared to W1, W3 and W4, which were similar in both experiments. Soil moisture content was significantly lower in W2 but similar in W1, W3 and W4. D2 had significantly lower soil moisture content than D1 in season two throughout the season. Thinnings biomass was higher where weeds were controlled and least in the weedy regime in both seasons. Thinnings biomass was significantly higher in D2 than D1 in both seasons and D1 had significantly higher maize grain yield than D2 in both seasons. Stover biomass was significantly higher in D1 than D2 in season one but was similar in season two. Total forage biomass from D1 was same as in D2 in season one whereas in season two was significantly higher in D2 than D1. Beans performed poorly due to low planting density and shading effects due to maize in both seasons. The tasselling rate was significantly lower in D2 than D1 while W2 had significantly lowest tasseling rate as compared to W1, W3 and W4, which had similar tasseling rate in both seasons. Maize plants were significantly short in W2 compared to W1, W3 and W4, which were similar. They were also shorter in D2 than in D1 in both seasons. Total weed biomass at 126 DAE was significantly higher in W4 than in W3 and in D1 than in D2 in both

seasons. The cattle-edible weed biomass at the end of the two seasons was at least 55% of the total. Thinnings had significantly higher digestibility (76) and crude protein (7%) than stover. Two times hand weeding (W4) was two to three times more expensive than using herbicide (W3).Weeds competed for light and water leading to reduced thinning, stover and grain yield but increased weed biomass, which was significantly lower than maize biomass in the weeded plots. High maize density increased intraspecific-competition (of maize in the hills) for water and light before thinning time (98 DAE) and significantly reduced plant height, tasseling rate and grain yield. Hand weeding is labour intensive and thus led to increased expenses than herbicide use. Planting maize at high density significantly increased forage quality and quantity, and overall light capture especially before thinning, but reduced weed biomass and grain yield.

Nkonge I. G. (2005). Light, water and nitrogen use in low input maize-pigeon pea intercrop in sub humid Kenya. Msc. Thesis, University of Nairobi, Kenya

A field experiment was conducted to investigate light, water and nitrogen use in a low input maize-pigeon pea intercrop system in sub-humid conditions at the University of Nairobi, Kabete Field Station. Treatments were three pigeon pea (*Cajanus cajan*) varieties; a medium duration (ICEAP 00557) and two long duration types, semi-erect (ICEAP 00040) or erect (ICEAP00053), planted alone or intercropped with maize (*Zea mays*) (H511). Two cotton (*Gossypium hirsutum*) varieties (Hart89M and UKA 59/146) were used as a reference crops to determine amount of N fixed by pigeon pea using the N difference method. The experiment was laid out in a randomized complete block design (RCBD) replicated six times. Data on canopy light interception, changes in soil water, crop dry matter accumulation, grain yield, plant total nitrogen and soil mineral N at key phenological stages was determined. There were two maize cropping seasons; April-September 2001 and October - April 2002 as seasons 1and 2 respectively, but one season of pigeon pea crop. Peak photosythetically active radiation (PAR) interception in intercropped pigeon pea occurred after maize was harvested in both seasons. The long duration varieties intercepted more PAR than medium duration variety. The long duration pigeon pea intercrop extracted more soil water than either of the component sole crops. Long duration pigeon pea had a larger canopy and extracted more soil water than the medium duration pigeon pea. Sole maize had highest water efficiency while sole pigeon pea had the least. Maize average grain yield was 4339 kg ha^{-1} and that of pigeon pea was 1400 kg/ha. Long duration pigeon pea had significantly higher yield (1600 kg/ha) than medium duration pigeon pea (935 kg/ha). The land equivalent ratio (LER) was 1.0. 0.96, and 0.84 for maize intercropped with the ICEAP 00040, ICEAP 00053 or ICEAP 00557, respectively, indicating lack of pigeon pea-maize-intercropping advantage. There was better N use in the intercrop than in the sole cropped pigeon pea system. The long duration pigeon pea fixed more nitrogen than the medium duration one early in the season. It was difficult to estimate the amount of N fixed by pigeon pea later in the season because cotton, the reference crop, accumulated more biomass than pigeon pea. Pigeon pea litter fall N contribution ranged from 58 kg/ha to 92 kg/ha in intercropped medium and long duration pigeon pea, respectively. The average grain yield of maize obtained from plots previously planted with the sole of long duration pigeon pea erect was higher (3940 kg/ha) than from plots that were previously intercropped with pigeon pea (3521 kg/ha) or those that were continuously planted with maize (1833 kg/ha). This may be an indication of increased nutrient supply from decomposed litter. Intercropping of maize with long duration pigeon pea improved light, water and nitrogen use in the system more than the medium duration pigeon pea.

Nzabi A.W., Kidula N., Mutai E. (2005). Effect of conservation tillage and cover crops on soil fertility improvement and maize yields in Kusa, Nyando District. Kenya Agricultural Research Institute-Regional Research Centre-Kisii, *Annual Report* pp. 118-123.

Soil erosion depletes soil productivity; regardless of current nutrient reserves, the rates of soil erosion serve as one indicator of the sustainability of soil fertility. Soil erosion results in adverse physical and chemical soil properties affecting crop yields. Conservation tillage reduces soil manipulation and therefore saves on labour requirement. It improves soil productivity by minimizing compaction and improving soil moisture storage within plough layer. In conservation tillage crop residues form mulch, which conserves moisture, reduces rain drops impact leading to reduced surface run-offs. The aim of conservation tillage is to reduce soil and water losses. Cover crops protect the soil from splashing rain and too much heat from the sun and reduce surface crusting and high fluctuation in soil temperature in semi-arid areas. Cover crops increase soil organic matter content. An experiment was carried out in Kusa in 2004 and 2005, with the main objective of assessing the effect of conservation tillage with green manure cover crops on soil fertility improvement, maize grain and stover yields and striga weed control. In a randomized complete block design, conventional tillage was tested against ripping, cover crops were also planted manure and fertilizers were applied for the purposes of comparison. The results showed that conservation tillage was superior to conventional tillage under Kusa semi-arid climatic conditions. Conservation tillage control soil erosion. It is faster and cheaper than conventional tillage. Conservation tillage together with legume cover crops improves soil fertility and moisture retention and suppresses weeds including striga weeds. All these factors led to increased maize yields with higher returns. It can therefore be recommended that farmers in Kusa and other semi-arid areas use conservation tillage together with Lablab or Mucuna are good as cover crops when intercropped with maize.

Kibe A. M., Singh S. and Kalra N. (2004). Consumptive use of water and water use efficiency by wheat (*Triticum aestivum)* in relation to irrigation and nitrogen. *Proceedings of the 12th regional wheat workshop for eastern, central and southern Africa*. Nakuru, Kenya, 22-26 November, 2004. Pp 21-34

A field experiment was carried out on a sandy loam soil to study the use relationships to yields of a late sown wheat cultivator, HD-2285 under limited and adequate water and nitrogen regimes. The experiment was laid out in a split - plot design with four irrigation levels (I0 no post - sowing irrigation; I1 one irrigation at CRI; I2, two irrigations, each at CRI, and flowering; I3, four irrigations each given at CRI, jointing , flowering and dough stages) in main plots and a combination of three N levels, viz. N0, N50 and N100 and two zinc levels, Z0 and Z5 in sub-plots, (subscript numbers signifying N and Zn qualities in Kg/ha), in three replicates. the Consumptive use of water (UC) by wheat increased with every additional level to a maximum of 328.4 mm and 301.7 mm. Water use efficiency (WUE) was maximum (1.38 kg grain/m^3 water use) with two irrigation treatments given at the crown root initiation (CRI) and flowering stages. This did not correspond with the above ground biomass and grain yield production, which were highest under four irrigation treatments (I3). The Moisture use rate increased with increase in irrigation water to a maximum of 2.74 and 2.51 mm/day in the first and second seasons, respectively. Moisture extraction was maximum (59.4% - 65.8%) from the 0-30 cm soil layer. water use efficiency increased markedly with increase in nitrogen application attaining a maximum (1.42 and 1.52 kg grain/m^3 water use) under 100 kg N/ha application. Maximum WUE did not correspond to the highest grain yield. The rate of increase in both grain yield and WUE started to decline as ET further increased beyond 270 mm.

Mugwe J., Mugendi D., Okoba B., Tuwei P., Onell M. (2004). Soil conservation and fertility improvement using leguminous shrubs in central highlands of Kenya NARFP case study. *In: Bationo A. (Ed.) Managing Nutrient Cycles to Sustain Soil fertility in Sub-Sahara Africa*. pp 277-298. AFNet.

Declining land productivity with reduced crop yields has been major problem facing smallholder farmers in the central highlands of Kenya. The major factors contributing to the land productivity is soil impoverishment caused by continuous cropping without addition of adequate fertilizer and manure and soil erosion to steep slopes. The national agroforestry research project (NAFRP) initiated research in 1992 to try and address the problems. The research work investigated the potential of using two leguminous shrubs (*Leucacaena lecocephala* and *Calliandra calothyrsus*) for improving soil fertility and soil conservation on steep slopes. The studies were carried out both at on station and on farm. Treatments where leafy prunnings of caliandra and leucacaena were incorporated yielded higher than control treatments without prunnings incorporation Leucaena alley cropping system was beneficial and maintained crop yields at 4 t/ha in most seasons. Calliandra hedge grow intercropping system on the other had depressed crop yields. However calliandra was effective in controlling soil erosion when planted as contour hedgerows in addition to conserving soil produced additional benefits in terms of high quality animal fodder. This study concluded that in the central highlands of Kenya where land is sloppy and similar areas it is advisable for the smallholder farmers to plant leguminous trees on terraces as contour hedgerows for both soil conservation and biomass production the resulting biomass could be incorporated in to the soil to improve soil fertility for farmers without livestock or fed to livestock for farmers who own livestock. If the biomass is fed to livestock possibilities of recycling nutrient through animal manure should be explored to soil nutrient replenishment.

Mutegi J., Mugendi D., Verchot L., Kungu J.B. (2004). Impacts of vegetative contour hedges on soil inorganic-N cycling and erosional losses in arable steep-lands of the central highlands of Kenya. *In: Bationo (Ed) Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa* pp. 187-197

Moderate to steep landscape and severe soil, water and nutrient losses characterize over 40% of arable land in the central highlands of Kenya. To study effectiveness of biological methods in management and enhancement of productivity of these arable land steep-lands, we established contour double row hedges of sole Calliandra, Leucaena and napier and combination hedges of either Callindra or Leucaena with napier. Hedges were established on slopes exceeding 5%, pruned regularly and the resulting biomass cut into fine pieces, which were incorporated into the plots they served. We then evaluated these plots for inorganic-N changes in depth, soil conservation and soil loss/crop growth relationships. We observed that accumulation of inorganic-N in the subsoil in the control and napier plots but a reduction of subsoil inorganic-N and its re-accumulation in the top-soil in the leguminous hedge plots after 20 months of trial. The first season on average, registered higher losses ($P=0.004$) than the second seasons for treatments with hedges and vice versa for the control. During the first season there were significantly lower ($P<0.001$) soil losses in plots with hedges relative to the control on slopes exceeding 10% but with the exception of naper, no significant differences among different types of hedges. We observed higher soil loss reduction in the combination hedge relative to individual tree hedges across the two seasons ($P=0.012$). The relationship between cumulative soil loss and any of the four crop growth parameters i.e. grain weight, plant height, stover weight and total above ground biomass was negative, linear and highly significant($P=0.0001$), indicating decreased crop growth with soil loss. We conclude that there are heavy productivity losses as a result

of soil erosion in arable steep-lands of central highlands of Kenya and that well spaced, managed and combined contour hedges of leguminous trees and napier can reduce soil and nutrient losses from steep arable landscapes while simultaneously enhancing soil fertility.

Ooro P.A., Kinyua M.G., Ogola J.B.O (2004). Efficiency as affected by moisture level under Rain-out shelter. *Proceedings of the 3rd Scientific Advisory Committee meeting 4-6 October 2010, EAIR Assembly* Addis Ababa pp. 1-6

About one-third of the developing world's wheat area is located in the environments that are regarded as marginal for wheat production, because of drought, heat, and soil problems. Nearly one-third of the area planted to bread wheat and about three-quarters of the area planted to durum wheat suffer from drought stress during the growing seasons. Despite these limitations, the world's dry and difficult cropping environments are increasingly crucial to food security in the developing world. Gains in wheat productivity in marginal environments are important because it is unlikely to that increased productivity in the favourable environments will be sufficient to meet the projected growth in demand from the present to 2020. This study was aimed at evaluating wheat genotypes' water use efficiency (WUE) as affected by moisture regime. An experiment was conducted under rain shelter for two seasons (2001-2002) with six cultivars (Duma, Ngamia, Chozi, Kwale, Mbuni and Pasa) tested under two moisture regimes (High and Low moisture regimes). The experiment was a randomized complete block design (RCBD) with split arrangement of treatments. Moisture regime was assigned as the main plot and cultivars as the sub-plot. An analysis of variance was carried on combined season using SAS computer package. The genotypes were significantly different in their water use efficiency (WUE) under both low and high moisture conditions. The drought-tolerant cultivars (DTC)-Duma, Ngamia and Chozi-had significantly higher WUE under moisture stress than drought-susceptible cultivars (DSC)-Kwale, Mbuni and Pasa. Under high moisture the WUE of the DTC was decreased by 10-19% and in the DSC, it increased by 26-29

Gicheru P., Gachene C. Mbuvi J. and Mare E. (2003). Effects of soil management practices and tillage systems on surface soil water conservation and crust formation on a sandy land in semi- arid Kenya. *Soil and Tillage Research*. Vol. 75:173-184.

The effect of different soil management practices on crust strength and thickness, soil water conservation and crop performance was investigated on a fabric lixisol in a semiarid environment of western Kenya. The study proved that manure and mulching with minimum tillage have a greater effect on water balance of crusted soil and maize emergence. There was increase in steady infiltration rates amount of soil water stored on the soil and the better drainage. The physical effect of mulch was less important in the rehabilitation of crusted soils in the study site when it was incorporated in to the soil. Manure and surface mulch with minimum tillage should therefore be taken into account in land management and water conservation in the semi-arid areas of Kenya. The response to crop in the improved water availability due to manure with minimum and with conventional tillage and surface mulch was very clear these management practices should be recommended when considering the effectiveness of soil and water management techniques in the study area.

Itabari J. K. Wambua J. M., Kitheka S. K., Maina J. N. and Gichangi E. M. (2003). Effects of water harvesting and fertiliser on yield and water use efficiency of sorghum in semi-arid Eastern Kenya. *East African Agriculture & Forestry Journal* 69 (4): 291-295

Sorghum (*Sorghum bicolor*) is the second most important cereal crop in semi-arid eastern Kenya after maize. Its production is constrained by low soil water and nutrient deficiencies, particularly nitrogen and phosphorous. Despite the low and erratic rainfall received in these areas, runoffs is a conspicuous feature of many rainfall events and has been observed from a rainfall event of as low as 7.8 mm. This runoff can be collected and impounded in the cultivated/cropped area, thereby increasing the availability of water to crops. The source of runoff (catchment) can be either external (macro-catchment) or within the cultivated area (micro-catchment). Improving soil water status through these techniques referred to as rainwater/runoff harvesting, has been shown to significantly increase sorghum yields in semi-arid areas of Kenya. Similarly, alleviation of nutrient deficiencies in these areas through application of chemical fertilizers has been shown to have a similar effect on sorghum yields. In the semi-arid regions of West Africa, it has been reported that application of fertilisers results in increased water use efficiency (WUE) of sorghum. A combination of agronomic practises that lead to increased availability of water to sorghum crop and an improvement in the nutrient status of the soil are, therefore, essential for maximisation of sorghum yields in semi-arid environments. This paper reports the results of the study conducted on a subsistence farm in semi-arid eastern Kenya to determine the response of sorghum to two water harvesting techniques at low and optimum fertility levels

Kamoni P.T. Mburu M.W.K., Gachene C.K.K. (2003). Influence of irrigation and nitrogen fertiliser on maize growth, nitrogen uptake and yield in a semi-arid Kenyan environment. *East African Agricultural and Forestry Journal*. Vol. 69: 99-108.

A field study was carried out for 2 seasons (November to February 1999 and April to August 2000) to investigate the influence of irrigation on maize growth, nitrogen uptake and yield. The experimental design was randomized complete block design laid out as split plot with water regime as main plots (irrigated, rainfed), and factorial combinations of N (0, 50, 100 Kg N/ha) and P (0, 25 Kg P_2O_5) as subplots. Data collected included leaf area index (LAI), photosynthetically active radiation (PAR) interception, total dry matter (TDM), nitrogen uptake and maize grain yield, so the data were pooled for P. In the wet (350 mm rainfall) Short Rains, 1999 (SR99), irrigation had no effect on LAI and fractional PAR interception but significantly increased total N uptake, TDM and grain yield by 50 to 100%. Under low rainfall (143 mm) in the Long Rains 2000 (LR00), irrigation increased LAI and PAR interception by 50 to 100% and N-uptake, TDM and grain yield by 10, 10 and 34 fold respectively. However there was no significant response to N fertiliser application without supplemental irrigation. Nitrogen application above 50 Kg/ha did not improve maize growth and yield in both seasons. Supplementary irrigation can therefore increase maize yield even at low fertiliser input level in semi-arid Kenya.

Okwach G. E., Siambi M. M., Simiyu C. S. (2003). Assessing the interaction in maize cropping density, nitrogen and soil moisture with a systems simulator in semi-arid Machakos District, Kenya. *East Africa Agriculture & Forestry Journal*. Vol. 69: 157-171.

The APSIM model was used to evaluate a range of maize densities on a sandy-clay loam at Kenya Agricultural Research Institute (KARI) - Katumani Research Centre in Machakos and 2 contrasting farmers' fields situated on sandy and clay soil types. Each simulation was initialised with actual soil parameters measured at the time of commencing the run. Simulations on the Katumani soil were done after 5 contrasting short rainy (SR) seasons of different rainfall regimes, namely SR 1996 (185 mm), SR 1995 (270 mm), SR 1991 (328 mm), SR 1992 (720 mm), and the El Nino season of SR 1997 (958 mm). Maize densities used were 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 plants/m^2. The model showed that maize grain yield declined as density increased under the poor 1996 season. Optimum crop density increased with seasonal rainfall, to reach 5.0 plants/m^2 in the 1992 and 1997 heavy rainfall seasons. On the farmers fields, APSIM showed that the clay soil out yielded the sandy soil in high rainfall, while the reverse was true on poorer seasons. Simulations were done to determine the effects of varying nitrogen at constant crop density of 5.3 plants/m^2. Nitrogen rates used were 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 130, 140, 150, 160, 170, 180, 190 and 120 kg/ha. The response of maize to N fertilizer varied with seasonal Rainfall. Grain yields were depressed when N was added to maize during the poorer SR 1996 and SR 1995 seasons. With higher seasonal rainfall, APSIM predicted a sharp increase in grain yield at low rates of N. Simulations of the effects of N on maize yield on the 3 farmers' fields (Clay and sandy soils) done for SR 1997 (1310mm) and SR1998 (122 mm) seasons, using N rates of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 kg/ha. The model predicted crop failure for the SR 1998 season on the clay soil throughout all levels of N rates. In the wet SR 1997, grain yields was low at 0 and 30 kg N/ha, and then increased sharply at levels greater than 30 kg N/ha. The response to N was, therefore, highest in the clay soil under wet conditions. Grain yield responded well in the sandy soil during SR 1997, though the rate of response was lower than in the clay soil. However, the sandy soil proved superior to clay in the poor season (SR 1998). A gradual response to N was predicted in the sandy soil, up to 30 kg N/ha. Sowing date was more important for sandy than clay soil type. Delayed sowing on the clay soil type did not adversely affect yield, whereas a week's delay on the sandy soils led to a yield decline even in a favourable season.

Angima S. D., Stott D. E., O`Niell M. K., Ong C. K., Weesies, G.A. (2002). Use of calliandra-napier grass contour hedges to control erosion in central Kenya. *Agriculture, Ecosystems and Environment*. Vol. 91: 15-23

Contour hedgerow systems consisting of various combinations of tree and grass species can be used on sloping lands to minimize erosion, restore fertility, and improve crop productivity, but there is need to evaluate the effectiveness of each system for its suitability at any locality as effective erosion control. The objectives of this study were to determine the amount of soil conserved by contour calliandra (*Calliandra calothyrsus*), napier grass (*Pennisetum purpureum*) hedgerows, and to develop a support practice P-sub factor for conservation planning in central Kenya. As a benefit beyond soil conservation, biomass yield and N and P retention by the hedgerows were determined. Cumulative data for five cropping seasons from 1997 to 1999 indicated that the contour hedges on 20% slope conserved more soil (168 Mg/ha) than on the 40% slope (146 Mg/ha) compared to the control plots. For both slopes, this was equivalent to a 0.7 P-sub factor for use by the Revised Universal Soil Loss Equation (RUSLE) model in predicting soil erosion. The N and P losses between the hedges and control were statistically significant only on the 20% slope (P=0.05). Combined biomass yield from the calliandra-Napier grass hedges were 12 and 9 Mg/ha per year and 40% slope, respectively. This soil conservation technology may be used by small-scale farmers that use mixed farming systems in the highlands of central Kenya and similar eco-regions as a step towards sustainable farming.

Wakindiki C. I. (2002). Soil mineralogy, slope and soil and water conservation on infiltration, seal formation, erosion and crop yield under semi-arid conditions. PhD. Thesis, Egerton University, Kenya

Soil erosion and runoff are serious and widespread land degradation problems in many parts of the world especially in the arid and semi-arid areas, where water is the main limiting factor for crop production. This thesis presents the results of three studies conducted to investigate the effcts of soil mineralogy, texture and slope gradient on seal formation and its properties and their effects on infiltration, runoff and erosion. Water and soil conservation effects on infiltration, erosion and crop yield under seal formation conditions in semi-arid conditions was also investigated. In the 1st laboratory experiment, soils with different mineralogy and texture were subjected to 80 mm of simulated rainfall at 9% slope gradient. The mean weight diameter (MWD) values were 2.8 mm in the kaolinitic soil, 0.25 and 0.31 mm in the montmorillonitic soils, and 0.84 and 0.87 mm in the non-phy-llosilicate soils. The final infiltration rate (IR) was 20.5 mm/h in the Kaolinic soil and ≤9.3 mm/h in the montmorillonitic soils. The kaolinitic soil had a thin crust (~0.1 mm) containing large particles (~0.1 mm), while the montmorillonitic soils had thicker crusts (>0.2 mm) comprising either small (~0.02 mm) particles with a very developed "washed in" zone underneath, or large (~0.2 mm and composed of fine materials between them. Crust layer in the non-phyllosicate soils was ~0.2 mm and composed of fine particles ~0.01 mm. The high aggregate stability and the low dispersivity of the kaolinitic soil, which decreased the transport capacity, limited the soil loss to 0.33 kg m^2. The low aggregate stability and high runoff of the montmorrillonitic soils contributed to their soil losses of 1.24 and 1.14 kg/m^2. The intermediate aggregate stability and the high runoff of the non-phyllosilicate soils accounted for their intermediate soil losses of 0.75 and 0.8 kg m^2. In the 2nd laboratory study kaolinitic and montmorillonitic soils subjected to 80 mm of simulated rainfall at 9%, 15%, 20% and 25% slope gradient. The slope factor (Sf) values of the kaolinitic soil at slope gradient >9% were lower than the corresponding values of the montmorillonitic soils. A positive linear regression significantly fitted the relation between the relative MWD (the ratio of the MWD values at any slope gradient that at 9% slope) values and the corresponding Sf values at 99% confidence level (r^2=0.78). It was concluded that the higher Sf values in the montmorillonitic soils than in the kaolinitic soil was a result of the high runoff rate in the former soils than in the latter soils. In the field study big trash line (BTL), small trash line (STL), and stone line (SL) techniques, and control were evaluated. These indigenous soil and water conservation techniques (ISWC) were assigned to 12 runoff plots (2 by 6 m each) with 10% slope in the semi-arid Tunyai area in Kenya, during five consecutive rainy seasons. The ISWC techniques significantly decreased the runoff and the soil loss, and increased the maize and cowpea yields compared with the control treatment in most of the rainy seasons. The BTL was the most effective technique, but no consistent differences were found between the STL and SL techniques. In BTL,STL,SL and control, the seasonal average runoff for each treatment was 25, 31, 29 and 51 mm, respectively, and the seasonal average soil loss was 0.23, 0.33, 0.3 and 0.67 /ha, respectively. The seasonal biomass increased linearly and significantly (α=0.01) with increasing water infiltration. Therefore as more water infiltrated, more water was available for crop production, and this resulted in higher crop yields.

Kipkech F. C. and Kipserem L. K. (2001). Use of tied ridging and soil fertilization to improve maize yield in Rift valley, Kenya. *Proceedings of the Seventh Eastern and Southern Africa Regional Maize conference* pp. 292-294

An experiment was carried out at Chemogoch in Koibatek district with the aim of developing management techniques that improve soil fertility and conserve soil moisture at low cost and thus improve yield. Two combinations of water harvesting techniques and organic and inorganic fertilizer were utilized. Maize (*Zea mays* L.) variety Katumani Mpya was used as the test crop. The 1997 results did not show any significant difference ($p<0.05$) between treatments, though the combination of tied ridging and 4 t/ha farm yard manure (W1T2) gave the highest grain yield (3.5 t/ha). In the second year the highest grain yield (5.3 t/ha) was obtained in the combination of the conventional water harvesting technique and CAN at 150 kg/ha (W2T3). The results indicate that the use of 4 t/ha farm yard manure in combination with tied ridging was beneficial in terms of giving reasonable crop yield and net benefit (Ksh 21,502.10/ha) at lower cost than of using expensive inorganic fertilizer and large quantities of farm yard manure. Generally, a combination of tied ridging and use of farmyard manure could improve crop yield as much as using inorganic fertilizer especially when rainfall is not enough to sustain a crop under the conventional water harvesting system.

Odhiambo H. O, Ong C. K., Deans J. D., Wilson J., Khan A. A. H. and Sprent J. I. (2001). Roots soil water and crop yield: tree crop interactions in a semi-arid agroforestry system in Kenya. *Plant Soil* (235): 221-233

Variations in soil water, crop yield and fine roots of 3-4 year-old *Grevillea robusta* Cunn. And *Gliricidia sepium* (Jacq.) Walp. Growing in association with maize (*Zea mays* L.) were examined in semiarid Kenya during the long rains of 1996 and 1997. Even though tree roots penetrated more deeply than maize roots, maximum root length densities for both tree species and maize occurred in the top 200 mm of the soil profile where soil moisture was frequently recharged by rains. Populations of roots in plots containing trees were dominated by tree roots at the beginning of the growing season but because tree roots died and maize roots length increased during the

cropping season, amounts of tree and maize roots were similar at the end of the season. Thus there was evidence of temporal separation of root activity between species, but there was no spatial separation of the rooting zones of the trees and the crops within that part of the soil profile. Although Grevillea trees were largest, plots containing *G. Sepium* trees always contained more tree roots than plots containing *G. Robusta* trees and Grilicidia was more competitive with maize than Grevillea. Overall, Gliricidia reduced crop yield by about 50% and Grevillea by about 40% relative to crop yield in control plots lacking trees and reductions of crop yield were greatest close to trees. There was less soil moisture in plots containing trees that in control plots. Such difference between control plots and plots containing trees were maximal at the end of the dry season and there was always less soil moisture close to trees than elsewhere in the plots. Plots containing Gliricidia trees contained less soil water than plots containing Grevillea trees.

Onchwari W.O. (2000). Hydrologic and crop response to tillage under semi-arid conditions in Kenya. Msc. Thesis, University of Nairobi, Kenya.

Effects of the rainfall variability on soil moisture (SM) over crop growth periods is a prerequisite for assessing and developing better soil moisture conservation practices in semi-arid areas. It was therefore necessary to quantify soil moisture variability as affected by rainfall availability for crop productivity. This leads to an investigation into hydrologic and subsequent crop responses. The study was based on data collected for Kalalu, Laikipia District during the short and long rains periods of 1988 and 1989 respectively. Maize and beans under three soil moisture management practices, namely tied ridging (TR), conventional tillage (CT) and residue mulch (RM) were studied. Data on rainfall, soil moisture and crop yields were used. Estimates of soil moisture and crop yields were used. An estimate of soil moisture variability in the rhizosphere by Land Use Specific Analysis (LUSA) method, crop evapotranspiration by Crop Water Requirement estimation Program (CROPWAT), Available Soil Moisture Index (ASI) and LUSA Methods were made. Potential crop yields were estimated through Wageningen and Agro-Ecological zone Methods for maize and beans respectively. Actual yields were estimated through CROPWAT, YES and Doorenbos Methods. Comparison between rainfall, soil moisture, available soil moisture, crop evapotranspiration and crop yields under the three tillage practices and the two crops were made. Increasing trends in soil moisture during both short and long rains period for the three tillage types were observed. The trend was more for the 1989 long rains season. Soil moisture during the short rains period in the three treatments reached their maximum within 18 days and remained constant for the next 20 days before declining with TR having the lowest declining rate. During the long rains, SM in both RM and CT reached their maximum within 43 days before declining while TR had a lower increasing rate reaching a maximum within 53 days before declining at a lower rate than the other two. Generally SM during the short rains period was higher than that of the long rains. Rainfall amount and distribution before and after tillage coupled with the tillage practices enhanced soil moisture with rainfall having more impact. There was little significant difference in cumulative crop water used under the three treatments. CROPWAT overestimated the crop water used during the long rains season. There was an overestimate of bean yields due to the unexpected high measured soil moisture. Major reduction in yield was due to water deficit. Water and temperature limitations were two major factors that reduced maize yields from 8.9 t/ha to 1.2 t/ha. These analyses showed that quantification of soil moisture and consequent crop water used within the crop growth stages will facilitate the choice of appropriate tillage practices. Early tillage especially after harvesting was necessary for soil moisture retention and availability to the crop. A combination of residue mulch and tied ridging will facilitate better soil moisture distribution necessary to reduce water deficits and improver crop productivity.

Kizito M.K. (1999). Comparative changes in soil fertility and crop yields of intensively cropped small-holder farms in Machakos District, Kenya. Msc. Thesis, Moi University, Kenya.

About 80% of Machakos District is arid or semi-arid, and the soils are low in the essential plant nutrients (nitrogen and phosphorus) and organic matter. However, in spite of the low inherent soil fertility, agricultural production and population in Machakos district has increased some six-fold between 1930 and 1990 and continues to increase. Intensive cropping of these medium to low potential areas whereby two crops are harvested each year, has been shown to exert heavy pressure on the soil resource; frequently resulting in lower crop yields even when rainfall is adequate. However, although there is overwhelming visual evidence that soil fertility and hence crop yields in the district are declining, quantitative information on the rate of this decline is lacking. This thesis presents the results of a study conducted to monitor changes in soil fertility and crop yields from consecutive cropping of the land, and to investigate the effects of various cropping systems on soil fertility and crop production. The study consisted of two components, the on-station and on-farm components. The on-station component was conducted on seven-year old runoff plots located at the National Dryland Farming Research Centre, Katumani, while the on-farm experimentation took place on newly opened farms in the Kathekakai settlement co-operative farm. Both sites are in Machakos District. The cropping systems involved two traditional systems, viz.; widely spaced maize (*Zea mays*) monocrop with no mulch cover or fertilizer application, and a maize and bean (*Phaseolus vulgaris*) intercrop, also with no mulch or fertilizer application. Other cropping systems involved increased

fertilizer application, mulch rates and plant population. On the other hand, the test farms at Kathekakai ranged from those reserved for livestock grazing (uncultivated) to those cultivated for over 10 years. A total of 10 farms/segments were studied. A number of parameters were measured and the data tested for statistical significance and correlation using the Least Significant Difference (LSD) and simple linear correlation analyses, respectively. Generally, soils in the newly settled farms at Kathekakai had not deteriorated markedly although there were signs of possible decline in soil fertility if the farmers continued to cultivate their farms without any nutrient restitution.

Rao M. R., Mwasambu G., Mathuva M. N., Khan, A. A. H., Smithson P. C. (1999). Effects of phosphorus on soil, water and nutrient conservation in phosphorus-deficient soils of western Kenya. *East Africa Agriculture & Forestry Journal*. Vol. 65 (1) 37-53.

In the highlands of western Kenya, poor crop growth due to severe nutrient depletion over the past two to three decades has exacerbated soil erosion. The potential benefits of phosphorus (P) recapitalisation with a large one-time application of 500 kg P/ha and agroforestry in terms of soil, water and nutrient conservation were investigated on P-deficient soils in western Kenya for 3.5 years. The agroforestry systems compared were one-season sesbania (sesbania sesban) fallow followed by annual crops, and contour hedgerows of calliandra (*Calliandra calothyrsus*) plus Napier grass (*Pennisetum purpurem*). Continuous cropping without P fertilizer produced an average runoff of 367 mm (37% of rainfall) and soil displacement of 105 t/ha per season, with a loss of 159 kg of total N and 46 kg of total P/ha. Phosphorus application reduced runoff by 31% and soil loss by 59% compared to non-fertilizer applied cropping. In P-replenished soils, neither one-season sesbania fallow nor contour hedgerows affected water runoff but one-season sesbania fallow reduced soil loss by 5% and contour hedgerows reduced soil loss by 20%, over P alone. Nutrient losses due to erosion occurred mainly through sediment movement, and losses through water runoff were negligible. Sesbania fallow and contour hedgerows prevented surface nutrient losses proportionate to their effects on reducing soil erosion. Integrating P and short-duration sesbania fallows in P-deficient soils increases crop yield and can contribute to soil, water and nutrient conservation by providing a rapid and prolonged ground cover with good crop growth and increased water infiltration into soil. The hedgerows have the added advantage of yielding fodder besides effectively reducing soil and nutrient losses.

Kironchi G. (1998). Influence of soil, climate and land use on soil water balance in the upper Ewaso Ng'iro basin in Kenya. PhD Thesis, University of Nairobi.

The influence of soil, climate and land use on soil water balance was investigated in 3 agroclimatic zones within the Upper Ewaso Ng'iro basin. Water balance was quantified for various land uses and management systems in each zone. These were natural forest (NF), grazing land (GL) and potato cropland (PC) on a mollic Andosol at Karuri, conventional tillage (CT), mulch tillage (MT), Overgrazing (OG) and controlled grazing (CG) on a ferric Luvisol at Kalalu and perennial grass (PO), enclosed perennial grass (PE), bare ground (BO), enclosed bare ground (BE) and runoff (bare ground with a bush and grass at the lower end (RO) sites on a chromic Luvisol at Mukogodo. Soil moisture, runoff and soil cover for each system and rainfall and evaporation at each site, were monitored for four rainy seasons (September 1993-August 1995). Selected soil physical properties for each system were also measured. The climatic water balance was negative at all sites as the ratio of mean annual rainfall to mean annual potential evaporation was 0.65, 0.47 and 0.16 for Karuri, Kalalu and Mukogodo respectively. The annual rainfall means during the monitoring period were similar to available long term records. Total mean runoff as a percentage of rainfall in the four seasons at Karuri was 6.6% in PC and 1.6% in GL; at Kalalu it was 6.6, 0.01, 30.0 and 4.0% in CT, MT, OG and CG, respectively and at Mukogodo it was 25.1, 35.2, 9.9, 51.1 and 47.6% in RO, PO, BO and BE respectively. Runoff from cropland at Karuri and Kalalu during big storms (>20 mm day-1) was up to 40% of rainfall, and for similar events up to 80% from overgrazed sites at Kalalu and Mukogodo. Bush canopy basal cover (RO) intercepted and infiltrated up to 50% of runoff flowing from bare ground. Both BO and BE at Mukogodo had similar cover. However, cover in PE increased to about 3 times that in PO. Runoff decreased with increase of cover in all sites and treatments. Calculated minimum (threshold) amount of rainfall required to generate runoff increased with soil cover and ranged from 11-14 mm/day in cropland and from 6-12 mm/day in grazing land. Runoff significantly correlated with amount of rainfall in cropland only at Karuri and for cover >30% (r^2=0.71), but all sites in grazing land (r^2 =0.65 at Karuri at Kalalu and 0.51-0.62 at Mukogodo). Runoff also significantly correlated with rainfall erosivity at all sites; that in grazing land (r^2=0.88 at Karuri, 0.56-0.98 at Kalalu, and 0.49-0.68 at Mukogodo) was stronger than in cropland (r^2 =0.49-0.79 at Karuri and 0.77 at Kalalu). Available soil water at Karuri ranged from 140,130 and 120 mm in the driest period to 230,205 and 185 mm in the wettest period of the year for NF, GL and PC respectively, in 160 cm soil depth. On annual average, NF (192 mm) had significantly higher available water than GL (169 mm) and PC (153 mm). Available water stored Kalalu cropland was 88 and 37 mm in the driest period, and 222 and 176 mm in the wettest period of the year for MT and CT, respectively in 160 cm soil depth. Higher moisture was recorded in MT and CT in both times. In grazing land, CG stored 46% more water (147 mm) than OG (101 mm) in the wettest period, but there was no available water in the driest period in both CG and OG. Moisture recharge in the wet seasons was limited to only 90 cm in OG, but like in cropland, it percolated beyond 120cm in CG. None of the treatments at Mukogodo had any available water in

dry seasons. Even in the wettest period, only 19, 13, 20, 9 and 7 mm of water was available within a depth of 80 cm in RO, PO, PE, BO and BE, respectively. That in RO and PE were significantly higher ($p<0.05$) than the rest. Moisture percolated to only about 50 cm under good cover and to about 30 cm on bare ground even in the wettest period at Mukogodo. Water use was higher in PC (4-18%) and GL (7-20%) than NF in the 4 growing seasons, indicating that the forest extracted less water than potato and grass from within the 160 cm soil depth. At Kalalu, MT used more (18-42%) water than CT during the long rains. However, in the short rains, some moisture was conserved and carried over, resulting in lower (10-26%) water use in MT compared to CT. Water use was higher (21-24%) in CG compared to OG in all seasons. At Mukogodo water use was 13-20% and 32-55% lower in PO and BO, respectively, than RO in the 4 growing season. In all seasons PE used significantly ($p<0.05$) more water than PO (23-61%) and BO (57-95%). Higher (8-33%) water use by PE than RO was attributed to higher evapo-transpiration by grass in the open compared to that under bush canopy. This water balance study indicated that apart from soils and climate, differences in land use and surface soil management also influenced soil water storage and subsequent use within the basin.

Mworia J. K., Mnene W. N., Musembi D. K. and Reid R. S. (1997). Resilience of soils and vegetation subjected to different grazing intensity in a semi-arid rangeland of Kenya. *African Journal of Range & Forage Science* 14 (1): 26-31.

The resilience of rangeland soils and vegetation to different levels of grazing is still poorly understood. A study was conducted to determine the recovery of a rangeland grazed at different intensities and allowed a two-year rest period. The following treatments were applied to 0.5 hectare plots: 0, 4, 8 and 16 heifers per hectare hereafter referred to as CL, X, 2X and 4X respectively. At the end of the grazing period, the highest stocked treatments (2X and 4X) had lower herbage biomass, higher soil bulk density, lower soil moisture and lower herbaceous cover than the lower stocked treatments (CL and X). Drought in the rest period caused an increase in bulk density and decline in soil moisture in all the treatments. Even after the two-year rest period, the more heavily grazed treatments had higher bulk density and lower soil moisture than the more lightly grazed treatments. Similarly, the herbaceous biomass in the 2X and 4X treatments did not recover after the two-year rest period and was lower ($P < 0.05$) than the CL and X treatments. At the end of the recovery period a trend of declining herbaceous cover with stocking density was still evident. The relative cover of forbs in the 4X treatments increased more than in the other treatments, while the cover of perennial grasses did not recover in the 4X treatments after the rest period. Thus, stocking above 2X produced negative soil and vegetation responses which did not recover during the two-year rest period. This study also indicated that drought can cause vegetation and soil responses similar to those of overgrazing.

Sigunga D.O. (1997). Interactive effects of drain depth, nitrogen source and time of application on nitrogen use efficiency by maize in vertisols in Kenya. PhD thesis, Chapter nine, Wageningen The Netherlands.

Fertilizer N use efficiency (NUE) by crops is influenced by interacting soil, climatic and management factors as well as fertilizer characteristics. The objectives of this field study were to determine interactive effects of drain depth (DD), time of N application (NT), and N source (NS) on nutrient uptake and NUE by maize grown on vertisols. The treatments comprised of 3 DD (0, 40, 60 cm), 3 NT 0, 0/40, 40 DAP) and 2 NS (NO_3^- N, NH_4^- N). A split plot design was used in which NT * NS formed split plots with drain depth as the main plots. The treatments were replicated 4 times and the experiment was conducted at two sites. Drains, 40 and 60 cm deep, resulted in significantly higher grain and total dry matter yields as well as in higher HI. The grain yields were increased as a result of drain provision by 31- 45, 31- 43 and 16-21% for the control, NO_3^- N and NH_4^- N treatments, respectively. Likewise, N recovery increased by 56 - 74 and 27-32% for NO_3^- N and NH_4^- N, respectively. The drains also significantly improved N, P, K uptake and NUE and reduced N losses. Applying all the NO_3^- N dose at planting time resulted in significantly lower N recovery and maize yields than did any of the rest of the treatments where drainage was not provided. The NH_4^- N was significantly better than NO_3^- N in terms of yields, nutrient uptake and NUE where drain was not provided. It is concluded that draining off excess soil water from the root environment is the key factor in improving NUE in these soils. Ammonium-N is preferable to NO_3^- N where NH_3 volatization is not a serious concern especially if there is no drainage.

Sigunga D.O. (1997). Effects of drain depth on temporal moisture variation and maize performance in a vertisol in Kenya. PhD thesis, Chapter seven, Wageningen University, The Netherlands

Low structural stability, low basic water infiltration rate and tillage difficulties are some of the salient constraints to utilization of vertisols for crop production. Water management is vital in the management of vertisols. The objectives of this study were to determine the effects of drain depth on temporal soil moisture variation, and rooting depth and yields of maize. The effects of 4 drain depths (0, 20, 40 and 60cm) on maize yields were investigated in two years. The effects of the drain depths on soil moisture variation and on maize rooting depth were investigated in 1994 and 1995 seasons, respectively. Drains, 40 and 60 cm deep, resulted in lower soil

moisture content within the 0 - 40 cm layer, deeper rooting system, and higher dry matter and grain yields than did the 0 and 20 cm deep drains. It was concluded that provision of 40 to 60 cm deep drains was necessary in preventing water-logging within the 0 - 40 cm soil layer, and in creating favourable root environment that was reflected in high maize yields.

Chepchirchir J. T., Kinyali S. M., Omulubi J. E. and Tirop S. K. (1996). The influence of magnesium to calcium ratios in irrigation waters on sodium adsorption on soils, Makueni district, Kenya. *In: Fungoh and G.C.O. Mbandi (Eds.) 'Focus on Agricultural Research for Sustainable Development in a Changing Economic Climate' Proceedings of the 5th KARI Scientific Conference*, October 14th -16th, 1996, Nairobi, Kenya pp 460-503.

Many arid and semi arid lands have been brought under crop production through irrigation. However, little or no water quality assessment is done before embarking on the irrigation. The sequences of this have been the salinisation and/or sodication of soils. To find out if the ratio of Mg:Ca had any influence on the resultant soil sodication, three existing land uses were selected randomly to represent treatments and they were (i) virgin natural savannah, (ii) semi-abandoned field and (iii) completely abandoned field. Three profile pits were opened per treatment and soil sampled from each horizon. The river waters used for irrigation were sampled for chemical analysis. Any groundwater observed was also sampled for analysis pH and electrical conductivity were then analyzed on the soils plus cations and the indices exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) calculated. The results showed that continuous use of saline irrigation waters with low sodium and high Mg: Ca ratios resulted in the exponential increase of soil SAR. From the results, it was found out that any increase in SAR of irrigation water increases the ESP of the soil. A linear relationship between SAR and ESP of the soil was found to be r^2-0.713.

Mburu M. W.K. (1996). The effects of irrigation, fertilizer nitrogen and planting density on bean (*phaseolus vulgaris*) yield under different weather conditions. PhD thesis, University of Reading, UK

The common bean (*Phaseolus vulgaris*) is an important food for many people in Latin America and Africa. However, bean yields are low because of the droughty and limited nitrogen supply conditions prevalent in the minimum input bean production system in these areas. The objectives of this work were: a) to identify the mechanisms by which water and nitrogen influence bean yield; b) to determine how the application of water and nitrogen interact with weather factors to influence bean yields under various climatic conditions; c) to identify possible management strategies to increase bean yields under various climatic conditions; c) to identify possible management strategies to increase bean yield by improving the efficiency of water use by the crop. Three field experiments were conducted; one at Sonning (Britain) and two at Kabete (Kenya) to determine the effect management and weather on bean yield. The management strategies to improve bean yield included irrigation, fertilizer nitrogen application and altering planting density. Bean total dry matter and seed yield were highest at Sonning and lowest at Kabete in the dry season. The differences in the amount of total dry matter produced in the three experiments were attributed to differences in LAI, leaf area duration of the canopy and the total amount of solar radiation intercepted. High planting density was the most was the most effective factor in increasing LAI if water and nitrogen were at levels that did not limit leaf growth. Nitrogen fertilizer effect on LAI was primarily through increased leaf emergence and extension rate. High temperature influenced the rate of crop development. Total plant nitrogen uptake and utilization depended on plant growth stage, soil water and nitrogen supply. Low crop growth rates due to limited soil water supply resulted in reduced fertilizer nitrogen recovery in the crop. There appeared to be only a limited extent to which intensifying crop production through the use of fertiliser nitrogen and increasing plant density could influence the partitioning between transpiration and soil evaporation. The micro-lysimetry measurements showed that, on average, measured rates of evaporation from the soil surface beneath a crop were only 20% slower than from bare soil. High planting density reduced soil evaporation for maximum of 2 days when evaporation was supply limited.

Gachene C. K.K. (1995). Effect of soil erosion on soil properties and crop response in central Kenya. PhD thesis, Uppsala University, Sweden

The effect of soil erosion on soil properties and crop response were investigated on runoff plots at Kabete, Kenya. The experimental site was selected on the basis of soil survey carried out in December 1989. The objective of the study was to quantify the impact of soil erosion on soil properties and maize (*Zea mays* L.) growth and yield on high potential land in Kenya, and to determine the critical factors causing yield reductions. During an initial phase of the experiment, lasting two years ('erosion cycle'), soil surface treatments included soil covers with fine (T1), medium (T2) and coarse (T3) wire mesh and bare soil plot (T5). In addition, two plots were cropped to non-fertilized (T4) and fertilized and mulched (T4F) maize. During the 1993 long- and short-rains, all the plots were cropped to maize. The mean runoff during the two-year erosion cycle was 1, 17, 18, 32, 71 and 89 mm in treatments T1, T4F, T2, T4, T3 and T5 respectively, while the corresponding values for mean soil loss were 0.8, 16.7, 40.5, 57.9, 171.3 and 247.3 t/ha. No runoff was generated in the 1993 long rains due to low rainfall while

runoff and soil loss ranged from 2 to 40mm and 0.5 to 57 t/ha during the 1993 short rains. The soil washed from the plots during the erosion cycle was 247 % to 936 % richer in P than the original soil. Changes in pH, %C and N were significantly correlated with cumulative soil loss (r values of 0.77**, 0.59** and 0.71**, n=20 respectively). Although changes in soil physical properties were not significantly correlated with soil loss, both saturated and near-saturated hydraulic conductivity and macro-and meso-porosity were larger in the least eroded treatments after the erosion cycle. Relative to the T1 plot, there was a decline in maize grain and above-ground dry matter yields of 214 kg/ha and 1135 kg/ha per centimetre of soil loss for the first 2.5 cm of topsoil for the fertilized crop during the 1993 long rains. Maize grain yields, above-ground dry matter yields, leaf area index and crop height were highly and negatively correlated with cumulative soils for both fertilized and non-fertilized crops during 1993 long and short rains. The % pH, %N and available P were highly and positively correlated with maize grain and above ground dry matter yields in both fertilized and non-fertilized crops.

Qureish N. M. (1995). Some physical and chemical properties of soils under natural and plantation forest in Kakamega Forest, Kenya. Msc. Thesis, Moi University , Kenya.

In this study some physical and chemical properties of soils under different forest vegetation types were evaluated in Kakamega forest, Kenya. A total of 12 sampling plots, measuring 25m^2 in 3 sites were studied. Soils were studied up to a depth of 200cm. Significant changes were observed in some physical and chemical properties especially in the top 30 cm depth. Below this depth, no significant differences were observed among the different vegetation types. Most significant changes were recorded particularly for those properties that are highly correlated to organic carbon (matter) in the soil. Bulk density, aggregate stability and moisture content were significantly different between soils under natural forests and those under plantation forests and grasslands (p=95%). However, re-afforestation of the sites with plantation forestry did not change the soil texture. Organic C, total N, available P, pH and exchangeable K and Na, declined significantly in the upper 30 cm of the soils under exotic tree plantations and grasslands but not with Maesopsis when compared to natural forests. Exchangeable Ca, Mg and effective CEC did not differ significantly in soils under the different vegetable types. C to N ratio and exchangeable acidity did not show any significant differences among the various vegetation types. From the study, some significant changes in soil physical and chemical properties occurred following the conversion of native natural tropical forests with consequent replacement with plantation species especially exotics. The data from the study should be taken into consideration together with economic and silvicultural factors when selecting species and sites for forest plantations in order to ensure a sound and effective soil management programme and sustained productivity.

Kilewe A. M., Esilaba A. O., Ikombo B. M., Miriti J. M., Metto J. K., Ademba J., Kamau F., Kaiyare J., Wanyama E., Gachui M. (1993). Measurement of vegetation cover for the major cropping system and levels of management - Phase 1. Kenya Agricultural Research Institute-Muguga South, *Annual report* pp. 39-46.

Vegetation cover is the most critical and sensitive variable in the erosion process. Different crops develop cover at different rates. By measuring the change in vegetation cover during a growing cycle and relating this to the rainfall drops that hits bare ground causing splash, a single figure can be developed that represents the efficiency of that vegetation in reducing erosion. Use of inorganic fertilizers is also paramount in maintaining crop productivity. An experiment was set up in Kiambu district with the major objective of developing quantitative expressions of the effect of vegetation cover on soil erosion for major cropping systems and levels of management. The experiment was expected to facilitate selection of cropping systems that give soil protection, identification of those cropping systems that have potential erosion hazard, and quick estimation of conservation merits of new crop varieties and cropping practices without the need for expensive long-term soil loss measurements. The results showed that maize yields were more in the intercrops whereas beans were higher in the pure stands compared to the intercrops. There was a decline in top soil organic carbon and nitrogen content. Sole maize cropping had the highest erosion while lowest erosion was either under intercrops or sole bean crop.

Miriti J. M. (1993). The effect of tillage, compost and mulch on soil physical properties and crop yield. MSc Thesis, University of Naiobi.

A study was conducted to assess the effect of tillage (double digging), compost and mulch crop yield and soil physical properties of a humic Nitisol. The experiment was a 2×2×2 factorial treatment design consisting of 8 treatments replicated 4 times. Sunflower (*Helianthus annus* L.) and maize (*Zea mays*) were used as test crops in the 1992 short rains and the 1993 long rains respectively. The results indicate that compost significantly ($p<0.05$) increased hydraulic conductivity by 47%, available water by 9%,total porosity by 4% and reduced bulk density by 8% at 0-5 cm layer when compared with treatments without compost. Only bulk density and total porosity were affected by mulch placement. Double digging reduced bulk density of the 25-30 cm and 50-55 cm layers and consequently resulted in significant increase in total porosity, hydraulic conductivity and water availability (w/w). A combination of compost and mulch gave significantly ($p<0.01$) higher sunflower seed yield (26%) and dry matter production (13%) than the control. Double digging and normal hand tillage produced similar

sunflower yields. Maize was adversely affected by drought. This study shows that compost and mulch are effective in increasing crop yields and improving soil physical properties of the top soil. Although double digging improved the physical properties of lower horizons, there was however no evidence that this tillage system had a significant influence on crop yield.

Nagaya M. L. (1993). Effect of tillage and farmyard manure on infiltration, runoff and soil loss of a crusting soil. Msc. Thesis, University of Nairobi, Kenya.

The effects of tillage and farmyard manure application on infiltration, runoff and soil loss of a crusting Luvisol (FAO/UNESCO Classification, 1974) were investigated under field conditions from October 1992 to May 1993(two cropping seasons) on micro plots of 2 m^2 at the National Dryland Farming Research Centre<Katumani, Machakos, Kenya. Four treatments (Zero tillage, ZT; Conventional tillage, CT; 5 t/ha farmyard manure, 5 FYM; and 10 t/ha farmyard manure, 10 FYM) with three replicates were applied on the micro plots. The plots were left bare to eliminate the influence of vegetative cover on measured parameters. The measured parameters included runoff, soil loss, bulk density, soil shear strength, soil penetration resistance and soil moisture content. The results obtained showed some significant changes in soil micro (cloddiness) and soil aggregation with rainfall events and soil treatments. Though soil loss was highly variable even within the same treatment and for the same amount of precipitation, it was in the order of CT>ZT>5FYM>10FYM. Farmyard manure was found to improve soil aggregation. At the end of February, a marked decline in soil organic matter was observed, the greatest decline being under CT. There was no significant differences at (P=0.05) between farmyard manure treatments over the experimental period. However, there were significant differences between tillage and farmyard manure treatments at P (0.05). Runoff increased with time and treatments in the order ZT>CT>5FYM>10FYM. The progressive increase in runoff and decrease in soil loss were attributed to an increase in soil compaction/crusting due to breakdown in soil aggregation by raindrop impact. The high generation of high amounts of runoff decreased infiltration and profile soil moisture. Soil shear strength and bulk density variations with the rainy season influenced soil erodability and the moisture retention characteristics of the top soil. This study did prove the significant role of tillage and farmyard manure application in facilitating better infiltration rates, improving soil moisture and reducing soil loss during the initial stages of the rainy season when there is no vegetative cover.

Odhiambo H. O. (1991). Effect of seasonal changes in soil moisture, atmospheric humidity, ambient temperature and radiation on shoot water status, growth and yield of four clones of tea (*Camellia sinensis*). MSc Thesis, University of Nairobi

Studies on the effect of soil moisture, ambient temperature, atmospheric humidity and radiation on the yields of four commercial Kenyan tea clones were undertaken. The experiment was laid in an established tea field of clones 6/8, 31/8, S15/10 and 57/15.This was randomised complete block design replicated three times. The results of the study shows that the temperature was the main factor which limited the yields of tea at Timbilili estate, Kericho, Kenya(altitude 2170 m.a.s.l) during the 24 months of this experiment. Soil moisture and high vapour pressure deficits (VPD) reduced yields in the hot-dry period between January and February. The tea clones gave variable response to these climatic factors. Clone 6/8 was susceptible to low soil moisture and high vapour pressure deficits and consequently it had low shoot water potential, reduced rates of shoot extensions, relatively low shoot density, low rates of shoot regeneration and lower yields than clones 31/8, S15/10 and 57/15 between January and February when the high VPD and low soil moisture prevailed. There was an increase in yields between October and December of both years when nearly 32% of the total annual yields were recorded. This was in response to the favourable environmental conditions. The high air temperatures, low soil moisture and low vapour pressure deficits were favourable between October and December. Among the yield components the rates of shoot extension and the number of shoots per unit area and partly the rates of shoot regeneration varied with changes in climate while the mean shoot weights remained largely unchanged. When subjected to the multiple regression analysis, the combined effect of the yield components, namely, the rates of shoot weights and the rate of shoot regeneration had highly significant (p=0.01) relationship with clonal tea yields, but the effects of individual components was highly variable and did not relate with the yield potentials of clonal teas.

Gicheru P. T. (1990). The effects of tillage and residue mulching on soil moisture conservation in Laikipia, Kenya. Msc. Thesis, University of Nairobi, Kenya

The effects of selected soil management practices (conventional tillage, tied ridging and crop residue mulching) on soil moisture conservation in a semi-arid area of Kenya (Kalalu, Laikipia) were studied during the short rains period, 1988, and long rains period, 1989. Two test crops maize and beans were used to monitor the effects of conserved moisture on crop performance (emergence, height and ground cover) and yield. Three treatments with three replications of each practice under a completely randomised block design were used in the study. Nine experimental plots, each of size 4m by 10m were set up on a slope of 2%. During the study period, soil moisture was monitored on a weekly basis using the neutron probe at predetermined depths up to a maximum depth of 120

cm. Crop performances was also monitored on a weekly basis throughout the crop growing periods. Calibration of the neutron probe was done for the soil (ferric Acrisol) at two depth ranges: 0-90 cm and 90-120 cm. The need to calibrate the probe for the 90-120 cm depth arose due to the presence of iron concentrations within this depth range. The results obtained from this study showed that overall, crop residue mulching despite lagging behind in seedling emergence, did conserve more moisture throughout the two crops growing periods and had a better crop performance and yield than the other two practices. The vigorous crop growth and good ground cover under residue mulch was attributed to high soil moisture content in the soil profile. The tied ridged plots had the lowest amount of soil moisture and hence the poorest crop performance and yield. Thus the application of surface crop residue mulch seems to be the best soil management practice for increased soil moisture conservation and improved crop performance and yield in Kalalu, Laikipia.

Kamindi M., Mose L. and Wekesa F. (1989). Evaluation of weeding methods under zero, minimum and conventional, tillage systems. National Agricultural Research Centre, Kitale. *Annual Report*, pp 71-72.

The objective was to determine the comparative effectiveness of some herbicides, hand weeding and their combinations on weeds with maize under zero, minimum (reduced) and conventional tillage systems. This was with a view to advising farmers on tillage-weeding systems which are both cost-effective and serve to conserve soil and soil moisture.

Kamindi M. and Mose L. (1989). Evaluation of new formulations of glyphosate herbicide for use in reduced tillage. National Agricultural Research Centre, Kitale. *Annual Report*, pp 73-77

To determine the efficacy of new formulations of glyphosate, namely: Mon 8751 and Mon 14477. Sometimes weeds start growing before a farmer plants because he has to wait for a planter which are in short supply. To eliminate such weeds a farmer can either harrow the field or spray Gramoxone to kill the weeds then plant. Wince tractors are in short supply, he would end up planting very late if he had to harrow. Monsanto have developed new formulations of Glyphosphate which are cheaper than Round up and can compete with Gramoxons which is a health hazard. The aim of this experiment was to assess the efficacy of these products and determine the rates at which they can be used.

Mwangi W.P. (1989). Effects of *Leucaena leucocephala, Cassia siamea* and *Terminalia brownii* leaf mulch on maize performance and soil nutrients under the semi-arid conditions in Machakos, Kenya. Msc. Thesis, University of Nairobi, Kenya.

The influence of three leaf mulches from three tree species on soil nutrients, maize performance and yield and N concentration of maize at various growth stages was studied for two very contrasting seasons (very dry 1987 "short rains" and wet 1988 "long rains") in the semi-arid district of Machakos, Kenya. Fresh leaf mulches of *Leucaena leucocephala*, *Cassia siamea* and *Terminalia brownii* were buried in the soil at a depth of 15 cm at 1 and 2 kg/m^2 rates. The mulching materials were buried in furrows 90 cm apart. The design of the experiments was randomised complete block replicated four times. After burying the mulches, Katumani maize was planted on ridges (above the mulch layers), at a spacing of 90 x 30 cm. Analysis of the leaf mulches for their nutrient composition showed that *Leucaena leucocephala* had the highest concentration of nutrients while *Terminalia brownii* had the lowest concentrations but highest C content. In terms of C/N ratio *Terminalia brownii* had the highest (average of 38.4) while *Leucaena luecocephala* had the lowest (average of 15.4), indicating a lower decomposition of the former. Soil analysis showed that the mulches increased soil pH, organic carbon, exchangeable bases, total nitrogen and phosphorus during their decomposition and even cumulatively over the trials. There was a progressive decline in the soil nutrient status in the unmulched plots, which is likely to be due to nutrient removal by the maize crop and leaching. Results on the mulches influence on maize indicated that mulch application significantly increased nitrogen concentration of maize ear leaves (cobbing stage). Maize grain yield was higher in the mulched plots compared to the unmulched, however the differences were not significant ($p = 0.05$). Maize grain yield was significantly and positively correlated with plant height, plant base diameter, leaf area index, cob weight, and grain size in the second trial.

Kilewe A. M. and Mbuvi J. P. (1988). The effect of crop cover and residue management on runoff and soil loss. *East African Agricultural & Forestry Journal* . Vol.: 53:193-203.

The highest runoff and soil loss was observed on the bare fallow soil. The maize with minimum tillage reduced runoff by 0.8 and 39.2% and soil loss by 53.0 and 58.7% as compared with that produced on bare fallow soil during the 1983 long and short rain seasons respectively. Application of 3 t/ha of maize residue reduced runoff by 58.7 and 78.6% and soil loss by 94.4 and 64.4 percent during the same period respectively. During the 1984 short and the 1985 long rain season, maize with conventional tillage reduced runoff by 20.1 and 25.1%and soil

loss by 39.5% and 8.1% respectively. Beans alone, however, reduced runoff by 41.1 and 29.7% and soil loss by 57.9 and 51.8% while maize intercropped with beans in alternate rows reduced runoff by 42.0 and 29.2% and soil loss by 47.5 and 22.3% during the same period respectively.

Musembi D. K. (1984). Identification of crop-growing seasons of semi-arid Kenya analysis of the soil moisture patterns. Msc. Thesis, Texas A&M University

Eight stations with over 30 years of rainfall record were selected in the dry region of Kenya, east of 37°E longitude, to study the nature of the crop growing seasons during the short and long rains (October through June). The rainfall data were reduced to soil moisture based upon area wide assumptions on the soil characteristics. The start, end and duration of the crop growing seasons were determined and tested for normality using a 10mm soil moisture threshold value at each station. Mean seasonal conditions were computed and comparisons were made between the two growing seasons within each station and among all the stations. Stations were grouped according to the magnitude of the co-efficient of determination between start and duration and regression equations were developed to predict season duration, from the starting dates. Equations are also derived to estimate the probable length of the growing season for various levels of crop moisture requirements. The exceptionally wet and dry years are examined. The distributions of the start, end and duration of the seasons are not significantly skewed or significantly different from the normal distribution. The start and end times of the short rain season have a southward trend. The start of the long rains season is widespread but the end of the season shows a northward trend. Durations in both seasons have no general patterns but reflect the influence of local factors. The short rains growing season is found to last longer and to have a higher soil moisture content than the long rains for the stations located south of the equator. The opposite is true for the stations north of the equator. The very wet and very dry seasons are not usually widespread. The occurrence of a very wet season appears to weaken the other season and 10-year periodicity is observed in the very wet and widespread seasons in the short rains seasons. Periodicity is not observed in the long rains reason or for the very dry seasons.

Chui J. N., Waweru E. S., Kungu N. K., Bendera N. (1983). Prediction of soil erosion and its effects on soil productivity. Kenya Agricultural Research Institute, *Annual Report*

This study was undertaken to determine the agronomic and economic feasibility of utilizing grain legumes in either rotation or intercropping systems as practical alternatives to commercial fertilizers for maize production. Seven cropping systems whose permanent plots were established in the short rains of 1981/82 used maize (Zea Mays L), Katumani Composite B) in both rotation and intercropping systems and grain legume beans (*Phaselous vulgaris* L., var. mwezi moja), cowpeas (*Vigna unguiculata* L, var. Machakos 68), tepary beans (*Phaselous acutifolius* A.Gay), and a two-season local variety pigeon peas (*Cajanus cajan* L). The cropping systems were composed of four groups (1) Continuous cropping systems: (a) Sole-crop maize, (b) Maize/bean intercrop (c) Maize/cowpea intercrop (2) Rotation between sole-crop maize and maize-legume intercrop (a) Sole-crop maize in the short rains and intercrops in the long rains (b) Maize followed by maize/bean intercrop (c) Maize followed by maize/cowpea intercrop (B) Maize/legume intercrops in the short rains and sole maize in the long rains: (2c) Maize/bean intercrop followed by sole-crop maize (2d) Maize/cowpea intercrop followed by sole-crop maize (2e) Two season maize/pigeon intercrop followed by two seasons of sole-crop maize (3) Rotation between sole-crop maize and sole-crop legumes: (A) Maize in the short rains and legumes in the long rains (3a) Maize followed by beans (3b) Maize followed by cowpeas (3c) Maize followed by tepary beans (B) Legumes in the short rains followed by maize in the long rains: (3d) Beans followed by maize (3e) Cowpeas followed by maize (3f) Sole-crop pigeon pea for two seasons followed by two seasons of sole-crop maize (3g) Sole-crop cowpeas for two seasons followed by sole-crop maize for one season (4) Maize and one-season legume intercropped with a two-season pigeon pea; (4a) Maize/pigeon peas followed by bean/pigeon peas (4b) Maize/pigeon peas followed by cowpea/pigeon peas. In all these cropping systems, maize and cowpeas populations remained at 55,000 plants/ha whereas that of beans was 110,000 plants/ha in sole-crop and 55,000 plants/ha in the intercrop system. Pigeon peas population remained constant at 22,500 plants/ha for both sole-crop and intercrop systems. These systems were not applied nitrogen fertilizer or farmyard manure. However, they all received 17.5 Kg P/ha, as triple superphosphate, each season. To determine the contribution of legumes to maize in terms of nitrogen nutrient, a continuous function line was developed from partial land equivalent ratios (LER's) of continuous maize fertilizer trial which was adjacent to the crop rotation plots. Economic evaluation of the systems was done using estimates of gross values of returns since labour for harvest, usually provided by the family is the only major variable cost. Data indicated that rainfall total and distribution were the major factors influencing the results. The differences between seasons were highly significant.

Kahumbura J. M., Michobo W. G. and Mugumu D. N. (1983). Agricultural engineering; application of methabenzithiazuron in reduced tillage trial. Ministry of Agriculture, Agricultural Research Department. *Technical report*

A long term reduced tillage trial designed to investigate effects of incorporating biologically degradable herbicides into the farming practices of smallholder farmers in medium potential farmlands of the eastern highlands. In the current season, the onset of the rains was delayed, thus greatly reducing the potential of good crop production under good agricultural practice and crop husbandry. Methabenzthiazuron is an herbicide that effectively controls young weeds when applied post or pre-emergent in moist soil conditions. The treatment was done eight days after planting while the rains started six days after treatment. Spraying was done at low volume concentration of 0.015 W/V of the active ingredient and the dose applied was 2.75 kg/hectare. A single treatment was done before the crop germination. The bulk of the germinating weeds consisted of *Hibisvus cannabinus, Amaranthus hybridus, Commelina africana, Setaria viridus, Digitaria senguinalis* and *Cynodon dactylon*. The dry spell after the treatment reduced the efficacy of methabenzthiazuron significantly. However, considering that under temperate conditions when methabenz-thiazuron is incorporated into the soil its residue activity lasts for about three months it was expected that even under these prevailing harsh conditions the residue activity would last long enough to inhibit vigorous development of weeds after the rains onset. If weed development could be inhibited initially, maize seedlings would then develop fast and effectively compete with late weed developments and so reduce degree of crop losses due to weeds. The amount of rainfall ten days after treatment was only 50mm. Considering the high infiltration characteristics of the soils in the plots it is unlikely that only herbicide was washed away from the plots through surface runoff. After the rains onset, some weeds germinated covering about 5% surface area only twenty days after the onset. More annual grasses developed resulting in intense competition for available soil moisture and plant nutrients. Rainfall distribution during the season was erratic. The total rainfall for the season was also lower than the potential evaporation for the same period. The ration between the rainfall and potential evaporation was below unit except for a short period during the months of April and May. The mild warm weather encouraged vigorous growth of *Hibiscus cannabinus* and *Digitaria senguinalis*. A high level of weeds regrowth continued to develop and cover more surface area. Weed samples taken 42 days after treatment showed an average total dry matter of between 30 and 230 kg/ha. The high weed population reduced the expected yield of maize. Comparing the yield from these plots with achieved from conventionally cultivated plots under similar conditions, the average maize grain yields were reduced from an average production of 58 bags per hectare. These were less than half the bags harvested from the conventionally cultivated plots. The relationship between the grain weight and total dry matter weight showed lower values for plots that were treated with methabenzthiazuron when compared with values achieved from the plots that were conventionally cultivated. Values from treated plots ranged between 0.25 and 0.18 while those from conventionally cultivated plots ranged from 0.33 to 0.25. Average total dry matter production of maize ranged between 9.3 and 6.5 t/ha for the treated plots. The amount was lower than that sampled from the conventionally cultivated plots which ranged between 22 and 14.5 t/ha. In the intercropped plots, the annual grasses greatly suppressed the normal growth of field beans. Weed interference affected the flowering with only a few pods in each shoot. A mild infestation of black aphids was also recorded during the season. The yield of the field beans was greatly reduced by the grasses which had overgrown most of the bean plants. While the yield conventionally cultivated plots was about three bags per hectare. Although it was not possible to isolate competition between maize and beans and maize and weeds, the intercropped plots seemed to have had more severe competition and hence higher production reduction. In general the grain yield deteriorated from 26 bags/hectare to 14 bags/hectare. The reduction from total dry matter was not significant but the ration of grain weight to that of total dry matter weight was reduced from an average of 0.22 t/ha to an average of 0.17 t/ha Therefore the weed competition affected more adversely the production of maize grain than the stalk sizes.

Kilewe A .M., Kamau F. N., Ngugi K. K., Njoroge J. M. and Gathiaka G. N. (1983). Prediction of soil erosion and its effects on soil productivity. Kenya Agricultural Research Institute. *Annual Report*, pp. 22-23

Since erosion by water is caused by raindrops impacting on unprotected soil surfaces and by concentrated runoff flowing down slope, the rate of erosion depends on a complex interrelationship among erosive forces of rainfall and runoff, the forces that existing soil cover absorbs, and the soil susceptibility to detachment and transport by remaining forces. Thus, methods of land management greatly influence these factors and resulting soil erosion. Soil productivity is the capacity of a soil, in its normal environment, to produce a particular crop or sequence of plants under a specified management system. Soil erosion decreases soil productivity through loss of plant available soil water capacity, loss of plant nutrients, degradation of soil structure, and non-uniform removal of soil within a field. Characteristics of individual soils, however can strongly affect the quantitative impact of soil erosion upon productivity. Until the relationship is adequately developed, selecting management strategies to maximize long-term crop production will be impossible. Wrong decisions can easily result in serious damage to soil resources and productivity may approach zero in severely eroded areas. Given the severity of the problem, runoff and erosion research facility was established by the end of 1981 long rains at Katumani National Dryland Research Station. This runoff equipment will facilitate the transfer of the universal soil loss equation (USLE) to Kenyan

conditions through the evaluation of the key parameters. At this stage, the runoff plots have gone through the three to four seasons of establishment period required after installation of the runoff equipment before accurate data collection begins. From 1981 long rains to 1982 short rains, the project has gone through an initial shakedown period which has provided valuable insights regarding the major parameters which need to be evaluated, the range expected among the variables and trained the technicians on how to operate and maintain the plots and equipment. Accurate data collection started at the beginning of 1983 long rains for the following treatments: 1) Sole maize up and down the slope 2) Sole maize up and down the slope mulched with maize residue at the rate of 3 t/ha 3) Sole maize on the contour 4) Bare fallow plots (Unit plots).

Kilewe A .M., Kamau F. N., Ngugi K. K., Njoroge J. M. and Gathiaka G. N. (1983). Topographic modification of land concentrates and redistribute runoff for crop production. Kenya Agricultural Research Institute, *Annual Report*

Low cost management systems aimed at improving moisture entrapment and conservation while creating an environment zone adapted to seedling germination and effective plant growth were developed. The systems included: (a) conventional contour furrows consisting of conventional beds and furrows formed on 0.75 metres centres with maize planted in each furrow (b) wide furrows consisting of 1 metre wide furrows and 0.5 metres wide beds with two rows of maize planted in each furrow, (c) mini bench consisting of narrow level conservation bench terrace with five 0.75 metres wide rows and (d) flat (no furrows) with five 0.75 metres wide maize rows. In all the cases the beds were about 0.20 metres high. All treatments were planted at 0.05 metres module using 0.75 metres row spacing and 0.30 metres crop spacing to give a population of about 44, 000 plants/ha. The conventional contour furrows, wide furrows and mini-bench retained all the runoff and resulted in significantly higher water storage capacity than flat treatment. There were no significant differences in water storage capacity among the runoff retaining treatments. However, the wide furrows consistently resulted in higher water storage capacity followed by the conventional furrows. The wide furrows treatment produced significantly greater yields and had a higher water use efficiency than all other treatment was 335 kg/ha greater than the next highest yielding treatment (conventional contour furrows) and 2323 kg/ha greater than the lowest yielding treatment (flat). The percentage annual increase in marketable maize yields on the runoff retaining treatments over the flat treatment ranged from 33.8% on the minimum bench treatment to 58.4% on the wide furrows. The percentage annual increase in water use efficiency on the runoff retaining treatments over the flat treatment ranged from 35.9% on the mini-bench to 67.9% on the wide furrows. The wide furrows system were found to be easy to maintain as permanent land features and therefore provide water conservation and considerable protection against soil erosion on a year-round basis, even after the prolonged hot and dry non-crop periods when high intensity rains occur. The conventional furrows were found to have a limited flexibility to accommodate the wide range of intercropping practices in the arid and semi-arid areas. The wide furrows however, can accommodate two, three or four rows of crop per furrow at 0.75 m 0.45 m and 0.30 m spacing respectively.

Kilewe A. M., Ulsaker L. G., Kamau F. N., Ngugi F. K., Kaiyare J. M., Njoroge P. K., Gathiaka G. N. (1983). Soil physical characteristics and their application to agriculture. Kenya Agricultural Research Institute. *Annual Report*

The particle size distribution, bulk density, structural and hydrological characteristics, moisture release characteristics, total profile water holding capacity and available water storage capacity for Kenya Agricultural Research Institute (KARI), and Katumani National Dryland Research Station (KNDRS) soils were determined for the depths of 10, 30, 50 and 100 cm. The bulk density for KARI soil increased with depth from 1.11 g/cm^3 at the surface to 1.22 g/cm^3 at 100 cm depth. However, the bulk density for KNDRS soils decreased with depth and varied between 1.52 g/cm^3 and 1.61 g/cm^3 at the surface to 1.29 g/cm^3 and 1.40 g/cm^3 at 100 cm depth. The sand the clay content for KARI soil varied between 28.8 and 35.1 percent at the surface and 10.3 and 72.4 percent at 100 cm depth respectively. The organic matter content ranged from 4.2 percent at the surface to 0.8 percent at 100 cm depth. This soil was classified at clay loam at the surface and clay at the lower horizons. The sand content for KNDRS soils varied between 59.9 to 67.1 percent at the surface and 30.5 + 051.7 percent at 100 cm depth. The clay content increased gradually with depth ranging from 22.2 to 28.2 percent at the surface and 33.3 to 50.0 percent at 100 cm depth. These soils were very low in organic matter content and exhibited a sand clay loam texture at the surface changing with depth to sandy clay and clay at the lower horizons. The clay soil had 64.2 percent pore volume at the surface decreasing with depth to 58.2 percent at 100 cm depth. The KNDRS soils, however, showed lower total pore volume ranging from 36.0 to 40.2 percent at the surface and 46.6 to 51.5 percent at 100 cm depth. The total water storage capacity for 100 cm depth of KARI soils was 444.1 mm of water at field capacity and 319.0 mm of water at wilting point. This implies that only water storage capacity for 100 cm profile depth of KNDRS soils ranged from 245.3 mm to 312.3 mm of water at field capacity and 132.4 mm to 182.8 mm of water at wilting point. The plant available water capacity, therefore ranged from 112.9 mm to 129.5 mm of water. In areas of erratic rainfall, which often occurs in brief intense storms, the physical condition of the soil can be a major factor in deciding whether a crop is a success or failure for they determine how water from an

intense storm is absorbed by the soil, and how much of the stored water is then available to the plants to enable them to survive until the next rainfall. In conjunction with climatic data, soil physical characteristics can provide a good indication of which drier areas may be suitable for agricultural development.

Mugah J. O., Stewart J. I., Ngugi J. K., Ademba J. and Hinga J. W. (1983). Yield water relationships of cotton (*Gossypium Hirsulum* L) and sunflower (*Hellianthus Annus L.)*. Ministry of Agriculture, Agricultural Research Department. *Technical report*

In last year's annual report, it was mentioned that agrometereological work on yield-water relationships of cotton and sunflower started in November 1982 was part of the USAID/KARI dryland cropping systems research project initiated in 1977. The work on cotton and sunflower was started with the primary objectives of: (i) determining water-use or evapotranspiration patterns of the two crops, the total depths of water taken up over the entire season and the corresponding yields (ii) quantifying yield reductions induced by evapotranspiration deficits, i.e. the difference between maximum evapotranspiration (etm) and evapo-transpiration as the water supply becomes limiting (iii) Selecting optimum population densities for different water regimes.

Wamicha W. N. (1983). Soils influenced by proclastics in the Nguu volcano area (wilaya ya Machakos, Kenya). Msc. Thesis, University of Nairobi.

A reconnaissance soil survey was carried out of sample strip about 2 km wide and running 14 km west from Nguu Volcano. The main objectives of the study were to find out the effect of the Nguu pyroclastics on the soils and to classify the soils. The thickness of the pyroclastic surface soils and their dominant particle sizes decrease away from the Nguu Volcano (source of the pyroclastics). On the volcano, there are blocks (>2.00 mm diameter) which constitute a coarse particle zone. Here are the entire soil profiles are developed from the pyroclastics per se. Between 2-10 km west of the Nguu Volcano, is a sand (2.0-0.2 mm) sized particle zone where the thickness of surface soils decreases gradually westwards from 65 cm to 46 cm. In this sand zone the soil profiles show surface soils, with additions of the Nguu pyroclastics and the paleosols being developed from the gneissses or basanites. West of the sand zone is a silt one (>0.2 mm) which extends from 10 km to the end of the project area (14 km). In the silt zone, the depth of surface soils increases from 46 cm to 60 cm corresponding to rising altitude and overlie the basanite paleosols. Using the FAO-UNESCO Legend' eight soil classification units were established which are found on four physiographic forms. On the Nguu Hill are found the vitric Andosols unit (Tv-6D/H/V), and orthic Andosols (To-5c/U/V). These Andosols are characterized by textural breaks which mark the different layers of volcanic pyroclastics from which the soils were developed. Further, the soils are dark coloured (dark brown) reflecting the dark vitreous pyroclastic index minerals (volcanic glass, olivine, augite and allophane) which shows that they are developed on the pyroclasticsper se. Compared with other soils in the area, the Andosls (TV- and To-) have abundant reserve of plant nutrients as reflected by; weatherable minerals (>20%) total bases (13-46 me/100 g soil) and CEC (20-45 me/100 g soils). But their agricultural use would be hindered by the steep slopes, stony-bouldery surface and pockets of very shallow soils. From the foot of the Nguu Hill to the end of the project area are the Orthic Ferralsols with units (Fo-3BC/U/U) on uplands and (Fo-5A/P/B) on plains. These Ferralsols are characterized by a layer of surface soils having additions of fine (<2.0 mm) pyroclastics overlying the gneissic paleosols (Fo-3BC) and basanitic paleosols (Fo-5A). The boundary between the surface soils and paleosols is marked by 'textural breaks' as indicated by; the sandy loam to sandy clay loam textures of the surface soils and clay loams of the paleosols. The distinction is also shown by darker (dark brown) surface soils compared with the respective paleosols that are strong brown. Further, the surface soils of Ferralsols (Fo-3BC and Fo-5A) contain volcanic glass, olivine, augute and allophane-the index minerals of pyroclastics. On the other than, the paleosols of unit (Fo-3BC) have muscovite, microline and hornblende minerals indicative of the metarmorphic gneissses. But, the paleosols of (Fo-5A) contain augite and olivine which are constituent minerals of pyroclastics as well as basanites. However, unlike the pyrocratics surface soils the basanite palesols of unit (Fo-%A) lack volcanic glass or allophane (index minerals of the pyroclastics). The nutrient reserve in the surface soils (weatherable minerals >10%, total bases 7.0 me/100g soil and CEC 9.0 me/100g soil) is slightly higher than in the paleosols (weatherable minerals <10% total bases 4.0 me/100g soil and CEC 7 me/100 g soil). These Ferralsols which are on gentle slopes, are very deep and have surface fertility, and are therefore suitable for cultivation of adaptable crops. A valley association of soils occurs along the intermittent Minor Valleys in the area. The chromic Luvisols (Lc-3BC/U/F) and Orthic Luvisols (Lo-3B/U/F) are on the valley sides while the Pellic Vertisols (Vp-LAB/V/X) and Dystric Planosols (Wd-6AB/V/F) occur into the valley bottoms. The valley sides are affected by severe soil erosion therefore conservation measures are required. The valley bottom soils (vertisols and Planososls) are imperfectly drained and have compact B-horizons. If the valley bottoms were to be cultivated, artificial drainage and deep tillage would be necessary. Thus the Andosols (Tv-andTo-) though with high basic fertility, their cultivation would be hindered by steep slopes of the volcanic cones, coarse pyroclastics on the surface and in places shallowness. On the other hand, the Ferralsols (Fo-3BC and Fo-5A) would be suitable for cultivation since they occur on gentle slopes, have moderate fertility in the surface soils and are very deep.

M'Arimi A. M. (1977). The effects of some tillage methods and cropping sequence on rainfall conservation in a semi-arid area of eastern Kenya. Msc. Thesis, University of Nairobi, Kenya

To the east and south of the Central highlands of Kenya lies in an area whose agricultural production is based on a low and unreliable rainfall. There are two cropping seasons per year of roughly equal duration, lasting three to four months but with the rainy portion of each season rarely exceeding two months. There is usually heavy rain during the first month of the rainy season which. Combined with the structurally weak sandy clay or sandy loam soils, result in large quantities of runoff. There is usually little or no rain during the second half of each season. This means that crops which take three to four months grow with reduced rain water and have to reach maturity with water stored in the soil. Hence there are frequent crop failures. Over the years some efforts have been made to improve and also stabilise crop yields and thus reduce the frequency of crop failures. Thus construction of the soil and water conservation structures (mainly terraces) have been constructed. The impact of these structures on crop yield reliability has been limited either because they were improperly built or because they were abandoned sooner or later, and therefore they never achieved the objective they were meant to. The crop scientists, have been producing crop varieties and cultural techniques suitable for the short seasons. The early Katumani maize varieties have been released to farmers with a recommendation to plant early, at some optimum plant population and with a good standard of weed control to ensure that moisture was available at the critical stages of grain setting and filling. This approach was fairly successful but failed to produce the expected results because it aimed at managing the crop plants and only to a limited extent the rainfall. In this research project an attempt was made to conserve rainfall through two approaches. The tillage methods were used to manipulate the infiltration capacity of the soil and hence influence the proportion of rain which is lost as runoff and which enters and is stored in the soil. Minimum, conventional, cloddy and tied-ridge tillage methods were tried. Secondly, the crop sequences were used to achieve varying amounts of residual moisture at the end of the first season which would be carried over the augment the amount of rainfall received during the second season. This would help obtain a better crop yield. Thus maize/maize, beans/maize and bare fallow/maize sequences were tried. The tillage methods and the crop sequences were combined. The project was carried out during the long (April) rainy and the short (November) rainy seasons 1976 and the long (April) rainy seasons of 1977. The results presented show that with a low rainfall similar to that received during the long and the short rains 1976 (200mm or less) the soil profile under the different tillage methods remained dry throughout because only a few of the daily showers received were large enough to penetrate the soil deeper than 15-20 cm. Crop establishment was good on the minimum and the conventionally tilled seedbeds but less so on the cloddy seedbed. Since the rain stopped too early for the maize to reach maturity dry matter was harvested which was lowest on cloddy seedbed. The long rains 1977 were good, maize on tied-ridges gave the highest grain yield while maize on the minimum tillage gave the lowest. There was no difference between the conventional and the cloddy seedbeds. Bean yields on the other hand were highest on the cloddy seedbed and the lowest on the tied-ridge seedbed, probably because the tied-ridges were too wet for the beans. With the low rainfall received during the long and the short rains 1976 the water content of the profile was not changed. Hence at the end of the long rains and after maize, beans or fallow, the profile was still at or below the permanent silting point with the profile under the crops (maize or beans) slightly drier than the profile under bare fallow. the maize results of the second season (short rains) 1976 show that maize benefited from the fallow. The maize results of the second season (short rains)1976 show that maize benefited from the fallow. Although the dry matter was not significantly different, the cob number and the dry yield were much higher with proceeding fallow than with preceding cropped plots. It was concluded that tied-ridge tillage methods was the best method for conserving rainfall and recommended that farmers should adopt it in order to boost their crop yields because the cropping seasons are usually intermediate between the 1976 seasons and the long rains 1977. It was further concluded that fallowing though insufficient in conserving moisture was a better method of improving crop yields through increased available water. It is recommended that farmers adopt it but spread the risk by fallowing one half or the field in one season, while the other is under the crop.

Law R. and Cooper J. M. (1976). The effect and importance of soil temperature in determining the early growth rate and final grain yields of maize in Western Kenya. East Africa Agriculture & Forestry 41 (3): 189-200

In the tropics it has been widely observed that maize planted at the onset of the rains gives higher yields than later plantings. (Hemingway, 1955;Moberly 1962;Goldson,1963;Akehurst and Sreedharam,1965;Allan,1972) In general these workers have all confirmed the importance of planting maize early in order to obtain high grain yields. Many varying explanations have been advanced to account for this time of planting(T.O.P) effect. Hemingway(1957) suggested that yields of late planted maize were reduced because the young maize plants were more severely attacked by fungal leaf disease than those in early planted maize. Others have suggested that early planted maize gives higher yields since it is able to take advantage of the flush of soil nitrogen mineralization that occurs when a soil undergoes wetting/drying cycles, as are likely to occur at the onset of the rains.(Birch,1960).Yet again in certain areas with short rainy seasons, it can be shown that late planted maize will suffer moisture stresses during the tasselling and grain filling stages and thus give yields lower than early planted maize which would reach these stages before the rains ended and soil moisture stress occurred. However, field trials by Allan(1972) demonstrated that none of the above explanations could account for the pronounced T.O.P effect in the highlands

of Western Kenya. He concluded from several years of field trials that low yields of late planted maize, were due mainly to poor soil physical conditions experienced by the late planted maize. Furthermore, in an artificial watering experiment, he found that increasing amounts of water applied in the period from planting to five weeks post-emergence caused corresponding reductions in early growth, grain yields number of kernels initiated. He suggested as a result of these experiments, and a study of rainfall distribution pattern, that poor soil aeration was the most important soil physical factor causing yield reductions in late planted maize. However, this hypothesis was not based on actual measurements of soil aeration, and later work by Cooper(1975) has shown that at Kitale(Western Kenya) the aeration status of the soil under young maize never reaches critical levels, even for planted maize. Further work at Kitale by Cooper(1974) and Law(1974) suggests that natural seasonal variation in soil temperature may be the primary factor responsible in yield of late planted maize. Coope(1974) has shown that the weekly mean soil temperature of a maize seeded in Western Kenya is controlled by the frequency and total amount of rainfall falling in that week, thus as rains proceed, the mean soil temperature falls rapidly from the high values occurring during the dry season(26oC February/March) to the very low values at the peak of the rains(180C July/August).The apical meristem of the maize plant is below ground level for the first four to five weeks after the plant emerges at Kitale, and during this time the meristem is influenced by the soil temperature. This has also been confirmed by Watts(1973).Early planted maize, therefore is likely to experience higher soil temperatures in the first five weeks post-emergence than later planted maize. Thus it may be expected that many of the physiological processes will advance at a faster rate in early planted maize. This agrees with Allan(1972) who observed that the initial growth of early planted maize was better than that of late planted maize. Detailed growth studies conducted in T.O.P trials at Kitale showed that if other factors do not become limiting later, the dry matter of a plant at five weeks post-emergence is well correlated with the final grain yield of the plant(Law,1974). Consequently any factor which enhances growth in the early post-emergence stages will give the plant a larger yield potential. The aim of the trial reported here was to measure growth of Zea mays when exposed to different soil temperatures achieved by using sol surface mulches, with special reference to the first five weeks post-emergence. It was accepted that environmental factors such as soil moisture, radiation, air temperatures and humidity within the canopy might be changed to a limited extent by the type of mulch used, but the influence of these compared to the effect of the soil temperature was considered very small.

Cooper P. J. M. (1975). Studies on the soil atmosphere composition under maize, grass and bare fallow in Western Kenya. *East African Agriculture & Forestry Journal* 40: 3

The importance of soil aeration has long been regarded as a factor affecting crop growth, and the subject has been extensively reviewed during the last 20 years (Russell 1952, Grable 1966, Greenwood 1970) states that the oxygen demand of different crops varies and that amongst other crops, maize possibly requires a very good supply of oxygen for optimum growth. Other workers (Bartrand and Kohnke 1957, Grable and Siemer 1968, Lal and Taylor 1969, Giesler 1966) have since confirmed that oxygen deficiencies reduce the growth and final grain yield of maize. Oxygen levels in soils are largely controlled by the combined demand of soil micro-organisms and plant roots, and the rate at which oxygen can diffuse through the soil mass to the zone of demand. Russell (1961) stated that in the tropics during the warm rainy season, high levels, of CO_2 and low levels of O2 may well occur. The oxygen demand of a soil containing active roots is related to the soil temperature by the equation (Monteith, Szeicz and Yabuki 1964.

Othieno C. O. (1978). Effects of different mulches on soil fertility and nutrient uptake by tea in Kenya. *East African Agricultural and Forestry Journal*. Vol. 44 (2) pg 76-84

Mulching particularly with organic materials such as grasses is practised extensively in tea plantations and in plantation of other tropical tree crops such as coffee and cocoa. Whereas mulching in other crops such as coffee depends entirely on material from outside sources, mainly of grass type, mulching in tea plantations with material from outside is done only in the first three years to five years following planting. This is done mainly for soil and water conservation. After this period, the tea plants start to generate their own mulching material in the form of leaf-fall and pruning litter. In some cases, especially where tea fails to establish satisfactorily within the mentioned period because of low soil fertility it may be necessary to continue mulching in an attempt to raise the soil fertility, particularly the organic content matter of the topsoil. In Kenya, mature tea plants are pruned every three to four years. The pruning is left in situ and together with leaf-fall provide enough mulch to last until the next pruning. In this paper results of effects of different types of mulches on plant nutrient elements composition in the soil and their uptake by tea plants, obtained from two different field experiments in Kenya, are reported.

van Den Weg R. P. (1974). Reconnaissance soil surveys for multipurpose land use planning and development with special reference to the Kindaruma area (Eastern Province), Kenya. Proceedings of the 13th Meeting East African Special Committee for Soil Fertility and Crop Nutrition.

In cooperation with the Netherlands Government, a soil survey project to run over five years was started as from mid 1972. The purpose of the project is to establish and operate a national soil survey programme designed to carry out soil surveys which will produce information on the soil and land resources of Kenya required for accelerated agricultural development and systematic land use planning. In order to staff the Kenya Soil Survey entirely by Kenyans by the end of the project period, the training of Kenyan counterparts in soil survey, soil science and land suitability classification will have first priority. This training however will be mainly on the job, by participation in the soil survey fieldwork and the subsequent suitability evaluation. Of the different types of soil surveys undertaken by the KSSP, (explanatory, reconnaissance type we are dealing with in this paper. The reconnaissance type of survey constitute the inventory proper of the soil and land resources of the country, to serve multipurpose land use planning. Reconnaissance soil maps form the logical basis for selection of areas to be developed for one or another specific type of land use, areas which subsequently should be covered by more detailed studies. It was decided to do the reconnaissance surveys in a systematic way and to follow the subdivision of the country in coordinate grid as being applied by the Survey of Kenya and the Geological Survey of Kenya. A mapping scale of 1:100000 for the high and medium potential areas was found to be appropriate. In this case besides for planning proper, the soil survey may also be used as a first base for extension of trials on the use of fertilizers, soil conservation and soil management in general. The reconnaissance soil survey involves both systematic aerial photointerpretation and a subseqential number of field observations. With the systematic use for aerial photographs the delineation of mapping units is on a physiographic geology, hydrology, vegetation and land use added. This physiographic approach allows easier understanding of the mappind pattern for non-soil scientists. The photointerpratation enables one to distinguish the main landscape units and to delineate further what are likely to become mapping units on the soil map. The photointerpretaion is followed by fieldwork. The field observations are chosen in relation to photointerpretation units, rather than located at regular distances forming a more or less rigid network. During this stage the soils are investigated, the boundaries delineated on the photographs, are checked and if necessary changed, the soils described and sampled for subsequent analysis in the laboratory. In conjunction with this field worm are also carried out, a vegetation survey mainly as an aid by the delineation of the ecological zones, a land use survey, measurement of infiltration and percolation rates of the major soil types; collection of ring samples for determination of water retention properties. Among the priority areas selected for reconnaissance soil mapping in Kenya, the area covered by quarter degree sheet 136 (comprising four topographical map sheets 136/1 to 4, scale 1:50 000) was selected in 1972 for the first mapping and to be printed on a scale 1:100 000. This map was finalised and printed early 1974. A soil map as the one for the Kindaruma area gives the basic information on soil and land characteristics. The information may be used for a variety of practical purposes such as various types of agriculture, range wildlife etc. Various systems have been used in the past for the interpretation of soil maps/data. In our land evaluation for the Kindaruma area it was attempted to follow as closely as possible the guidelines recently laid down by F.A.O. bases on an International Expert Consultation held in 1972 in Wageningen, the Netherlands (ref. 2,3, and 4). Basic in this approach is that land evaluation is meaningful only in relation to a clearly defined use and therefore relevant land use possibilities (land use alternatives, land utilization types) should be identifies at any early stage in the land evaluation procedure.

Wangati F. J. (1970). A study of water use efficiency in field crops of maize and beans. Msc. Thesis, University of East Africa (University of Nairobi)

Crop water use efficiency may be defined as the ratio of total dry matter produced to total evaporation from the crop and the soil. In East Africa, the areas of high photosynthetic potential (highest number of sunshine hours) are also the driest. Success in growing annual food crops like maize and beans in these areas is therefore heavily dependent on the date of planting and the ability of the crop to complete all its stages of growth within the short rainfall seasons. While breeding of short term and high yielding varieties has been emphasized, little has been done in finding out the water use patterns of the varieties. Experiments were therefore designed to provide information on the water use patterns of one hybrid of maize (H511) with a medium maturity period (4 months) and one popular variety of field bean (*Phaseolus vulgaris* var. Canadian Wonder), in all stages of growth, and to observe the effect of reduced soil moisture on the water use and rate of growth of these two crops. Ratios of crop water use (Et) to Penman estimate of open water evaporation (E_o gave values as high as 1.4-N 1.5 maize and 1.3-1.4 for beans under wet conditions. It is shown that the excess water use, at least in the maize crop, may be due to the combination of large net interception of rain and low aerodynamic resistance. There was a reduction of 20% in water use and 40% in yield in the dry treatment of the maize experiment. Measurement of soil moisture in situ by the neutron scattering technique was studied with the intention of using the method for routine determination of crop water use in the field. Although reliable calibrations were obtained for two makes of neutron moisture meters, E.A.L. and N.I.V.I, the method was shown to be successful only in the absence of drainage. Because of errors in calibration and spatial variations in moisture contents, the precision of soil moisture determination by the

neutron moisture meter is not adequate for small differences and the interval between measurements should be at least 7-10 days. In irrigated fields, the inherent poor distribution of irrigation water is a major limitation. Attempts to derive drainage correction data from tens-iometer readings were not successful. Theoretical estimates of gross photosynthesis have been successfully correlated with measured dry matter production in maize and beans. The correlations suggest that in the local environment respiration loss for the two crops is a constant proportion of gross photosynthesis in all stages of growth. These results enable the prediction of the maximum yields of these crops from meteorological data, mainly solar radiation. Studies of partition of energy in field crops of maize and beans have shown that in the local environment, when the crops are supplied with adequate water, all net radiation may be converted into latent heat, and for periods of 1-2 hours during the day, latent heat may greatly exceed net radiation, the extra energy being derived from the air.

Dagg M. (1969). The water use of perennial grasses at Muguga. East African Specialist Committee on Soil Fertility and Crop Nutrition. March 25th-27th, 1969 Makerere, Kampala, Uganda.

Resistance units were installed to a depth of 6.1 metres under five paddocks of newly planted grasses, two varieties of *Cenchrus ciliaris*, *Chloris gayana*, *Themeda triandra*, and *Cynodon dactylon* and under well-established stands of elephant grass (*Pennisetum purpurem*) and Kikuyu grass (*Pennisetum clandestinum*). The records showed that all of these important perennial grasses are capable at Muguga of drying out the soil to wilting point to a depth of at least 6.1 metres. From planting on April 26th 1965, the roots were extracting water from 3.7 metres by October and, after the short rains, to a depth of 6.1 metres by February 1966. Lysimeter studies at Muguga showed that the evapotranspiration rates from well-watered star grass were about 0.75 E_o. The average rate from June to September 1965 was 0.73 Eo, from June 1965 to February 1966 was 0.71 E_o, and from June 1965 to October 1966 was 0.66 Eo, showing that the grass maintained very near null potential transpiration rates despite soil moisture deficits of 350 mm and more. If water was extracted from beyond 6.1 metres then the observed rates could be an underestimate. An indication of the state of soil moisture under a standard cover (or covers) is a useful piece of information for interpreting the results of field experiments on research stations besides being of considerable hydrological significance. At the recent Specialists Meeting on Applied Meteorology, it was recommended that two or three profiles of resistance units should be placed under an indigenous vegetation cover and the records sent in with the standard agricultural metrological returns. It was hoped that this recommendation would be adopted by many agricultural research stations.

Wangati F. J. (1969). Water use of maize and beans at Mwea irrigation settlement. East *African Specialist Committee on Soil Fertility and Crop Nutrition*. March 25th-27th, 1969-Makerere, Kampala, Uganda.

In connection with an experiment partially financed by the International Atomic Energy Agency, measurements of the water use of two crops of maize and one crop of beans were obtained from hydraulic lysimeters. The rates of water use were greatly influenced by the incidence of rain despite an adequate water supply at all times from irrigation. The pattern of water use anticipated was that shown by the maize in the 1968 crop. The E_t/E_o ratio rose more or less steadily from 0.3 to about 1.0 near silking and it would have been expected to drop thereafter on the senescence of the leaves. Rain in October 1968, however, caused a sharp rise in the Et/Eo ratio well above 1.0, similar to those encountered in the 1967 maize crop and the bean crop grown in the 1968 April-May rainy season. It was demonstrated that large-scale advection effects in these periods of high E_t/E_o ratios were highly unlikely. It must be concluded that the rate of evaporation from wet leaves from the aerodynamically rough crop is appreciably in excess of that from an open water surface or from a freely transpiring, non-wet crop. The frequency of significant amounts of rain must therefore be taken into consideration in calculating the water balance of the crops.

Stachys N. M. (1967). Conservation of one season's soil NO_3^- N and moisture for the benefit of following crops in areas of low rainfall. *East African Specialist Committee on Soil Fertility Meeting Report*. pp.10

The results presented have shown the effect of a follow in preservation of both soil moisture and nitrate. These I turn have been shown to have a great influence on the yield of crops which follow. During years of drought following is the only insurance that a crop is obtained in absence of irrigation. During years of adequate rainfall the residual nitrate on fallows help to increase the yields. However, the frequency of adequate rainfall years is very low. The danger of growing local maize continuously on the same land is manifested by complete failure of or depressed yields. In contrast the short term Taboran maize rotation with bean fodder crops or fallow has resulted in a stabilization of production from one season to the next.

Blere T. W. D. (1964). A preliminary report on soil moisture studies in Kenya arabica coffee. Specialist Committee on Soil Fertility pp 7. Coffee Research Station.

The work of Peraira (1957) and Wallis (1963) has led to the detailed knowledge of the physical preparations of the kikuyu Red loam soil and the development of a method of estimating irrigation requirements for Arabic coffee growing on the soil type east of the rift valley in Kenya. Seasonal factors, relating the water use of un-irrigated coffee to the readings of an evaporation pan were presented by Peraira (1957) and Wallis (1963) modified the method slightly in order to estimate the water use of irrigated coffee. The latter showed that during the month of peak evaporation, and maximum irrigation requirement sunken pan is more accurate than a raised pan and he therefore took the rained pan as his standard. This standard has been maintained in the present paper. Soil moisture changes under Arabic coffee in Kenya therefore merit detailed investigation, and a programme of soil sampling began in 1962, on the general coffee culture trial at the coffee research station at Ruiru. The objects of this soil sampling programme are to measure the soil moisture status at frequent intervals. Also included in this trials is a comparison of clean weeding during the rains with slashing, but the study of effects of these treatments on soil moisture would have made the above programme too expensive to be carried out with the available facilities. The method of soil sampling was similar to that described by Wallis (1963). Moisture contents in each sample were determined gravimetrically and converted to inches of water using Hosegood's conversion factors for the Kikuyu red loam soil. Irrigation was applied using under-tree sprinklers and was measured by water applied to each plot. Rainfall and sunken pan evaporation data were collected about a quarter of a mile from the coffee in this experiment, and these data were used in the computation of the rate of water use by the coffee, and the direct calculation of seasonal factors relating the water use of the coffee, to the sunken pan evaporation. One of the difficulties encountered is that when the top 10 ft. of soil have reached field capacity, it is impossible to differentiate water used by the coffee and water which was lost by drainage to the lower depths. However, it is clear that irrigated coffee has withdrawn water more rapidly from the soil than has un-irrigated coffee, and this is reflected in the higher seasonal factors. This was recorded during most months when rainfall was low. Seasonal factors are subject to considerable variation, and it would be unwise at this stage to modify Pereira's method of estimating water use by coffee. On the irrigated coffee, the rate of water use has been underestimated using the method of Wallis except during the wet month of April and for some inexplicable reason, August. Factors obtained by direct soil sampling have been 0.11 to 0.56 higher on the irrigated coffee than on the un-irrigated coffee. The estimation of water use on coffee which is irrigated ad lib therefore appears to need revision. The mulching treatment in this trial is an application of a 6 ft band of napier grass mulch in alternate inter-rows in alternate years. The mulch is applied in February/March each year. At no stage were there striking differences in the quantity of water in a 10ft. profile due to mulching. It has been claimed that the moisture conservation effect of grass mulches are primarily to the greater depth to which rainfall penetrates under the favourable surface conditions occurred under the mulching and that this effect is quantitatively greater than the subsequent protection of the soil surface by drying out. It was later found out that in the present study, hat the maximum difference in the quantity of soil moisture due to mulching were observed in the top 30 inches of soil. The mulch has considerably improved the penetration of irrigation water when it was applied and delayed the drying out of the top soil i the un-irrigated coffee. However these differences are small and cannot be considered to account for the large yield increases that are to be associated with mulch. In 1963, irrigation failed to increase the yields significantly but both treatments affected the height of the new heads. It is therefore apparent that if the same amount were pruned off all plots in 1964, the irrigation treatment would considerably increase the yield potential of the trees, by means of increasing the amount of bearing wood.

Jones G. H. G. (1948). Colonial soil types Systematic soil classification and Nomenclature, Commonwealth. Bureau of Soil Sciences Technical Communication 46: 85-93.

In this paper which I have been invited to write for the Conference, an attempt will be made to suggest a tentative systematic system for the classification of natural soil types that obtain in Kenya colony, such that it can be fitted into a wider system for the classification of natural soil types that obtain in Kenya colony, such that it can be fitted into a wider system for the classification of Colonial Soil Types. It has not been possible to devote any time to a special pedological survey of soils and their distribution in Kenya, but the opportunity has been taken to collect data on the morphology of soils while travelling about the Colony and carrying out Land Utilisation Surveys during the past seventeen years. Hardly any soil analysis of a non-agronomic value have been undertaken and the writer is fully conscious of the scarcity of mineralogical and chemical data that are required for the sound classification of many soils. The suggested preliminary classifications and groupings of soils now made will have to be modified and perhaps drastically altered when such information, covering scores of soil types, has been obtained. However, it is felt that it would be preliminary soil classification, though the data available is based mainly on a knowledge of the nature of the parent material and mode of formation, the morphology of the soil profile and some value relating to soil fertility.

Analytical Methods

Overview

Soil and plant analysis are crucial for development of appropriate site-specific fertilizer recommendation and for determination of the nutrient content of the consumable plant materials. Additionally, water analysis is crucial for determination of the appropriateness of water for domestic, irrigation and industrial use. Development and validation of appropriate methods for these tests is a continuous process. This section highlights the initiatives that have taken place to develop and test various analytical procedures.

Plate: Soil analysis laboratory (Adapted from AGRA, 2011 report)

Savini I., Koala S., Kihara J.(2015). Minjingu phosphate rock availability in low-pH highly weathered soil as affected by added salts. Scientia Agricola,N.5, p.440-451; http://dx.doi.org/10.1590/0103-9016-2014-0315

Concentrations and identity of ions in the soil solution may affect soil phosphorus (P) reactions and P availability. In this study, the magnitude of these reactions was evaluated following the application of Minjingu phosphate rock (MPR) combined with chloride and carbonate salts of Na and Ca within an incubation experiment. Twenty-one days later NaOH-P and HCl-P were determined. This investigation was undertaken with the aim of identifying the role of Ca-ion activity in the liquid phase on the solubilization of MPR and formation of insoluble Ca-P phases. The increase in pH was higher with Na_2CO_3 than with $CaCO_3$, while both $CaCl_2$ and NaCl resulted in slight decreases in pH. The dissolution of MPR was higher overall when MPR was applied singularly than for the combined application of the phosphate rock with salts of calcium or sodium after 60 days of incubation. Dissolution of MPR decreased as levels of $CaCO_3$ or $CaCl_2$ increased but the decrease was more pronounced in $CaCO_3$-treated than in $CaCl_2$-treated soils. Ca-ion activity in the liquid phase is the main factor responsible for the insolubilization of MPR and the formation of insoluble Ca-P phases (HCl P). The formation of Ca-P solid phases increased with the concentration of Ca-ions, and was governed by the pH and nature of the accompanying anion. For soils with low levels of exchangeable cations and where liming is a recommended intervention measure, Ca from lime will form insoluble P phases and reduce the dissolution of PR and P availability to plants.

Waruru B. K., Shepherd K. D., Ndegwa G. M., Kamoni P. T., Sila A M. (2014). Rapid estimation of soil engineering properties using diffuse reflectance near infrared spectroscopy. Biosystems engineering 121 (2014) 177 -185

Materials testing involve complex reference methods and several soil tests have been used for indexing material functional attributes for civil engineering applications. However, conventional laboratory methods are expensive, slow and often imprecise. The potential of soil diffuse reflectance near infrared (NIR) spectroscopy for the rapid estimation of selected key engineering soil properties was investigated. Two samples sets representing different soils from across the Lake Victoria basin of Kenya were used for the study: A model calibration set (n ¼ 136) was obtained using a conditioned Latin hypercube sampling, and a validation set (n ¼ 120) using a spatially stratified random sampling strategy. Spectral measurements were obtained for air-dried (<2 mm) soil sub-samples using a Fouriertransform diffuse reflectance near infrared (NIR) spectrometer. Soil laboratory reference data were also obtained for liquid limit (LL), plastic limit (PL), plasticity index (PI), linear shrinkage (LS), coefficient of linear extensibility (COLE), volumetric shrinkage (VS), clay activity number (Ac), total clay content, air-dried moisture content, and cation exchange capacity (CEC). Soil reference data were calibrated to smoothed first derivative NIR spectra using partial least squares (PLS) regression. At the calibration stage, coefficient of determination for full cross-validation (R2) of _0.70 was obtained for CEC, mc, LL, PI, LS, COLE and VS. Further independent validation gave R2 _ 0.70 and RPD (ratio of reference data SD and root mean square error of prediction) 1.7e2.2 for LL, PI, mc and CEC. The results suggested that NIRePLS has potential for the rapid estimation of several key soil engineering properties. Further work should focus on extending calibration libraries using more diverse soil types and testing alternative infrared diffuse reflectance based methods.

Shepherd K.D., Vanlauwe B., Gachengo C.N. and Palm C.A. (2005) Decomposition and mineralization of organic residues predicted using near infrared spectroscopy. Plant and Soil (2005) 277:315–333: DOI 10.1007/s11104-005-7929-y

Characterization of decomposition characteristics is important for sound management of organic residues for both soils and livestock, but routine residue quality analysis is hindered by slow and costly laboratory methods. This study tested the accuracy and repeatability of near-infrared spectroscopy (NIR) for direct prediction of in vitro dry matter digestibility (IVDMD) and C and N mineralization for a diverse range of organic materials (mostly crop and tree residues) of varying quality (n = 32). The residue samples were aerobically incubated in a sandy soil and amounts of C and N mineralized determined after 28 days. IVDMD and quality attributes were determined using wet chemistry methods. Repeatability was higher with NIR than the original wet chemistry methods: on average NIR halved the measurement standard deviation. NIR predicted IVDMD and C and N mineralization more accurately than models based on wet chemical analysis of residue quality attributes: reduction in root mean square error of prediction with NIR, compared with using quality attributes, was IVDMD, 6%; C mineralization after 28 days, 8%; and N mineralization after 28 days, 8%. Cross-validated r2 values for measured wet chemistry vs. NIR-predicted values were: IVDMD, 0.88; C mineralization, 0.82; and N mineralization, 0.87. Direct prediction of decomposition and mineralization from NIR is faster, more accurate and more repeatable than prediction from residue quality attributes determined using wet chemistry. Further research should be directed towards establishment of diverse NIR calibration libraries under controlled conditions and direct calibration of soil quality, crop and livestock responses in the field to NIR characteristics of residues.

Savini I., Smithson P. C. and Karanja N. K. (2006). Effects of added biomass, soil pH and calcium on the solubility of Minjingu phosphate rock in a Kenyan Oxisol, Archives of Agronomy and Soil Science, 52:1, 19-36, DOI: 10.1080/03650340500471922

The effect of added biomass (dried leaves) of tithonia (Tithonia diversifolia [Hemsley] A. Gray), soil pH, and soil calcium (Ca) saturation on the dissolution of Minjingu phosphate rock (MPR) was examined in two incubation experiments in a Kenyan Oxisol. Anion exchange resin (AER) and mixed anion-cation exchange resin (ACER) were used to estimate plant-available P. Selected treatments at 2 and 16 weeks of incubation were sequentially extracted with 0.5 M $NaHCO_3$, 0.1 M NaOH and 1 M HCl. AER-P from triple superphosphate (TSP) treated soil was initially higher than that from MPR treated soils (p50.001), but by the end of the incubation AER-P from the two P sources were not significantly different. Dried tithonia leaves at 10 tonnes/ha in combination with MPR (150 kg/ha) caused a significant (p50.01) reduction in AER-extractable P. Sequentially extracted $NaHCO_3$-P and NaOH-P were lower in MPR tithonia treatment compared with MPR only treatment, while HCl-P was higher in treatments containing tithonia. ACER-extractable P concentrations were higher than those of AER-P, and ACER-P from MPR was greater than that from TSP at all dates (p50.001). Calcium additions, either as $CaCO_3$ or $CaCl_2$, reduced AER-P significantly (p50.001) at all sampling dates. However, while $CaCl_2$ addition reduced ACER-P, $CaCO_3$ addition increased ACER-P. Sequential P extraction indicated that $CaCO_3$ reduced MPR solubility more than $CaCl_2$ did. The results indicate that Ca exerts a significant control on PR dissolution, with pH as an additional effect.

Shepherd K. D. and Walsh M. G. (2002) Development of Reflectance Spectral Libraries for Characterization of Soil Properties. Soil Science Society. Published in Soil Sci. Soc. Am. J.66:988–998

Methods for rapid estimation of soil properties are needed for quantitative assessments of land management problems. We developed a scheme for development and use of soil spectral libraries for rapid nondestructive estimation of soil properties based on analysis of diffuse reflectance spectroscopy. A diverse library of over 1000 archived topsoils from eastern and southern Africa was used to test the approach. Air-dried soils were scanned using a portable spectrometer (0.35–2.5 μm) with an artificial light source. Soil properties were calibrated to soil reflectance using multivariate adaptive regression splines (MARS), and screening tests were developed for various soil fertility constraints using classification trees. A random sample of one-third of the soils was withheld for validation purposes. Validation r^2 values for regressions were: exchangeable Ca, 0.88; effective cation-exchange capacity (ECEC), 0.88; exchangeable Mg, 0.81; organic C concentration, 0.80; clay content, 0.80; sand content, 0.76; and soil pH, 0.70. Validation likelihood ratios for diagnostic screening tests were: ECEC <4.0 $cmol_c\ kg^{-1}$, 10.8; pH <5.5, 5.6; potential N mineralization >4.1 mg kg^{-1} d^{-1}, 2.9; extractable P <7 mg kg^{-1}, 2.9; exchangeable K <0.2 $cmol_c\ kg^{-1}$, 2.6. We show the response of prediction accuracy to sample size and demonstrate how the predictive value of spectral libraries can be iteratively increased through detection of spectral outliers among new samples. The spectral library approach opens up new possibilities for modeling, assessment and management of risk in soil evaluations in agricultural, environmental, and engineering applications. Further research should test the use of soil reflectance in pedotransfer functions for prediction of soil functional attributes.

Karuku G. N. and Mochoge B. O. (1991). Organic Nitrogen Fraction in Three Kenyan Soils. *In: Magoggo et al (Eds) Proceedings of the 10th Annual General Meeting of the Soil Science Society of East Africa*, December 3rd to 7th 1990. pp 83-88. Arusha, Tanzania.

The objective of the experiment was to determine the organic N forms in three Kenyan soils. The soils were selected on the basis of differing organic matter content, soil pH and differences in land use. Gituamba Andosol had the lowest pH followed by Kitale Ferralsol and then Katumani Luvisols. Gituamba soils also had the highest organic matter content and Katumani the lowest. The hydrolysable organic N for the 0-15 cm and 15-30 cm depths was 57.2 and 59.3% for Gituamba; 59.6 and 61.9% for Kitale; 39.0 and 42.1% for Katumani. Amide N ranged from 11.6 to 21.4% of total N; Hexosamine N from 5.2 to 10.1% and amino acid N from 26.2% to 37.1%. Amino acid N formed the highest portion followed by Amide N.

Esilaba A. O. and Ssali H. (1987). Sulphur Status of Selected Kenya Soils. *East African Agricultural and Forestry Journal*, Volume 4 1987

Sulphur (S) deficiencies have been detected in parts of Kenya and S fertilization has been recommended in some areas for satisfactory crop growth. Many areas in Kenya are considered potentially deficient in S since the soil organic matter reserves are generally low and atmospheric S additions are small. Sulphur deficiency can seriously decrease maize yields and that under conditions of acute deficiency the response to nitrogen (N) and phosphorus

(P) can be greatly reduced. The S efficiency problem is likely to become acute following introduction of high yielding varieties, high intensity cropping and the use of high analysis fertilizers. The main objective of this study was to assess the S status of major agricultural soils of Kenya and obtain information required for the evaluation of the needs for S fertilization in these Kenya soils.

Ntuma A. S. N. (1982). Sorption isotherms for evaluating phosphorus requirements of soils and residual effects of fertilizer phosphorus Msc. Thesis; University of Nairobi, Kenya

Sorption isotherms were used to evaluate phosphorus (P) requirements and residual effects of P on 7 soils representing different soils types in Kenya. Preliminary studies indicated an equilibration time of 10 days. Soils demonstrated diverse P sorption capacities. Gituamba (a humic Andosol) sorbed the most (5,387 ug P/gm) and Mtwapa (an Orthic Ferralsol) a sandy soil (88% sand) sorbed the least (380mg P/gm). Sorption capacity was better related to the TAmm AI content of the soils. Isotherms displacements clearly demonstrated residual effects of P on NARL (a humic Nitisol) and Gituamba soils. At NARL, P had been applied 6 years before the study. Yields of Serena sorghum (*Sorghum Vulgare Pers*) on NARL Soil (79% clay) demonstrated residual effects of P and was 90 to 95% of maximum at 0.075 ppm P in soil solution. Yield on the sandy Mtwapa soil (88% sand) did not reach maximum at 2ppm soil solution P although P extraction methods (Olsen, Bray I and Bray II) indicate adequate P levels. For Gituamba soil yield of sorghum was too poor to allow for meaningful discussion of the results probably due to detrimental soil acidity effects in this soil.

Garberg, P. K. (1969). A note on water soluble silica and phosphorus tests in soils- Possible chemical tests for defining relationships between yield and yield response to phosphorus fertilizer. *EAAFRO, Conference Proceedings; East African Specialist Committee on Soil Fertility and Crop Nutrition*. March 25th-27th, 1969- Makerere University, Kampala, Uganda.

Soil samples (0-15 cm) and yield data were obtained from maize fertilizer experiments, (NP and NPK) carried out over three seasons (1963/64 - 1964/65 and 1965/66) in Western Tanzania. The soils were classified into light and heavy texture and analyzed for water soluble silica, available inorganic P, and inorganic + organic P. Data from 13 trial sites in 1964/65 season and 24 trial sites in the last season were examined. Information about the method of sampling and location of the sites are given elsewhere. It is often observed in East Africa that some soils do not give the expected response to phosphate fertilizer, despite low P analyzes by conventional methods. This may be due to high phosphate fixing capacities in the soils or to the fact that the contribution of organic phosphorus to the nutrition of the crops following mineralisation to available inorganic phosphorus is an important source of this element. Remwall (1957) stated that the recovery of fertilizer phosphorus by the crop that is planted immediately after the fertilizer application amounts to only 10-30 percent of the quantity added to the soil. The remaining 70-90% has been assumed to be consumed by micro-organisms, precipitated by soluble cations in the soil solution or sorbed by the soil complex. Birch (1953) stated that in some instances high phosphate fixing soils were associated with lower crop responses than could be anticipated and vice versa. Relationships between citric acid soluble iron and response to phosphate were not clear, but he did observe satisfactory relationship between citric acid soluble and water soluble silica and response to phosphate fertilizer. In his review concerning phosphate fixation, Hemwall (1957) states that Kittrick and Jackson (1955, 1956) explained phosphorus fixation on the basis of the solubility product principal, they show electron microscope pictures of aluminium and iron oxide surfaces in contact with phosphate solution. With time the iron and aluminium oxide phase disappeared and a separate iron or aluminium hydroxy phosphate phase formed. The reaction of phosphorus with clay minerals in soils has also received a great deal of attention. Hemwall stated that phosphorus fixation in acid soils is primarily due to the formation of iron and aluminium phosphate compounds and the iron and aluminium containing soil minerals including the clay minerals, are the source of this iron and aluminium. Under certain conditions, the compounds form a precipitate, whereas under other conditions they are adsorbed. Several workers (Datta et al 1962, Khan and Roy, 1964, Gausmann 1962, and Russell, 1961) have recorded increased crop yield when silica was added to the soil. Du Plessis and Du T. Burger (1966) investigated the effect of silicate application to plants in a pot experiment and the nature of the effect on yield and P uptake in eight sandy soils. They stated that the beneficial effect of silicate application to plants was probably due to a decrease in phosphorus fixation when silica and phosphorus applications were combined. The work reported here was concerned with an examination of soil silica value and its relationship with crop yield and response to phosphorus fertilizer. In particular the value of a soil silica analysis for predicting crop response to applied phosphorus fertilizer was investigated.

Ogot P.O. (1969). The assessment of the reliability of soil test methods for available phosphorus by greenhouse and laboratory tests. *Conference Proceedings; East African Specialist Committee on Soil Fertility and Crop Nutrition* March 25th-27th, 1969; Makerere University, Kampala, Uganda

One of the most important aspects which have a direct bearing on soil fertility in general and soil tests in particular is the availability concept. This concept recognizes that it is often the relatively small amount or rather highly available form which has the most influence on crop growth. While several soil tests for available phosphorus have been developed none of them is universally applicable. Furthermore, phosphorus and its availability to plant is one of the major soil fertility problems because: (i) a relatively small amount is present in most soils, (ii) the original phosphates are very slightly soluble and (ii) most soils cause rapid fixation of soluble phosphates. Soil test for the available phosphorus helps as a guide to better use of fertilizer and manure; and more conventional methods have been readily adopted by soil scientists in East Africa (3, 5). However, most of the methods available in the literature have been developed for conditions pertaining elsewhere. More investigations are, therefore, needed to find out suitable methods for estimating the available phosphorus in relation to crop response. The object of this investigation was, therefore, to evaluate soil test methods for the available phosphorus in terms of correlation between soil test values and uptake as well as direct dry weight, and to select the best method for use for Kenya soils.

Wapakala, W.W. (1967). Reliability of prediction ESP from ph and soluble cations in saturation extracts of sodium-affected soils of the lower Tana River basin. National Agricultural Laboratories. *East African specialist committee on soil fertility meeting report, Technical report Nairobi* pp.17

An attempt has been made to clarify and evaluate the nature of the relation between the PH and ESP and between experimentally determined ESP and ESP obtained by using the ion equilibrium equations proposed by the US Salinity Laboratory staff and Gapon by simple correlation analysis. Although PH of the saturation paste was found to be positively correlated with the experimentally determined ESP, the correlation coefficients(r) were very low, indicating that PH could not be validly used to estimate ESP. On the other hand, determination of ESP values using Gapon's equation was found to give very good estimates of these values for both saline-alkaline and non-saline-alkaline soils. The U.S. salinity laboratory equation, though not much different from Gapon's equation in the derivative of ESP gave very poor estimates of ESP. Although soluble sodium percentage of saturation extracts was found to be poorly correlated with ESP there were stronger linear relationship between the two values when log 10 ESP was used instead.

Bellis E. (1964). Report on current soils investigations. A *Scott Agricultural Soils Laboratories. Specialist committee on soil fertility. Technical report*. pp.2. Nairobi, Kenya

Phosphate fractionalization studies indicate that applied water soluble phosphates is held by the grey soils of the Kinangop mainly in combination with aluminium and by the red soils of the high country partly in combination with iron and partly in reluctant soluble or occluded forms of even lower availability. only on limed land is an appreciable portion held in combination with Ca. Initial fixation taking place within a few hours but thereafter there is a slow process of increase in the more strongly fixed forms of phosphate at the of more available forms. On basis of these investigations it was estimated that to saturate the fixating capacity of the plough layer of the grey soil, approximately 11/4 t/acre concentrated superphosphate would be needed. For the red soil, the amount is 4 to 41/2 tons. there is a drop of 1-1.5% of the carbon content for each year that land is kept under cultivation but even so the organic matter content and C/N ratio of land which has been long under cultivation in the high country of Kenya remains quite high and no consistent decreased has been observed in the total humic colloid or in the contents cultivations. With depth in the nitrogen content of the organic matter generally was constant or decreased and the sulphur contents remained constant or increased. The phosphorous content increased in the red soil and decreased in the top 20 inches in the grey soil. These trends were more pronounced on deep than on shallow soils. The voltage fluctuations which have long be-devilled the operations of the x ray unit by chance were traced to the faulty connections. This corrected, the equipment has functioned well. A major advance in clay mineralogy was the calculation on the theoretic grounds that the relative intensity of the diffraction peaks of any pair of diffraction component in a mixture whatever its complexity, is directly proportional to the relative concentration of the components and the demonstration that this relationship holds for ternary as well as binary mixture of clay minerals. The relationships ground of the eastern flank of rift valley. Samples were drawn from the profiles mainly in Fort hall district in typical ridge top and side situations at elevations covering the range 3500 to 10000 feet, wherever possible, near the sites of fertilizer trials. The results of the investigations to date add strength to the view that the most important single factor determining soil characteristics and hence fertility in the parent material. Above 6000 feet the nutrients status of the soil is very much lower than at low elevations and the soil clay contains increasing amounts of intergrades material and decreasing amounts of Kaolinite. Clay mineral studies have also been undertaken in connection with two soil research projects at Makerere. Nutritional studies on sisal, pyrethrum and pineapples continued. Following the 1962 observations on pyrethrum and effectiveness of various level of N, K, Ca and S (the nutrients then indicate to be needed in great amounts) has been investigated. N, K and

Ca requirements are proving to be particularly high. The basic nutrients balance studies have shown that pyrethrum yields best at 6-6.5 and that best results are obtained when the nutrient medium is richer but not excessively high in Ca than Mg or K. The lower the ph of the nutrient solution below ph 6, the greater is the proportion of Ca needed in the nutrient solution to ensure good growth and even survival of the plants. Leaf tissues of sisal plants in the 1961 study were analysed for major elements and interrelations between nutrition and nutrients status determined. The parallel streak investigations have now established that sisal plants at all elevations in Kenya are predisposed to the condition but that the condition manifests itself only where growing conditions particularly night temperatures, are cool and subsides as weather or climate becomes warmer, coolness of the rooting medium seems particularly important. Major and minor element deficiency symptoms have been developed in pineapples. Field fertilizer and drainage trials in collaboration with the general agricultural research staff continued on a wide variety of crops in a wide range of localities. A review of all the fertilizer work yet done on pyrethrum has been undertaken and as a result the due importance of adequate phosphate has been reaffirmed.

Mehlich A. (1964). Negative Permanent and Variable Charge Properties of Synthetic Alumino Silicate Department of agriculture. *Specialist committee on soil fertility. Technical report* pp.5

Negative charge properties of Alumino-silicate prepared under varying conditions and precipitation, such as pH, Si/Al ratio and salt concentrations have been studied. The total negative charge was obtained either from titration data with NaOH at pH 8.2 or with $BaCl_2$ buffered at pH 8.2 with triethanolamine. Permanent negative charge was obtained by saturation acidified gel (pH 5.5) with $BaCl_2$ followed by determination of the exchangeable variables or pH dependent negative charge. CECv was obtained by deducting CECp from CECt. The principle results from $AlCl_3$-disilicate ($Na_2Si_40_9$) were: CECp in general increased with increasing Si/Al ratio. CECv was the predominant charge at Si/Al ratio at pH 5 than at pH 6.3. CECp and CECv developed in the absence of divalent cations when the Alumino-silicate gels preparations were initiated from an acid media. Gel formation did not take place when the $AlCl_3$ + Silicate + NaOH were not added simultaneously at pH 5.7 and 8.3 unless salts of divalent cations were introduced. Aging of $AlCl_3$ + acidified silicate at pH 2 for a period of 10 days prior to titration with NaOH greatly reduced CECt, virtually eliminating CECv and left CECp as the predominant charge. The implications of these observations have been briefly discussed in relation to certain factors in soil forming processes and in relation to the use of synthetic alumina-silica as cracking catalysts in the oil industry.

Mehlich, A. (1964). The hydrolysis product of aluminium and iron hydrogen di-acid phosphate. Department of agriculture. *Specialist committee on soil fertility. Technical report* pp.12

Synthetic Alumino and Iron di-hydroxy di-acid phosphate have been prepared and following treatment with various increments of NaOH the hydrolysis product was identified as being largely the HPO_4^- ion. It was postulated that release of phosphate via hydrolysis mechanism is dependent on initial neutralization of the sorbed $H_2P0_4^-$ to form -HPO_4 and H_2O. Hydrolysis of the latter promotes a reversible reaction leading to formation of $Al(OH)_3$, $Fe(OH)_3$ or FeO.OH and the $H_2P0_4^-$ ion.

Theisen, A. A. (1964). X-ray spectroscopy and its application to agriculture. Scott Agricultural Laboratories. *Specialist committee on soil fertility. Technical report* pp: 5. Nairobi, Kenya.

X-ray generation is a function of energy level changes associated with electronic shells next to the nucleus of an atom. The continuous spectrum is due to a slowing down of bombarding electrons. Thus both continuous and characteristic spectrums of x-ray tubes are caused by a high speed electron beam travelling from cathode to anode. Each element has a different characteristic x-ray spectrum is used in diffraction. Since the continuous spectrum is a function of the slowing down of electrons, sample elements do not exhibit a continuous spectrum. Although no continuous spectrum is generated, background is still present. The most serious limitation is the inability of the method to touch elements below atomic number 12. Elements of atomic number less than that give off x-ray wavelength that is so soft that absorption takes place even in vacuums. Matrix effects are noticeable when one element in matrix of material absorbs characteristic radiation given off by elements under observation. In many instances, particularly in industrial application where great accuracy is not demanded, it is possible to convert an absolute number of counts to percentage composition through a set of standards. This simplified procedure is not possible when the sample is made up of many elements. Brandt and Lazar, the first to apply x-ray spectroscopy to agricultural problems, developed a technique for the analysis of plant materials that employ a ratio of peak count to the count of scattered radiations in a region free from lines. In industry use ranges from analysis of ceramics and glass to the study of dynamic systems such as rate of diffusion, precipitation and solution.

Tubb, D. J. (1964). Problems with the spectrograph in routine analysis' work chemistry division. *Specialist committee on soil fertility. Technical report* pp.8. Nairobi, Kenya

Potassium chloride buffer to be replaced by potassium sulphate. High portions of graphite to be used. Improved mixing of standards and samples. Improved line pairs to be used i.e. having similar excitation potentials and of the same excitation table. The three step filter used to cut down the intensities of some spectral lines to a measurable level, to be replaced by a 3 step rotation sector. This will be comparable with the 7 step for plate calibration.

Robinson, J.B.D. (1956). A note on Kjeldhal soil Nitrogen determinations. *EAAFRO Conference Proceedings; Conference on Nitrogen status of soils*-Muguga, 25th April, 1956.

Arising from a comparison of Kjeldhal digestion methods carried out in connection with soil nitrogen studies on the Kikuyu red loam coffee soil, the results of an experiment are presented here which have some bearing on the question of the proportion of organic nitrogen in the soil determined by various Kjeldhal catalysts. This investigation is part of a survey of Kjeldhal digestion methods made with the objective of selecting a suitable method for routine analysis on the basis of rapidity, ease of handling and reproducibility of results.

Socio-Economics

Overview

The uptake of various technologies is a function of various social, cultural and economic factors. Effective technologies may not be taken up if they are not socially and culturally acceptable within the society or when their ultimate economic returns are not attractive. Some of the economic parameter used to measure acceptability of technologies include: benefit cost ratio, value cost ratio, and net benefits among others. This section presents an evaluation of various technologies for their socio-economic acceptability.

Diwani T. N., Asch F., Becker M. and Mussgnug F. (2013). Characterizing Farming Systems around Kakamega Forest, Western Kenya, for Targeting Soil Fertility-Enhancing Technologies. *Journal of Plant Nutrition Soil Science* 176, 585-594

Kakamega district in Western Kenya represents the smallholder farming systems typical for much of the densely populated humid highlands in East Africa. A specific feature, however, is the presence of a protected forest reserve (Kakamega Forest National Park), covering some 20% of the district area. Year-round crop production with little use of external inputs is resulting in declining soil fertility and crop yields. Technologies to counteract fertility constraints are rarely implemented, as they do not consider system diversity or farm-specific characteristics. We surmised that farm type–specific targeting of technology options to address soil fertility–related production constraints would reduce the anthropogenic pressure on the resources of the adjacent Kakamega rainforest reserve. Based on Kenyan national census data, we selected 168 farms in physical proximity of the Kakamega forest and characterized them regarding production system and soil attributes. Cluster and principal component analyses identified five distinct farm categories. Three representative farms from each cluster group were subsequently selected to establish labour-use patterns, draw resource-flow maps, and determine NPK balances. Small subsistence-oriented farms were most common (> 50%), with maize yields of 0.9 t/ha (Cluster 1). Most farmers relied on the forest to provide fire wood, animal feed, and medicinal plants. Mixed farms, combining subsistence maize with industrial crops, were differentiated by soil type, with tea being grown on Ferralsol (Cluster 3), and sugar cane being grown on Acrisol (cluster 4). The dependence on forest resources was limited to animal grazing and the collection of feed stuff (Cluster 3), or the extraction of medicinal plants (Cluster 4). Only few farms showed a high degree of market orientation of the food-crop production. These comprised either small farms with high investments in fertilizer and maize yields close to 2 t/ha (Cluster 2), or larger farms (1.6–3.9 ha) with low fertilizer but high hired-labour use (Cluster 5). Their reliance on forest resources was generally low. Resource flows showed mainly patterns of nutrient export in subsistence farms, and more complex flow patterns, involving several farm compartments, in the diversified farms. Partial nutrient balances were strongly negative for N and K, irrespective of soil or farm type. Soil-fertility characteristics reflected the nutrient balances with generally low C and N in all farms on Acrisol, and low P in farms not applying mineral fertilizers or farmyard manure. The proposed typology is expected to improve the targeting of technologies addressing soil fertility–related production constraints, and to reduce the pressure on forest resources. This is of particular importance in the case of small-scale subsistence and mixed farms close to the forest margin.

Ndiiri J. A., Mati B. M., Home P. G., Odongo B., Uphoff N. (2013). Adoption, constraints and economic returns of paddy rice under the system of rice intensification in Mwea, Kenya.

***Journal Agricultural Water Management,* Vol. 129 pp. 44-55**

A detailed farm survey was conducted in Mwea irrigation scheme, Kenya during the 2010/2011 and 2011/2012 main growing seasons to assess the adoption and to quantify the net income advantages of using system of rice intensification (SRI) management over farmer practices (FP) for rice cultivation. Data were collected through questionnaires and structured interviews with farmers who were practicing both SRI and FP methods of rice production on their farms. Under FP, three seedlings aged 28 days are transplanted in respective hills at random spacing. The fields are then flooded with water throughout the growing period. For SRI practice, factors considered as essential were transplanting only one seedling per hill aged 8 - 15 days with spacing of at least 20 cm by 20 cm; weeding the crop at least three times at intervals of ten days; and intermittently irrigating the fields. The contributions of using organic manure for fertilization and soil-aeration weed control methods were not considerations in this study since the availability of organic materials and mechanical push weeders were challenges at the time of study. A total of 40 farmers in 10 units out of the 50 SRI farmers from 18 units of the irrigation scheme were sampled. Benefit-cost relationships were estimated using tabular analysis of all variable costs and income from production using the survey data. On average, yield under SRI management increased by 1.6t/ha (33%), with seed requirements reduced by 87% and, water savings of 28%. SRI required 9% more labour than FP on average, but this factor of production showed great variability; in three Mwea units, labour costs were reduced by an average of 13%. SRI required 30% more labour for weeding than FP in the first season, but this was reduced to 15% in the second season when push-weeders became available. The results showed SRI giving a higher benefit-cost ratio of 1.76 and 1.88 in the first and second seasons, respectively, compared to 1.3 and 1.35 for FP. The results indicated that SRI practices of planting younger seedlings, with wider spacing and intermittent irrigation, lead to increased paddy rice yields with concomitant rise in the income accruing to farmers. Possibly further increases in net benefits could come with enhanced availability of mechanical weeders and using organic material for fertilization. Up-scaling of SRI in Mwea can be expected to help achieve greater national and household food security.

Adolwa I. S., Okoth P. F., Mulwa R. M., Esilaba A. O., Mairura F. S., Nambiro E. (2012). Analysis of Communication and Dissemination Channels Influencing the Adoption of Integrated Soil Fertility Management in Western Kenya. *Journal of Agricultural Education and Extension.* Vol. 18, No. 1, 77-86

The following study was carried out to evaluate the socio-economic factors influencing access to integrated Soil fertility Management (ISFM) Information and knowledge among farmers in western Kenya, and subsequent ISFM uptake with a view to assessing communication gaps. Structured questionnaires were administered to 120 farmers from Vihiga and Siaya Districts. In Vihiga, Farmers were sampled in a systematic random manner from farmer group lists, whereas in Siaya, farmers were selected based on randomly diagnostic trial sites of the Africa Soil Information Service (AfSIS) Project. Community based and mass media channels were found to be significantly advantageous to farmers, farmers' preferred information sources and channels included own experiences, farmer field days and farmer groups, respectively. A probit regression model indicated that off-farm income, education level, distance from the nearest information centre, livestock value and district residence were the socio-economic variables that significantly influenced farmer access to ISFM information and knowledge, and subsequent uptake. In conclusion, farmer field days and farmer groups should be promoted as vehicles for the agricultural information communication and dissemination. The study has practical implications for the dissemination of agricultural technologies, especially in small-holder farming regions, characterised by high poverty and poor infrastructure. The study is original because the channels for communication and dissemination of ISFM technologies are poorly documented or non-existent in western Kenya, and in most small-holder farming systems in Africa. The adaptation behaviour of ISFM technologies in relation to socio-economic factors by farmers is still poorly understood.

Mugwe, J.N., Mairura, F., Kimaru, S.W., Mucheru-Muna, M. and Mugendi, D.N. (2012). Determinants of adoption and utilisation of integrated soil fertility management by small holders in Central Kenya. Research Application Summary. *Third RUFORUM Biennial Meeting 24 - 28 September 2012, Entebbe, Uganda*

Per capita food production in Africa has been declining over the last two decades, contrary to global trends due to soil fertility decline. The study sought to determine factors that influence adoption and utilization of integrated soil fertility management (ISFM) technologies by smallholder farmers in central Kenya. Two hundred and forty (240) farmers were randomly sampled and data collected through face-to-face interviews. Data were subjected to binary logistic regression to determine factors that could explain adoption and utilization of the ISFM technologies. Results showed that in regard to combined organic and inorganic fertilizers utilization, positive associations were detected with occupation, farming experience, perception of soil degradation, external assistance, off-farm income, perception of food and cash security, tropical livestock units, and house-hold size. The study concludes that there is need to examine the critical role that socio-economic variables contribute in the farming system during the development of ISFM.

Otinga A. N. (2012) Soil fertility and the use of fertilizers in western Kenya: A field evaluation based on farmers assessment and corresponding laboratory measurements of selected soil properties. PhD Thesis, Chapter 2, Katholieke Universiteit Leuven

Attaining sustainable food productivity in sub-Sahara Africa (SSA) remains a great challenge and there is a dire need to improve the situation as the region's population continues to grow. Most parts of SSA are characterized by underdeveloped and/or not poor agricultural productivity. Low soil fertility largely contributes to this poor productivity. In this region, crop productivity is predominantly limited by Nitrogen (N) and Phosphorous (P) deficiencies and soil acidity per se and its related problems such as aluminium (Al) and Manganese (Mn) toxicities. Phosphorous deficiency remediation presents a particularly difficult situation because of its low bioavailability in the soils. Soil P deficiency can theoretically be managed by the use of mineral fertilizers, organic fertilizers and/or combinations of both. While mineral fertilizers are largely limited by cost and infrastructure, organic materials on the other hand are limited by availability in the right amounts due to their low nutrient contents. High quality organic crop residues such as Tithonia dives folia have been reported to increase microbial biomass carbon and enhance N and P availability consequently improving agricultural productivity. Even though this option seems feasible in replenishing P fertility, its adoption has been low in part because it is highly expensive in terms of labour and land. Materials such as farmyard manure (FYM), even though often lower in quality than Tithonia diversifolia are more widely adopted. Similarly, combinations of small rates of FYM and mineral fertilizers are widespread in the region. Thus a need to find strategies that would combine inorganic and organic fertilizers in a way so as to enhance their agronomic efficiency with concomitant increased agricultural profitability arises. The general objective of this study was to determine how P use efficiency can be maximised for limited quantities of mineral and organic fertilizers in 3 districts of western Kenya: Siaya (Sega), Bungoma (Bokoli and Mabanga) and Teso (Angurai). Firstly we carried out a field survey to evaluate the use of organic and inorganic fertilizers on crop production and assess soil fertility status based on farmers' perceptions on the fertile and infertile areas of their farms and relate to their observations to laboratory analyses of selected soil properties. We found that contrary to belief, farmers in this region use fertilizers, albeit in limited quantities. However, the use if highly skewed towards

di-ammonium phosphate (DAP), Calcium ammonium nitrate (CAN) and urea. Application of agricultural lime, Potassium (K), Magnesium (Mg) and Sulphur (S) fertilizers are mostly neglected. Further, a strong similarity was observed between farmers' assessment of fertility on their fields and the measured soil properties. Secondly we investigated the possibility of enhancing the agronomic P fertilizer use efficiency (APE) and profitability when low rates of both inorganic and organic fertilizers were applied at Sega, Bokoli and Angurai in 2 cropping seasons: 2009 long rain season (LRs) and 2009 short rains season (SRs). In this part, we aimed at reducing the amounts of organic fertilizers/materials required to attain a specific/recommended P rate which is possible in principal by concentrating the application only in planting rows. Thus, field experiments were set up to study the effect of substituting inorganic (TSP) by organic (FYM) at different rates and the application of FYM in different areas of the planting rows on maize yields, APE and profitability at Sega, Bokoli and Angurai sites. In this study also explored the possibility of using FYM as an alternative to manage soil acidity in the more acidic soil of Sega, since access of agricultural lime is limited by high costs. Treatments included substituting TSP by FYM at 0, 25 50, 75 and 100% of the 26 kg P/ha recommended rate. Further 13 kg P/ha FYM was either applied to 100% of the planting area (i.e. broadcast) or localized in only 50% or 25% of the planting area of the maize row. For soil acidity management 2 and 4 t/ha agricultural lime applied either alone or combined with TSP at 26 kg P/ha were included. Corrections for N and K were made in the treatments to ensure that P was the only limiting nutrient. All sites responded to the application of P and when FYM and TSP were combined, maize yields increased from 16-60% at Sega, 7-34% at Bokoli and 7-36% at Angurai compared to sole TSP during the 2009 SRs. The APE largely depended on the seasons and the relative fertility of the soils but increased with the increase in % P applied in FYM. Better APE was recorded in the short rain season. We attributed this to improved moisture retention by the FYM. At the Sega site, response to FYM as well as soil pH, available P and reduced Al concentration in the soil. At Angurai, better APE was attributed to additional carbon concentration in the soil. Lower response at Bokoli site was due to relatively better soil fertility as compared to other sites. Maximising P from FYM in the substitutions increased profitability of the system relative to sole application of mineral fertilizers, but this depended on the site. Nevertheless, mineral fertilizers were also found to be profitable despite their high costs. Further, in our study we were able to confirm that it was possible to reduce the quantity of organic materials required to supply a specific rate of P if the application was done only in planting rows. In management of soil acidity, agricultural lime was generally more effective in increasing soil pH and reducing Al concentrations in the soil. Application of FYM, however, increased the pHcac12 by 0.39 units and reduced the Al concentration by 70% relative to control. In applying low rates of TSP and FYM, we envisaged that although minimal P inputs would be attractive for nutritional disorders in crops. Thus we carried out a study to diagnose nutrient deficiencies for nutrients N, P, K, Calcium (Ca), Magnesium (Mg) and Sulphur (S) in low P input systems using Diagnosis and Recommendations Integrated System (DRIS) Where N was adequately supplied, no N deficiencies were diagnosed except when optimum or near optimum yields were obtained. The results showed that P was critically deficient at the Sega site. Further, DRIS diagnosed S deficiencies at Sega and Mg and S deficiencies at Bokoli and Angurai sites highlighting the need to include these nutrients in fertilizer recommendations. The P deficiency in Sega was attributed to the high P fixing capacity of this site and this deficiency was consequently eliminated by liming. The Mg and S deficiencies were attributed to negligible application of these nutrients in fertilizers. Finally we investigated the possibility of improving the APE in a legume-maize rotation by preferential seasonal allocation of P and incorporation of P efficient legume germplasm into the rotational system. Thus, we carried out a legume-cereal rotation study at Mabanga during 2 complete rotation cycles: 2009 SRs-2010 LRs and 201 SRs-2011 LRs. The study was carried out to compare the rotational effects of 2 soybean cultivars (TGx 1895-33F and TGx 1448-2E commonly referred to as SB 8 and SB 20, respectively) in relation to their biological nitrogen fixation (BNF) potential and P uptake and assess the possibility of increasing APE and profitability by targeting the P fertilizer to the soybean rather than the maize in a soybean-maize rotation. These were compared with a continuous maize-maize mono-crop at 0, 26 and 52 kg P/ha. Out of the 2 cultivars, TGx 1895-33F was considered as the most P efficient cultivars as it showed consistently higher P uptake and gave higher total above ground biomass and grain yields at low (0 kg P/ha) and moderate (26 kg P/ha) P levels notwithstanding the large variance of the field and the un reliable rainfall in some seasons. This was partly related to higher BNF potential of the cultivar. Maize yields in the rotations were significantly higher than the yields in the maize mono-crop. In the TGx 189533F: maize rotation, maize yields were higher than the yields in a mono-crop by 78 and 46% at 0 and 26 kg P/ha, respectively. Similarly, in the TGx1448-2E: maize rotation, yields were higher than yields in the mono-crop by 65 and 25%, respectively at the same P rates. Application of 52 kg P/ha to both soybean cultivars also increased the yields of maize grown in rotation. Although both cultivars gave rotational benefits, net benefits and benefit cost ratios were significantly larger only when TGx 1895-33F was incorporated into the rotation system. In fact losses were incurred in the 2010 SRs, when TGx 1448-2E was incorporated into the system generally because of the low soybean grain yield obtained. Targeting 52 kg P/ha to TGx 1895-33F was much more profitable than when the same rate was applied to TGx 1448-2E in a legume cereal rotation or maize in a maize-maize mono-crop. We could not detect differences in APE between 2 soybean cultivars. Similarly, the APE in maize grown in rotation with either soybean cultivars was not different from that of a maize-maize mono cropping. We attributed this to the large variance of the field that could have obscured treatment effect. Several conclusions were drawn from this study. Firstly the study confirmed that it is possible to reduce the quantity of FYM if it is applied only in the planting rows but its profitability largely depends on the quality of the material selected and the site soil characteristics. Agronomic

efficiency of the P fertilizer depends on the relative fertility of the soils. In general, however, maximising P from Organic materials enhances the APE. We showed that FYM can be used in the management of the soil acidity at least in the short term but cannot entirely substitute agricultural lime. We also noted that in using FYM on acid soils, P and lime requirements may be considerably reduced. The P deficiency at Sega may be managed by increasing the pH and reducing the Al concentrations to improve the availability of P and the Mg and S deficiencies by including these nutrients in fertilisation schemes. Of the 2 soybean cultivars in the rotation study, TGx 1895-33F was considered the most P efficient. We therefore concluded that to enhance the agronomic and economic efficiency of a cereal-legume rotation in a P depleted soil, P efficiency and high yield traits of the grain legume would be the most desirable traits to consider.

Kimaru S.W. (2011). Enhancing communication for effective dissemination of soil fertility management in the central highlands of Kenya. Msc. Thesis, Kenyatta University, Kenya

Increased recognition of soil fertility depletion as the main biophysical factor limiting crop production in many African small holder farms has renewed interest in the dissemination of soil fertility management (SFM) practices. Despite soil technology development and research outputs, few of the recommendations from soil fertility management research have been put into use by the targeted end users. Accessibility and utilization of the existing knowledge is inadequate due to the communication methods and tools used in dissemination and up scaling of soil fertility management practices. With this background, this study was set out with the following objectives; i) to investigate availability and reliability of sources on SFM for farmers, ii) to identify communication channels used by researchers and extension agents and iii) to determine socio- economic factors that influence preference of communication methods by farmers, in the Central highlands of Kenya. Questionnaires were used to collect information from 22 researchers and 105 extension workers. In order to determine the socio-economic factors influencing farmers' preferences of communication methods, individual household interviews were conducted where 240 randomly selected farmers were interviewed. Data was analyzed using descriptive statistics (frequency, mean, percentages and Chi-square). Spearman correlation coefficient and logistic regressions were used to test the magnitude of the relationship between dependent and independent variables using statistical package for social sciences (SPSS) programme. Results showed that farmers perceived other farmers as the most available and reliable source of information on SFM while radio were perceived as highly available but relatively unreliable by farmers. Demonstration, farmer to farmer extension and workshops/seminar were sequentially ranked as the first three methods preferred by the farmers. Majority of the researchers and extension officers frequently used field days and demonstration as methods of communicating to farmers on soil fertility management. Preference of demonstration by farmers in training on green manure was positively influenced by age (r=0.158, P=0.05) and number of non formal trainings (r=0.114, P=0.05) but negatively influenced by farm size (r=-0.132, P=0.05) and gender (r=-0.184, P=0.01). Gender, education, number of non formal trainings attended, farm size and number of times a farmer had been visited by an extension agent were significant predictors in preference of field days in training on animal manure. Continued use of demonstration method was recommended as it was highly preferred by the farmers as well as considered effective by the extension agents and researchers. For effective dissemination of SFM, agricultural stakeholders should consider farmers' socio-economic characteristics while designing extension intervention strategies to be used in dissemination of soil fertility management practices. This is envisaged to increase adoption of SFM practices which will consequently lead to increased crop production and contribute to reduction of extreme poverty.

Adolwa I. S., Esilaba A. O., Okoth P.O., Mulwa M. R., (2010) Factors influencing uptake of integrated soil fertility management knowledge among small holder farmers in western Kenya. In: *Ouda et al (Eds) Proceedings of the 12th Kenya Agricultural Research Institute Biennial Conference*. pp. 1140-1152

Limited access to timely and accurate information has been identified as a major impediment to the development of rural agriculture in Kenya. This has impacted negatively on the socio-economic well-being of agricultural producers resulting in high poverty levels of 65% and 61% respectively. A study was carried out to evaluate the integrated soil fertility management (ISFM) information/knowledge sources and channels and assess the influence of economic factors on access and usage is ISFM knowledge among small holder farmers in western Kenya. Structured questionnaires were administered to 120 farmers from Vihiga and Siaya districts. In Vihiga a systematic random sample was designed from available list of participants and non- participant farmers involved in a previous ISFM study whereas in Siaya farmers were selected based on randomly selected diagnostic trial sites of the Africa soil information services (AfSIS) project. Farmers preferred information source were own experience farmer field days and farmer groups respectively. The least preferred information source channel and knowledge source were farmer cooperatives internet and website respectively. A probit regression indicated that off-farm income, education level, distance from nearest information centre livestock value and district of residence were the socio-economic variables that significantly influenced farmers access and up take of ISFM knowledge. In conclusion farm field days and farmer groups should continue to be promoted as vehicles of information dissemination and communication. Investing education and information centres as well as using ICTs to complement community-based channels will enhance farmer access to ISFM information and knowledge.

De Groote H., Vanlauwe B., Ruto E., Odhiambo G., Kanampiu F., Khan Z. R. (2010). Economic Analysis of Different Options in Integrated Pest and Soil Fertility Management in Maize Systems of Western Kenya. *Agricultural Economics Journal, International Association of Agricultural Economists* 41 471- 482

The major biotic constraints to the production of maize, the major staple food in Western Kenya, are field pests such as *Striga* and stem borers, and low soil fertility. To counter these constraints, new cropping systems have been developed, including "push-pull," rotations with promiscuous soybean varieties and green manure crops, and imidazolinone resistant- (IR-) maize. To analyze the technical and economic performance of these technologies, both with and without fertilizer, on-farm researcher-managed long-term trials were implemented over six seasons in two sites each in Vihiga and Siaya districts of Western Kenya. The economic results, based on marginal analysis using a multi-output, multi-period model, show that the new cropping systems with fodder intercropping (push-pull) or soybean rotations were highly profitable. Push-pull is more profitable but requires a relatively high initial investment cost. Green manure rotation, IR-maize, and fertilizer all increased yields, but these investments were generally not justified by their increased revenue. We argue that research on rotation and cropping systems to tackle pest and soil fertility problems in Africa deserve more attention. This will require increased collaboration between agronomists and economists to set up long-term experiments with new cropping systems to develop proper economic models.

Kathuli P., Itabari S.N., Nguluu S., Gichangi E. M (2010) Farmer perceptions on sub-soiling/ripping technology for rain water harvesting in mixed dry land farming areas in eastern Kenya. *In: Ouda et al (Eds), 12th KARI Biennial Scientific Conference*, 8-12, November, 2010, pp. 1253-1259

Sub-soiling/ripping technology for rain water harvesting was demonstrated to farmers in agro-ecological zones (AEZs) 4 and 5 in Mwala, Yatta and Kitui districts in eastern Kenya from 2007-2009. Participating farmers were involved in evaluating the benefits of enhancing soil moisture through use of this technology. The results showed that sub-soiling/ripping for rain water capture increased maize mean total dry matter (TDM) by 29-117 % compared with convectional tillage. Mean maize grain yields (kg/ha) was increased by 84% in Yatta AEZ 5 and by 38% in Mwala AEZ 4. Yield increases were more for Katumani composite B (KCB) maize planted in AEZ 5 than that planted in AEZ 4. The benefits of rain water harvesting through sub-soiling and ripping were increased when combined with application of 20 kg N plus 20 kg P_20_5/ha at planting in AEZ 5 and 5t/ha FYM and topdressing with 20 kg N/ha for KCB maize in AEZ 4. Sub-soiling/ripping significantly ($p<=0.05$) enhanced soil moisture retention in the 10-30 cm soil depth. Farmers expressed their willingness to adopt the technology, but indicated the need for the technology to be modified for enhanced adoption. In terms of yield increase, the effect of this technology is greater in AEZ 5 than in AEZ 4.

Macharia C. N., Njeru C. M., Gichangi A., Shiluli M. S., Ombakho G. A. (2010). Agronomic and financial implications of using farm-saved seed from naturally segregating certified maize hybrids by small holder farmers. *In: Ouda et al (Eds) Proceedings of the 12th KARI Biennial Scientific conference.*

Use of farm saved maize seed continues to be widespread in medium altitude ecosystems of western Kenya. The practice is contrary to current recommendations and is the cause of low maize yields in the area. In order to determine the agronomic and financial implications of using farm-saved seed and certified hybrid maize, experiments were conducted on farmers' fields. First generation seed (CG1) of certified seed of two commercial hybrids (H513 and H614), a local maize variety and the respective first and second segregating generation (SG1 and SG2) of H513 and H614 seed were evaluated with and without inorganic fertilizer. Significant differences ($P<0.05$) in maize grain yield were observed with the first generation certified hybrids consistently yielding more than their respective SG1 and SG2 generations. Fertilizer application on CG1, SG1 and SG2 of H513 and H614 resulted in significantly (<0.05) higher yield. The farmers' variety did not show a significant ($P>0.05$) response to fertilization. Financial analyses showed that although certified seed with fertilizer yielded approximately one ton more grain per hectare than unfertilized local maize, the marginal rate of return on hybrid seed and fertilizer was only 15%. This was below the rate of return generally accepted as sufficient to encourage farmers to abandon old technologies in favour of a new technology. It was evident from this study that, while use of certified maize seed and inorganic fertilizer will significantly increase maize yield, the increase cannot economically absorb the additional costs of certified seed and fertilizer. Since smallholders cannot use improved seed and fertilizer profitably, intervention at policy level may be necessary to safeguard national interests and public good so as non-use of these inputs limits overall productivity, degrades farmland and threatens food security.

Murua E. (2010). Utilization of soil fertility management knowledge among smallholder farmers in Chakol Division, Kenya. Msc. Thesis, Kenyatta University

This study investigated soil fertility knowledge and how it influenced the selection and effective use of various soil fertility technologies among small holder farmers in Chakol Division has a high population density of approximately 427 persons per sq. km while absolute poverty levels for the district stand at 56%. Poverty levels have been worsened by poor agricultural production while continuous cropping of land with little restoration of soil nutrients through application of organic manures and mineral fertilisers have contributed to the increase of soil degradation over time. The need to improve agricultural productivity through better soil fertility management is therefore paramount considering that Teso District mainly relies on agriculture 65% of the population being involved in agriculture activities. In order to address this problem, a call for a holistic approach that is socially acceptable hence easily adaptable and fit for purpose is necessary and therefore the concept of Integrated Soil Fertility Management (ISFM) strategy. This ISFM strategy at TSBF-CIAT aims to maximise on nutrient recycling on farms, replenish soil nutrient pools, reduce soil nutrients losses to the environments and improve the efficiency of external inputs. It was applied through Folk Ecology Initiative (FEI) approach which attempted to strengthen farmers' understanding of soil fertility management through community-based interactive learning. This current study grew out of the FEI approach and it involved both quantitative and qualitative data collection techniques using questionnaire surveys, focus group discussions and in-depth interviewing. A total of ninety smallholder farmers were carried out. SPSS was used to analyse the data collected through questionnaires and a narrative log used for the case studies. Study findings showed that farmers in Chakol had knowledge on the preparation, benefits and drawbacks of soil fertility technologies but the decisions they made towards the selection and application of technologies such as compost, natural fallows, cereal-legumes rotation, biomass transfer and fertiliser were mostly affected by capital, land, labour and other social constraints. Preference was given to technologies such as farmyard manure and crop residue incorporation since they were socially convenient in terms of labour and time demands; were comparatively less complicated to apply, cheaper and easier to get. However, less accessible technologies such as mineral fertilisers, no matter how important, were least preferred or selected. It is therefore concluded that soil fertility knowledge is necessary for meaningful decision making. It played a vital role in the selection and application of soil fertility technologies. However, poverty played a major constraining role. It is therefore recommended that strategies to boost farmers' incomes should be strengthened. For instance, through encouraging farmers to form marketing groups and linking them to markets to generate incomes that can then be ploughed back in the recapitalisation of the local degraded soils. Alternative livelihood sources to cultivation such as bee-keeping should also be encouraged. Such enterprise as bee-keeping requires lesser labour, land and capital and can therefore be profitably carried out in spite of the decreasing land sizes.

Odendo M., Obare G., Salasya B. (2010). Farmers' Perceptions and Knowledge of Soil Fertility Degradation in Two Contrasting Sites in Western Kenya. *Land Degradation Development. 21:557-564*

Soil Fertility degradation is often acknowledged as an insidious and slow process, yet farmers ' perceptions of severity of the problem and associated yield losses are critical in influencing adoption of soil fertility enhancing practices. Against this backdrop, this study investigated farmers' perceptions and indicators of soil fertility degradation and identified factors that make a difference in the perceptions among farmers in western Kenya. Data for this analysis were collected from a random sample of 331 household in Vihiga and Siaya Districts and analysed by descriptive statistics and ordered logit model. Results showed that 90 percent of the households perceived that soil fertility was declining using different indicators, especially decreasing crop yields, poor crop growth vigour, presence of indicator weeds and soil colour. The key determinants of farmers' extent of perceptions were farm and farmer characteristics as well as institutional factors. This study recommends the use of farmers' perceptions and knowledge as important entry points for research and dissemination of appropriate soil fertility management practices.

Ogola A.H., Ogutu M., Malaya H. (2010). Evaluation of Cropping Systems Involving Finger Millet, Green Gram, Soybean and Desmodium in a Striga Infested Area. In: Ouda J. *et al.*, (Eds.) Proceedings of the 12th Biennial Conference of the Kenya Agricultural Research Institute, Nairobi, Kenya, November 8th -11th 2010 pp. 267-279

Various intervention measures/options have been developed for improvement of soil fertility and *Striga hermonthica* management. Such strategies include, among others, incorporation of grain and herbaceous legumes in the farming systems. A study was initiated with the objective of determining the effect of finger millet - legume intercrops on Striga incidences as well as the effect of the legume intercrops on finger millet grain yield. The study was conducted in a field severely infested with striga during the 2007 and 2008 long rains at Kibos north. A total of twelve treatments were tested. The treatments consisted of mono crop of three finger millet varieties (Gulu. U-15 and P224) and intercrops of each of the varieties with green gram (N-26 variety), soybean (Nyala Variety) and *Desmodium uncinatum*. The experiment was laid on a split plot design and replicated four times. Finger

millet varieties formed the main plots while legume species made up the split plots. Finger millets were seed drilled at a row spacing of 60cm while legumes were hill planted between rows of finger millet. The variety P224 gave impressive performance when intercropped with soybean while Gulu was identified as the most compatible variety with grain legumes tested. Intercropping with Desmodium was the most effective option in suppressing Striga emergence as well as depleting Striga seed bank.

Mugwe J., Mucheru-Muna, Mugendi D., Kung'u J., Bationo A., Mairura F (2009). Adoption potential of selected organic resources for improving soil fertility in the central highlands in Kenya. *Agro systems Journal*. Vol. 76:467-485

Soil fertility decline is the major cause declining crop yields in the central highlands of Kenya and elsewhere within the African continent. This paper reports a study conducted to assess adoption potential of two leguminous trees, two herbaceous legumes, cattle manure, and Tithonia diversifolia either solely applied or combined with inorganic fertilizer, for replenishing soil fertility in the central highlands of Kenya. The study examined biophysical performance, profitability, feasibility and acceptability, and farmers experiences in managing and testing the inputs. The study was based on a series of studies incorporating both sociological and experimental approaches for two and a half years. Results of on farm trials showed that manure + fertilizer and Tithonia + fertilizer treatments increased yields by more than 100% above the control. These treatments were the most profitable having the highest net benefits and benefit cost ratios. They were also the most commonly preferred by farmers who used them on larger plots compared to the other inputs. In conclusion, cattle manure and Tithonia were found to be organic materials with the highest adoption potential in soil fertility improvement in this area. *Calliandra calothyrus* and *Leucaena trichandra*, on the other hand, have potential for use as animal fodder. The herbaceous legumes had the least adoption potential due to poor performance recorded on the farms that possibly led to low preference by the farmers. However, issues of sustainable seed production could have played a role. This study recommends some policy issues for enhancing adoption and research issues focussing on exploring strategies for increasing biomass production and use efficiency on farms.

Mungai, N. W, Bationo, A, Waswa, B, (2009). Soil Properties as Influenced by Soil Fertility Management in Small Scale Maize Farms in Njoro, Kenya. *Journal of Agronomy* Vol. 8, 131-136

Most farmers are aware of soil fertility gradients within their farms which influence their management decisions and further accentuate these variations. The purpose of this study was to assess the effect of soil amendments on soil properties under farmer's management. Soil sampling was done in 37 small scale maize farms in Njoro Division of Nakuru District at 0-20 cm depth. Results of a structured questionnaire showed that 65% of the farmers used inorganic fertilizers predominantly diammonium phosphate (DAP), 15% used only farmyard manure, 15% used both organic and inorganic fertilizer, while 6% did not use any soil amendments. Most of the farms had a high pH ($CaCl_2$) of less than 5.2, 27% of the farms had a pH lower than 4.0. Organic carbon (C) ranged from 1.6 to 5.8%, with a median value of 2.6%. Most of the farms were phosphorus (P) deficient with an Olsen-P of less than 10 mg/kg. All farms had sufficient amounts of extractable potassium (K). Total nitrogen (N) ranged from 0.12 to 0.33% with 97% of the farms with N content (>0.12%). Farms amended with farmyard manure had higher organic C and total N levels in Kikapu with correspondingly lower C: N ratios. Soil pH and total N were higher for farms with gentle and undulating slopes. Overall most of the farms were acidic and of moderate fertility. Liming increased maize biomass production in Njoro. This study underscores the need for organic inputs and regular soil testing for small scale farmers.

Paswel P. Marenya C., Barrett B. (2009). Soil Quality and Fertilizer Use Rates among Smallholder Farmers in Western Kenya. International Association of Agricultural Economists 40; 561-572

Studies of fertilizer use in sub-Saharan Africa have been dominated by analyses of economic and market factors having to do with infrastructure, institutions, and incentives that prevent of foster increased fertilizer demand, largely ignoring how soil fertility status conditions farmer demand for fertilizer. We apply a switching regression model to data from 260 farm households in western Kenya in order to allow for the possibility of discontinuities in fertilizer demand based on soil carbon content (SCC) threshold. We find that the usual factors reflecting liquidity and quasi-fixed inputs are important on high-SCC plots but not on those with poorer soils. External inputs become less effective on soils with low SCC, hence the discernible shift in behaviours across soil quality regimes. For many farmers, improved fertilizer market conditions alone may be insufficient to stimulate increased fertilizer use without complementary improvements in the biophysical conditions that affect conditional factor demand:

Tittonell P., Van Wijk M. T, Herrero M, Rufino M. C., de Ridder N. and Giller K. E (2009). Beyond resource constraints- Exploring the biophysical feasibility of options for the intensification of smallholder crop-livestock systems in Vihiga district, Kenya. *Agriculture Systems*. Vol. 101 pp. 1-19

During participatory prototyping activities in Vihiga, western Kenya, farmers designed what they considered to be the ideal farm. Four case studies were selected crop-livestock farms of different resource endowment (Type 1-4- excluding the poorest farmers, Type 5, who do not own livestock) and quantified all relevant physical flows through and within them. With this information we parameterised a dynamic, farm scale simulation model to investigate (i) current differences in resource use efficiencies and degree of crop-livestock interactions across farm types; and (ii) the impact of different interventions in farm Types 3 and 4 on producing the desired shifts in productivity towards the ideal farm. Assuming no resource constraints, changes in the current farm systems were introduced stepwise, as both intensification of external input use (fertiliser and fodder) and qualitative changes in the configuration of the farms (i.e. changing land use towards fodder production, improving manure handling and/or changing cattle breeds). In 10-year simulations of the baseline, current scenario using historical weather data the wealthiest farms Type 2 achieved food self-sufficiency (FSS) in 20% of the seasons due to rainfall variability, whereas the poorer Type 4 only achieved FSS in 0 to 30% of the seasons; soil organic C decreased during the simulations at annual rates of -0.54.-0.73,-0.85, and -0.84t C/ha on farms of Type 1-4, respectively; large differences in productivity and recycling efficiency between farm types indicated that there is ample room of improve the physical performance of the poorer farms (e.g. light and water use efficiency was 2-3 times larger on wealthier farms). Simulating different intensification scenarios indicated that household FSS can be achieved in all farm types through input intensification, e.g. using P fertilisers at rates as small as 15 kg/ farm/ season (i.e. from 7 to 28kg/ha). Increasing the area under Napier grass from c. 20 to 40% and reducing the area of maize, beans and sweet potato in farms of Type 3 and 4 increased their primary productivity by c. 1t/ha/season, their milk production by 156 and 45 L/season, respectively, but decreased the production of edible energy (by 2000 and 250 MJ /ha/ season) and protein (by 20 and 3 Kg/ha/season). Br bringing in a more productive cow the primary productivity increased even further in the farm Type 3 (up to 5 t/ha/season), as did milk production (up to c. 1000 L/season), edible energy (up to c. 10,000 MJ/ ha/season) and protein (up to c. 100 Kg/ha/season). The impact of livestock management on the recycling of nutrients and on the efficiency of nutrient use at farm scale can be large, provided that enough nutrients are present in or enter the system to be redistributed. An increased in N cycling efficiency through improved manure handling from 25 to 50% would increase the amount of N cycled in the case study farms of Type 1 and 2 by only ca. 10 Kg/season, and only 1-2 Kg/season in Type 3 and 4. The various alternatives simulated when disregarding resource constraints contributed to narrow the productivity and efficiency gaps between poorer and wealthier farms. However, the feasibility of implementing such interventions on a large number of farms is questionable. Implications for system (re-)design and intensification strategies are discussed in the paper.

Franzel S., Nanok T., Wangia S., Dewolf J. (2008). Collaborative monitoring and evaluation: Assessing the uptake of improved fallows and biomass transfer in western Kenya. *Experimental Agriculture,* Vol. 44, pp. 113-127

Few references are available on collaborative monitoring evaluation, that is, how organizations prompting similar innovations can together asses their efforts. We examined the experience of 30 organizations working together in western Kenya, from 1999 to 2003, assessing their impact in helping farmers to adapt two soil fertility practices. While the collaborative process improved the flow of information among organisations, it did not reduce monitoring costs, but rather increased them. The process increased participating organisations' awareness of farmer innovations and the number being promoted. The process also contributed to the formation of a consortium among the participating organisations. We viewed the benefits of the collaborative approach as greater than the costs, but recognised that the resources for implementing such exercises may often not be available.

Kipkemoi P. L, Wasike V. W, Ooro P. A, Riungu T.C, Bor P.K, Rogocho L.M (2008)

Effects of intercropping pattern on soybean and maize yield in Central Rift valley of Kenya. Kenya Agricultural Research Institute. *Annual report*. pp.1478-1484

Intercropping is being adopted as a method of crop production in Kenya. Farmers often intercrop legumes with non-legumes. A study to assess the productivity of maize (*Zea mays* L) and soybean (*Glycine max* (L.)Merr.) in sole cropping and intercropping systems were done at National Plant Breeding Research Centre-Njoro in 1997 and 2001 seasons. Soybean was seeded in one, two of three rows between two maize and on the same row maize. The maize population densities of about 44,000 and 36,000 plants per hectare were used in 1997 and a uniform plant population of about 44,000 plants per hectare was planted in 2001. The control treatments were sole cropping maize and sole cropping soybean at about 55,000 and 222,000 plants per hectare respectively. The trial layout was completely randomized block design with four replicates in both years. Intercropping significantly (P=0.05) reduced soybean number of pods per plant and 100 seed weight in 1997 but not in 2001. Grain yield of soybean in the soybean-maize intercrop was reduced by 59% to 75% in 1997 and 21% to 68% in 2001 compared to sole

cropped soybean. Land equivalent ratio on both years was greater than one, indicating that this cropping system is profitable in terms of land utilization. It was concluded that maize is a dominant crop in maize and soybean intercropping system and that is advantageous to intercrop.

Kiptot E. (2008) Adoption dynamics of *Tithonia diversifolia* for soil fertility management in pilot villages of western. *Experimental Agriculture*. Vol. 44, pp. 473-484.

This paper presents the results of a study that was undertaken to asses' adoption dynamics of *Tithonia diversifolia* in Siaya and Vihiga districts of western Kenya from 1997 to 2004. This study was undertaken among a random sample of 120 farmers from eight pilot villages exposed to the technology. Descriptive statistics and a logit regression model were used to analyse data. The findings show that more farmers in pilot villages of Siaya are taking up the use of Tithonia than in Vihiga. As of 2004, 52% of farmers in Siaya were adopters compared to only 8% in Vihiga. Results of the logit regression model show that the use of Tithonia biomass for soil fertility management (SFM) is more likely to be adopted in a context where there is a scarcity of animal manure; farmers are willing to plant it on farms and hire casual labour. The use of Tithonia by smallholder farmers for SFM is therefore a promising low-cost option that can be scaled up to areas where farmers face similar constraints.

Kipkoech A. K, Okiror M. A, Okalebo J. R, Maritim H.K. (2007). Production efficiency and economic potential of different soil fertility management strategies among groundnut farmers of Kenya. *Science World Journal*. Volume 2. pp. 15-21

This paper provides the economic evaluation of different soil fertility replenishing technologies (use of inorganic fertilisers, organic manure, and rhizobium inoculants) that were tested during field studies and recommended to groundnut farmers. Data on soil fertility technologies used by households, groundnut yields, and resource use and farm characteristics were collected through administration of a questionnaire to a sample of 332 farmers from three districts of western Kenya. The data was analyzed to determine whether adoption of the technologies would increase household incomes and production efficiency. Benefits and costs of each of the technologies were computed through the use of budgets. Technical allocative inefficiencies are investigated by fitting a Cobb-Douglas production function. The technical efficiency of the farmers varied between 0.56 and 0.69 while labour allocative efficiency varied between 0.81 and 0.93. Farmers applying organic fertilizers only were technically more efficient but had lower potential yield compared to farmers who applied inorganic or a combination of organic and inorganic fertilizers. Use of inorganic fertilizers lead to a benefit cost ratio of up to 3:1. Organic manure had the lowest benefit-cost ratio (2.2:1) even when compared with that obtained when farmers did not apply any fertility replenishing input resulting from high cost of labour required to use technology. There is a high potential for farmers to increase their groundnut yields and incomes by improving on production efficiency and by fertilizing their groundnut farms.

Anjichi V. E., Mauyo L., Kipsat M. J. (2007). The Effect of socio-Economic factors on a farmer's decision to adopt farm soil conservation measures. An application of multivariate logistic analysis in Butere/Mumias District, Kenya. *In: Bationo, A. et al.,* (Eds.) *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*. Pp.915-919

This study was conducted to identify the various socio-economic variables and how they affect farmer's decision to adopt soil resource conservation measures in Butere Mumias District. Soil is a fixed national asset which is essential to guarantee food security, cash crop and industrial crop production. It is important to conserve this resource since it cannot be expanded. The study considers the policy framework that needs to be put in place to stimulate the adoption of soil conservation measures. The study area was divided into five clusters and using households as sampling units, forty households were used were selected per cluster using the simple random sampling technique. A total of 200 respondents were interviewed using structured questionnaires. A logit model was employed to identify the main factors influencing adoption of soil conservation measures on farms surveyed in the district. The SAS computer package was used to run the model, to derive maximum likelihood estimates of the adoption process and to calculate the chi-square. The results of Logit analysis showed that education, age, gender, and land size were significant at 0.05 level of significance. This is an indication that these are the critical factors influencing adoption of soil conservation measures in the district. Formal education is vital and farmers should educated on the need to adopt soil conservation measures on their farms. Attention should be focused on the farmers who are over 50 years old who are the main decision makers in most households. The role of extension in promoting individual and corporate soil conservation measures should not be down played especially as concerns providing technical advice. Small-scale famers should been encouraged to intensify soil conservation as this will improve their soil fertility and improve their yields making their farming profitable. Keywords: soil resource conservation, socio-economic factors, soil fertility degradation.

Ndufa J. K., Cadisch G., Poulton C., Noordin Q., Vanlauwe B. (2007). Integrated Soil Fertility Management and Poverty Traps in Western Kenya. *In Bationo et al* (Eds.) *Advances in integrated Soil fertility management in sub-Saharan Africa: Challenges and Opportunities*, pp.1061-1075, 2007

Based on agro-climatic conditions, the highland districts around Lake Victoria in Western Kenya should be a food surplus area. In practice, they are heavily dependent on food imports, whilst national poverty surveys consistently show them to be among the poorest in the country. At the root of this problem, are high population densities and, therefore, small land holdings and limited access to markets. As a result of continuous cropping with very little investments in soil fertility replenishment the soils have become severely depleted. Many Poor households in these districts are now caught in a "Maize-focused poverty trap" whereby their first agricultural priority is to provide themselves with maize for home consumption, yet yields are low and returns are insufficient to support investments in either organic soil fertility enhancement technologies or inorganic fertilizers. Thus, despite that the majority of average household puts large portions of its land under maize during both cropping seasons; it is still unable to feed itself for several months of the year. In addition, to the problem of low soil fertility, continuous cropping of maize has also led to an endemic infestation of the striga weed throughout these districts, further depressing maize yields. To invest in soils, most households (unless they have a reliable source of non-farm income) need to diversify into higher value crops than maize. However, the combination of small land holdings and existing maize deficits mean that they will only plant other crops if they can simultaneously raise their maize yields. Achieving this requires that a number of conditions must be in place. Firstly, households must be linked to markets, so that they can identify higher value cropping opportunities and be able to market their crops once they have grown them in the western highlands, most producers are only familiar with local markets (where opportunities are limited) and they can initially only offer small quantities of produce which reduces their attractiveness to potential buyers. Secondly, they need technical knowledge, on best cultural practices for the new crops and, critically, on how to manage their natural resource base, so as to increase their yields both of maize and of the new crops. Thirdly, they need to be able to access good quality seeds for crop varieties that are both suited to their local productions and are demanded in the market-place. Finally, most will also need access to credit, so as to be able to acquire inputs for more intensive maize production. This credit can then be repaid out of the sale of additional crops later in the year. Critically, all these conditions need to be in place within their local area before poor households can hope to shift from a maize-only production system to one that delivers enhanced food and cash, whilst simultaneously enhancing the soil fertility on which future production depends. This paper reports the experience of a DFID- funded action research project that, since 2001, has been exploring the potential for coordinated development interventions to enhance livelihoods through the promotion of integrated soil fertility management in collaboration with national and international institutes and extension services. Experiences with the provision of technical advice, the development of a community based credit scheme for agricultural inputs, initial steps towards linking farmers to new markets and making new seeds available to producers are reviewed and constraints identified, along with initial indications of the impact that coordinated service provision could have on agricultural production and livelihoods. Finally, the over-arching challenge of how to coordinate the provision of these services on a sustainable basis is considered.

Njunie M. N, Muli B., Mureithi J. G (2007). Economic benefits of integrating forage and grain legumes in maize/cassava relay and rotation cropping systems in coastal Kenya. KARI Mtwapa, *Annual report*

Variety screening of legumes for coastal region of Kenya led to the identification of several *Vigna unguiculata* (cowpea) varieties suitable for grain, leaf and dual-purpose (grain and leaf) production. Also, herbaceous forage legumes adaptable to various coastal Kenya agro ecological and farming systems were identified. *Mucuna pruriens* and *Lablab purpureus* were recommended for green manure and forage and their growth habit allows them to fit in the same niches as cowpea. In addition, dolichos' uses are much similar to cowpeas particularly as a food for humans and its potential for soil fertility improvement. A study to assess the costs and benefits of incorporating forage and/or green manure legumes in maize/cassava production systems was implemented. Five legume levels (no legume; mucuna; dolichos; cowpea-Samburu variety and cowpea -mtw63) and 3 production systems: conventional maize production- no legume in system; Legume relay cropping in maize; Legume grown for grain/seed production in rotation with maize or maize/cassava, were studied. The legumes and component food crops were established in 2004 and 2005 long rain and short rain cropping seasons. The cost of production was estimated per hectare by summing up the costs of appropriate inputs used for a cropping system, mainly: animal manure, bulldock/pesticides and labour for their application; labour for cultural activities like land preparation, weeding and harvesting. The labour equipments were based on published information provided by farmers through focused group discussion. The rates of application of nutrients from different sources per ha of maize were based on the recommendation package(s) developed for improved crop production in the coastal region. The presence of more than one food crop component enhanced the total income generated from a cropping system, with all maize-cassava cropping systems resulting in the top 3 net incomes. The lowest annual total cost of inputs for maize production was observed where maize was grown without application nutrient inputs. Higher costs of production were associated with complexity of cropping system. Considering the maize crop grown with no nutrient inputs, the presence of cassava in the cropping system increased inputs costs by 24% (KES 16,052 for

maize without inputs compared to KES 20,490 for maize-cassava system without external nutrient supply). The presence of cassava in the system and /or fodder legume relay crop in maize enhanced the net income from the cropping system. The highest net and gross incomes were achieved where mucuna or dolichos were components of the maize-cassava system, emphasizing potential benefits from crop-livestock interactions.

Noordin Q., Mukalama J., Rotich D., Wabwile E., Lynam J. (2007). Scaling up options on integrated Soil Fertility management in western Kenya. The Case of COSOFAP: Challenges and Opportunities. *In Bationo et al* (Eds) *Advances in integrated Soil fertility management in sub-Saharan Africa: Challenges and Opportunities*, pp. 993-1000

Western Kenya, a densely populated region of the country is an example of many areas in Africa where continued threat to the world's land resources is compounded by the need to raise food production and reduce poverty. Attainment of food security is intrinsically linked with reversing agricultural stagnation, safeguarding the natural resource base, slowing population growth rates, combating the negative impacts of HIV/AIDS pandemic on the community and reducing poverty. Over the last 12 years, the World Agro-forestry Centre (ICRAF) in collaboration with Kenya Agricultural Research Institute (KARI), Kenya Forestry Research Institute (KEFRI) and Tropical Soil Biology and Fertility Programme (TSBF) and with support from the Rockefeller Foundation developed several integrated soil fertility management (ISFM) options. Examples are; (i) short-duration improved fallows with leguminous nitrogen-fixing species, such as *Sesbania sesban* and *Crotolaria grahamiana*; (ii) biomass transfer of *Tithonia diversifolia*; (iii) dual Purpose Legumes like soy beans and cowpeas and iv) the combination of phosphorus fertilizers, including the Minjingu phosphate rock, with the above organics and farmyard manure. These options that can increase yields of Maize by 2-3 folds were tested and adopted by thousands in pilot project sites in Vihiga and Siaya Districts. Other work has been pioneered by ICIPE on Push-Pull technology, MBILI by Sacred Africa, Green manuring by the Legume Research Network. Besides yield improvements, other benefits associated with improved soil fertility management strategies include striga control, fodder, wood fuel production and stakes for climbing beans. However one of the biggest challenges is to scale these initiatives to more farmers in the region. To scale up this and other promising technologies, a Consortium for scaling up options for Improving SOIL Fertility in Western Kenya (COSOFAP) of over 80 partners in January 2001. COSOFAP covers 22 districts of western Kenya and reaches thousands of farmers with quality germplasm and information. Links to private sector and policy makers have also been strengthened. This paper highlights some of the salient features of the ISFM options available and their dissemination pathways through the consortium of partner institutions and the empowerment of farmers to train others and scale up the options through Interactive Learning Sites.

Mairura F., Mugendi D. N., Mwanje J. I., Ramisch J. J., Mbugua P. K., Chianu J.N (2007) Integrating scientific and farmers' evaluation of soil quality indicators in Central Kenya, Geoderma, Vol. 139 pp. 134-143

A study was conducted to determine farmers' perceptions of soil quality and common soil management practices that influenced soil fertility within farmers' fields in Chuka and Gachoka divisions, Kenya. Soils were characterized by smallholders after which they were geo-referenced and sampled at surface depth (0-20 cm) for subsequent physical and chemical analyses, to determine differences within farmers' soil quality categories. Indicators for distinguishing productive and non-productive fields included crop yield and performance, soil colour and soil texture. There were significant differences among soil fertility categories, using parametric techniques (ANOVA) for key soil properties ($p<0.005$), implying that there was a qualitative difference in the soils that were characterised as different by farmers. Fertile soils had significantly higher pH, total organic carbon, exchangeable cation and available-N. Factor analysis on the 15 soil properties identified 4 main factors that explained 68% of the total variance in soil quality. The four Varimax-rotated factors were designated as contrasts that described soil quality status on farmers' fields. The first factor grouped calcium, magnesium and soil pH, while the second component comprised available nitrogen, while the fourth factor comprised soil physical properties (macro-aggregates, micro-aggregates, silt and clay). Soil fertility and crop management practices that were investigated as a resource to maintain or enhance agricultural productivity.

Mairura F.S., Mugendi D.N, Mwanje J.I., Ramisch J.J., Mbugua P.K (2007). Assessment of farmers' perception of soil quality indicators with small holder farms in the central highlands of Kenya. (Bationo Eds) *Advances in integrated soil fertility management in sub-Sahara Africa: challenges and opportunities*, Springer 1035-1046

A study was conducted to determine farmers' perception of soil quality and soil management practices that influenced soil fertility within farmers' fields in Chuka and Gachoka divisions in central Kenya highlands. Soils were characterized by farmers in which they were geo-referenced and sampled at surface depth (0-20cm) for subsequent physical and chemical analyses to determine differences within farmers' soil quality categories. Special attention was given to agricultural weed species. Indicators for distinguishing productive and un-productive fields included crop yield. Crop performance soil colour and soil texture. A total of 18 weed species were used to distinguish between high and low soil categories. Significant difference among soil categories implied that there

were qualitative difference in the soils that were characterised as different by farmers. Fertile soils had significantly higher pH total organic carbon and exchangeable cations with available-N being significantly differently in Gachoka. Factor analysis on 15 soil properties identified 4 factors that explained 65% of the total variance in soil quality. Soil fertility and crop management practices that were investigated indicated that farmers understood and consequently utilized spatial heterogeneity and temporal variability in soil quality status within their farms as a resource to maintain or enhance agricultural productivity.

Mairura F. S, Mugendi D. N, Mwanje J. I, Ramisch J., Mbugua P.K, Chianu J.N. (2007) Scientific evaluation of smallholder land use knowledge in Central Kenya. *Land degradation and development Journal* Vol.19; 77-90

The following study was conducted to determine smallholders' land use management practices and agricultural indicators of soil and quality within farmers' fields in Chuka and Gachoka divisions in Kenya's Central Highlands. Data on cropping practices and soil indicators were collected from farmers through face-to-face interviews and field examinations. Farmers characterised their fields into high and low fertility plots, after which soils were geo-referenced and sampled at a surface depth (0-20cm) for subsequent physical and chemical analyses. Farmers' indicators for distinguishing productive and non-productive fields included crop yield, crop performances and weed species. Soils that were characterised as fertile had significantly higher chemical characteristics than the fields that were poor quality. Fertile soils had significantly higher pH, total organic carbon, exchangeable cations and available nitrogen. Factor analysis method identified four main factors that explained 76 per cent of the total variance in soil quality. The factors were connected with farmers' soil assessment indicators and main soil processes that influenced soil quality. The factors were connected with farmers' soil assessment indicators and main soil processes that influenced soil quality in Central Kenya. Soil fertility and crop management practices that were investigated indicated that farmers understood and consequently utilised spatial heterogeneity and temporal variability in soil quality status within their farms to maintain and enhance agricultural productivity.

Misiko M. (2007). Smallholder amendments to cereal-legume rotations in western Kenya. Fertile Ground, PhD thesis Chapter 2, Wageningen University, The Netherlands

Between 2003 and 2005, a scheme of cereal-legume rotations was tested through an interactive learning process to manage soil fertility by farmers in western Kenya. The learning process included demonstrations that were collectively planned and designed by farmers and researchers from the Tropical Soil Biology and Fertility Institute. The main objective of this process was to illustrate the potential of multipurpose grain legumes both as crops and as a means of improving yields of subsequent cereal crops when used in rotations. Yield data were collected by researchers, while farmers carried out regular participatory monitoring and evaluation and managed the demonstrations. Participant observation, in-depth interviews among forty households, and focus group discussions were carried out to document the extent to which farmers adopted and amended or adapted the proposed rotation scheme. Results show that alternative (i.e. not-for-soil-fertility-management) uses of legumes need for mineral (P) fertiliser in the implementation of the rotation scheme, cultural aspects and perceptions of convenience were the key factors underlying farmer amendments and soil fertility impact. The paper concludes that it is important for crop rotation schemes to include legume varieties with utility beyond soil fertility management alone. Such schemes should result in readily observed gains when applied under minimum local conditions.

Misiko M. (2007). Integrating new soybean varieties for soil fertility management in smallholder systems through participatory research: lessons from western Kenya. Fertile Ground, PhD thesis Chapter 3, Wageningen University, The Netherlands

Soybean (*Glycine max* |L.| Merr.) promiscuous varieties were screened and evaluated in western Kenya through participatory approaches. Farmers selected preferred varieties and explained their reasons (criteria) for making the selections. Seven promiscuous varieties had better yields than a local one on the 2.5m x 3m plots that were managed according to farmers' practices. Farmers` selection criteria fell into three broad categories relating to yield, appearance and labour. Selection criteria were not primarily aimed to improved soil fertility. This created a challenge to embed the new varieties within the local farming systems for soil fertility improvement. This study shows that farmer criteria for selecting varieties overlapped with scientific procedures. We propose co-research activities targeted to strengthen farmer experimentation skills, their understanding on N addition and the role of P.

Misiko M. (2007). Farmers' evaluation of biomass transfer technologies and the concept of organic resource quality: integrating knowledge brands for soil fertility management. Fertile Ground, PhD thesis Chapter 4, Wageningen University, The Netherlands

The research concept of organic resource quality (ORQ) for soil fertility improvement, referring to the performance of different locally available resources when used as soil amendments, was shared with farmers

through participatory demonstrations in four sites of western Kenya. Local farmers evaluated different treatments of selected organic resource materials, namely *Tithonia diversifolia*, *Calliandra calothyrsus*, maize stover and farmyard manure (a common farmer practice), applied to the soil in plots in which maize (*Zea mays*) was grown. Participant observation, in-depth interviews and focus group discussions indicated that farmer knowledge was influenced in a way that resulted in changes in farm-level practices. These changes consisted of varying rates and styles of application of demonstrated organic resources resource treatments. Besides labour constraints, availability of organic resources, land and capital, and farmers' experiences and cultural constructs were the basis for interpretation and application of the ORQ concept. For instance, Tithonia was perceived as a "hot resource" that could be added to composts o increase the "speed of cooking". Calliandra was perceived as fodder, preferably fed to cows, which would in turn provide valuable farmyard manure, instead of applying it directly to the soil as demonstrated through the biomass transfer system. Such "ordinary" usage, long-held perceptions and perceived inconveniences, reflecting mainly labour constraints and poor economic returns, resulted in limited application of the ORQ concept for soil fertility improvement among local farmers. It is therefore suggested that relevance of the ORQ concept be enhanced through refocusing research through paying close attention to farmer knowledge and motivations and makes sense in terms of their own rules for soil fertility management and experimentation.

Misiko M. (2007) Strengthening understanding of mineral fertiliser among smallholder farmers in western Kenya. Fertile Ground, PhD thesis Chapter 5, Wageningen University, The Netherlands

It is widely recognised that mineral fertiliser will need to play an important part in improving agricultural production in western Kenyan farming systems. However, use and disuse of mineral fertilisers is influenced by farmers' understandings among other factors. We show that farmers' notions were broadly generated by poor or unsteady yield responses when fertilisers are used, association with high cost (especially if recommended rates were to be applied), awareness of alternative technologies, association of certain crops and seasons with fertilizer use, technologies associated with its use such as hybrid maize, problems with accessing available but inappropriately packaged information (or lack of it), long-held beliefs, and historical factors. This study assessed these factors by analysing results from farmer-researcher fertiliser-response demonstrations, farmer notes taken during a participatory monitoring and evaluation process. Participant observation and in-depth interviews among 40 households. We identified that fertiliser promotion must be tailored to be a component of existing, albeit imperfect, systems of crop husbandry. In these systems, complex relationships affect fertiliser use response and hence farmer attitudes. These attitudes cannot be changed by promoting more fertiliser use alone but require a more basic approach that, for instance, also encourages farmer experimentation and practices to enhance soil properties such as carbon build-up in impoverished local soils. It is concluded that such an approach would improve chances of better yield after fertiliser use and therefore contribute to more sustained use by smallholder farmers.

Mucheru-Muna M., Mugendi D., Mugwe J., Kung'u J. B (2007). Economic evaluation of local inputs in Meru South District, Kenya. In: Bationo, A. *et al* (Eds.) *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*. Pp. *443-448*

Declining land productivity is a major problem facing smallholder farmers in Kenya today. This decline is a result of reduced soil fertility caused by continuous cultivation without adequate addition of manures and fertilizers. Low soil fertility is one of the greatest challenges facing farmers in the central highlands of Kenya. A farmer participatory trial was established in Meru south District, Kenya in 2000 to investigate feasible soil nutrient replenishment technologies for poor resource small holder farmers. Results across seven seasons indicate that sole Tithonia gave the highest grain yield followed closely by Tithonia with half recommended rate of inorganic fertilizer with 6.4 and 6.3 Mg/ha respectively. The control treatment gave the lowest yield of 2.2 Mg/ha across the seasons. The integration of organic and inorganic nutrient sources of N gave higher maize grain yield as compared to the sole organic materials in all seven seasons. Economic analyses indicate that on average Tithonia with half the recommended rate of inorganic fertilizer recorded the highest net benefit (US$787.2) whereas the control treatment gave the lowest benefit (US$271.7). On the other hand the recommended rate of inorganic fertilizer gave the highest (US$12.5) return to labour while sole tithonia gave the lowest (US$4.0). On average in farmers fields, manure alone gave the highest return to labour of US$3.6 while the control treatment gave the lowest return to labour US$-0.2.

Mureithi B. M., Kimani S. K., Odera M. M., Mwangi E. M., Gachanja E. (2007). Factors influencing Choice and Adoption of Integrated Soil Fertility Management Technologies in Central Kenya Highlands. In: Bationo, A. *et al.,* (Eds.) *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*. Pp. 941-946

The paper presents the findings of a study conducted to determine farmers' perceptions of some of soil fertility management-specific attributes and influence on adoption decisions. The specific objectives were: (1) to determine the relationship between perceptions and choice of integrated soil fertility management (ISFM), and (2)

to evaluate the perceptions among farmers for specific attributes inherent in some of ISFM strategies Mother trials were established in a centralized place in Mukandani Village of Central division of Kirinyaga district and Kariti in Kandara, Maragua district during the long rains of the year 2003. Fourteen ISFM strategies were established in the two seasons wherein the farmers were exposed to the fourteen strategies in the participatory manner. It was anticipated that after the initial exposure to the technologies, the farmers would be encouraged to replicate the same on their farms within the constraints of resource endowment and preference considerations. The results of the project activities revealed the following: (1) Majority (70.2%) of the willing participants were predominantly male (2) Majority (52.6%) of the participating farmers had below secondary school level of education. (3) the participants were elderly (49.0 years average), (4) the average farm size in across the two villages was 1.92 acres (std. dev =1.7), (5) approximately 73% of the farmers confirmed that availability of the inputs used in the ISFM strategies is important (5) about 98.2% of the farmers confirmed that the use of some of the ISFM strategies resulted in enhanced crop growth vigour (6) majority of the farmers (66.7%)did not find labour associated with the use of technologies an important factor in determining their adoption decisions, (7) about 94.7% of the farmers consider use of Tithonia a viable ISFM option (8) approximately 38.6% of the farmers consider cost implication of the technologies an important factors in determining their adoption decisions, and (9) use of green manures is not a preferred ISFM option but fertilizer manure mixtures produce favourable results hence attractive to over 70% of the farmers. The study concludes that future technology up-scaling efforts put into consideration the farmers' prevailing circumstances and the identified farmer preference considerations in promotional strategies

Odendo M., Ojiem J., Bationo A., and Mudeheri M. (2007). On-farm evaluation and scaling-up of soil fertility management technologies in western Kenya. ***In: Bationo et al (Eds) Advances in Integrated Soil Fertility Management in sub-Saharan Africa: challenges and opportunities. pp: 969-978***

Low soil fertility is a fundamental constraint to crop production in western Kenya. Although researchers have developed many soil fertility-improving technologies, adoption of the technologies is low due to inadequate awareness of the technologies, poor access to requisite resources and unsuitability of the technologies to the farmers' conditions. On-farm experiments were conducted during 2002/3 long rain cropping season in two village clusters in Vihiga and Kakamega Districts in order to introduce farmers selected soil fertility improving options and elicit circumstances; and compare farmers' evaluation with the results of economic assessment. Five treatments were 60 kg P/ha plus 60 kg N/ha (inorganic fertilisers); and 2.5 t/ha FYM (farm yard manure); 60 kg P/ha plus 60 kg N/ha (inorganic fertilisers); and 2.5 t/ha FYM plus 30 kg P/ha (Inorganic fertilisers), alongside farmers practice, using maize, the staple food as a test crop. Farmers were involved in routine management, monitoring and evaluation of the experiments and field days were organises to introduce more farmers to the technologies. Results show that application of 30 kg P/ha plus 2.5 t/ha FYM gave economically viable yield response that was sustainable even under projected adverse decline in maize grain yield and increase in price of chemical fertilizers and the treatment was also the most preferred option by farmers. Results of this study should be used for validation of the promising options and planting of future experiments. In 1994 first rains, the effectiveness of crop residues (maize stover, groundnut trash and *Acacia mearnzii* prunings) on-farm manures and Minjingu phosphate rock (PR) was tested on maize yields at Ndeiya, Gatuanyaga and Malava sites. The organics above were incorporated into soils individually or in combinations giving a target or economical rate of 60 kg N/ha, while the PR was added at a uniform rate of 40 kg P/ha in various combinations of the organics.

Odera M. M., Kimani S. K., Esilaba A. O., Kayaire J. M., Mwangi E., Gachanja E. (2007). Factors determining integrated soil fertility management in Central Kenya highlands: Participatory Learning and Action Research (PLAR) model analysis. ***In: Bationo et al*** **(Eds.)** ***Advances in integrated soil fertility management in Sub-Sahara Africa: Challenges and opportunities*****. pp. 1019-1025**

This paper presents the results of a participatory learning and action research (PLAR) model analysis of factors determining integrated soil fertility management among subsistence smallholders in central highlands of Kenya. The data was collected during three days PLAR model guided focus group discussions in Mukanduini village of Central division Kirinyaga district in Kenya. The objectives of the study were: 1) to guide farmers through participatory identification and ranking of key socio-economic and bio-physical factors that influence integrated soil fertility management (ISFM), and 20 to guide farmers through participatory identification and ranking of probable solutions to identified problems. The PLAR model analysis of the study was able to categorize the farmers in the village into three groups on the basis of existing ISFM on their farm holdings, and on wealth status. The key community-level factors constraining ISFM were: rainfall/moisture, low crop yields, poor markets, and low livestock yields. The farm-level factors constraining ISFM were identified to be: lack of proper soil water conservation methods, lack of adequate soil nutrient amelioration, improper soil residue management, and poor tillage systems. Suggested solutions included increased use of inorganic fertilizers, optimal quantities of inorganic inputs. proper management and use of crop residues incorporation of agro-forestry species in cropping system, practising crop rotation, installation of soil and water conservation measures, deep tillage, and planting crops like cassava and sweet potato, which give reasonable crops yields in poor soils.

Okoba B. O., Tenge A. J., Sterik G., Stroonsnijder L. (2007). Participatory Soil and water conservation planning using an erosion mapping tool in the central highlands of Kenya. *Land degradation and development Journal*. vol. 18: 303-319

Despite several approaches that aimed at mobilising East African farmers to embrace soil and water conservation (SWC) activities, farmers hardly responded since they were seldom involved in the planning of SWC activities. Two tools that employ farmers' participation were developed and applied at Gikuuri catchment in Kenya. The first tool involved farmers to map soil erosion using their own indicators and determine the soil erosion status at catchment scale. Farmers also predicted crop yield losses based on the soil erosion status. Farmers widely approved the soil erosion status map since their own indicators and perceptions were used. The second tool provided cash flow trends for a variety of SWC activities and farmers situations. Farmers can use land with a high, moderate or low erosion status and often have rather different socio-economic settings. The net benefits over 5 yr for bench terraces, fanya juu terraces and grass strips were illustrated to assist farmers in making informed decisions on SWC adoption. The two tools increased awareness on the collective actions among farmers and showed fields that can run-on on down slope fields. The improved awareness of erosion problems and the related financial consequences increased farmers' willingness to share the investment costs for cut-off drains.

Woomer P. L. (2007). Cost and Returns of Soil Fertility Management Options in Western Kenya. *In Bationo (Eds) Advances in integrated Soil fertility management in sub-Saharan Africa: Challenges and Opportunities*, Springer, pp. 881-889

Several Alternative soil fertility options were compared in small holders' croplands in western Kenya including "Green Revolution" fertilize technologies (FURP), soil nutrient replenishment with rock phosphate (PREP), fortified composting (COMP), relay intercropping with *Lablab purpureus* (LABLAB), modestly-fertilized, staggered-row maize-groundnut intercropping (MBILI) and short-term improved *Crotolaria grahamiana* fallows (IMPFAL). These managements were established side by side on 140 farms in western Kenya in 2002 and examined, along with a Maize-bean control receiving no external output, over the next three growing seasons. Data were collected on crop yield, input costs, labour requirements and economic returns. Average maize yield (LSD 0.05 =0.2) ranged between 1.5 t/ha (No Inputs) and 2.8 t/ha (MBILI). Average legume yields (LSD 0.05=27) ranged between 203 kg/ha (No inputs bean) to 500 kg/ha (MBILI groundnut). Overall benefit: cost ratios (LSD=O.17) were FURP (2.22) =no inputs (2.28) <COMP (2.48) =LABLAB (2.52) < IMPFAL (3.03) < MBILI (3.44). Incomplete reports due to crop or experimental failure affected 31% of the farms. When all managements except the control were considered, modest or strong economic returns (benefit: cost >2) were reported for 46% of the trials while economic loss or poor returns (benefit: cost >2) were experienced by 23%. Clearly, all of these "recommended" technologies offer potential to many farms in western Kenya, but the ability of farmers to provide the necessary input costs and labour remains uncertain.

Muriu F. W. (2006). Farmers' decision-making in their preference for soil nutrient replenishment technologies in the central highlands of Kenya. Msc. Thesis, Kenyatta University, Kenya

Soil erosion, reduced land productivity, population pressure on land, low income, inappropriate and inadequate use of farm inputs such as fertilizers are some of the interrelated problems experienced and affecting smallholder farmers in Kirege location of Meru South District. These problems have culminated in increased food insecurity in the area over the years. In an effort to address these problems, soil nutrient replenishment technologies have been reported from the use of Tithonia, Calliandra, Leucaena, Mucuna and crotalaria biomass. Some farmers have adopted the introduced soil nutrient replenishment technologies; others have tested and opted out over the years while others have never attempted using the technologies. The main objective of this research was to establish the criteria used by farmers in their decision to reject, abandon or adopt the above-mentioned soil nutrient replenishment technologies. Data were collected using key informant interviews, structured interview schedules and focus group discussions. The sample comprised of 74 respondents, 45% male and 55% female. Of those interviewed, 61% were between the ages of 31-50 years. The research generated both qualitative and quantitative data. Means, percentages, spearman rank correlation and ANOVA were utilized for analysis. Results show that leucaena tree biomass was used as incorporation materials by 7% of the respondents as compared to 16% who used it as fodder supplement. Preference for Calliandra had increased from 7% at the testing stage to 18%. There was a clear gender effect on the criteria used by farmers' in taking up soil nutrient replenishment technologies. Marketing fodder value, fuel, labour requirement and land availability were found to differ significantly ($P<0.05$) in their rating between male and female farmers. The need to closely monitor the adoption and adaptation of soil nutrient replenishment technologies is dependent on socio-economic constraints of the target group. This is demonstrated using Tithonia which was seen to have lost popularity among farmers dropping from 29% at the testing to 22% at the adoption stage; however, another 18% of the farmers utilizing it as mulch or cattle bedding for quality manure without incorporating it directly into the soil as was first introduced.

Miriti J. M., Odera M. M., Kimani S. K., Kihumba J. N., Esilaba A. O., Ngae G. (2005) On-farm demonstrations to determine farmers' subjective preference for technology-specific attributes in tied-ridges. *Soil Science Society of East Africa, Proceedings of the 21st Annual Conference* 1st - 5th Dec. 2003, Eldoret, Kenya, ISBN number 9966-879-59-5

On-farm demonstrations were conducted in the semi arid areas of Ndeiya Location (Kiambu District) in central Kenya to assess the farmers' subjective preference for the technology specific attributes inherent in tied-ridges moisture conservation practice, and its impact on their preference criteria. Three farmers' fields in the focal area of National Agricultural and Livestock Extension Project (NALEP) were selected for the demonstrations. Interviews were conducted using structured questionnaires to capture data on impact of farmers' subjective preference for technology specific attributes on the adoption decisions. Data was also gathered on the impact of the farm and farmer related socio-economic variables on preference criteria and thus, potential adoption behaviour. The results reveal that both technology specific attributes and farm and farmer related socio-economic variables have an impact on adoption decisions for tied-ridges technology. The tied ridges technology had a positive impact on the overall maize biomass yield compared to conventional land preparation practices. Tied-ridges technology also kept the maize stover green for a relatively longer period and this benefited the smallholder dairy production in the mixed farming production systems that characterize the study area. The root zone moisture content in the tied-ridges plots was relatively higher compared to plots prepared in a conventional way. Tied-ridges technology, when adequately promoted and demonstrated has the potential of increasing productivity in the semi arid ecosystems of central Kenya highlands.

Mugendi D., Mugwe J., Mucheru-Muna M., Kung`u J., Bationo A. (2005) Adoption of organic resources for soil fertility improvement in Meru South District, Kenya. *Proceedings for Crop science conference*, Uganda. Volume 7 pp. 1443-1447

A study to assess adoption potential of organic resources for replenishing soil fertility by farmers within Chuka division, Meru South District was done in 2002. The study examined feasibility, acceptability, biophysical responses, and farmers' experiences as indicators of adoption. Results showed that farmers initially selected soil fertility improvement resources that combined organic and inorganic resources, with majority of farmers implementing Tithonia and cattle manure possibly due to availability. Later more farmers were interested in leguminous trees that could also provide fodder. However farmers used new technologies on relatively small plots (0.02 to 0.05 acres) indicating that they wanted to see the results first. Farmers have benefited in terms of increased crop yields. Some of the constraints farmers were experiencing were lack of inadequate biomass for biomass production on their farms and by 2002 long rains season some farmers had planted up-to 700 trees. The study has revealed the need to monitor how farmers adopt technologies as it facilitates in identification of issues and constraints that might hinder adoption and that could possibly feed into second-generation research agenda.

Olale E. K. (2005). Adoption of soil fertility management technologies in the semi-arid areas of Kenya: the case of Machakos, Makueni and Kitui districts. Msc. Thesis, University of Nairobi

Agriculture is the main economic sector in Kenya and contributes significantly to national development. For the sector to play this central role in a sustainable way, rapid growth in output and productivity is critical. One of the major factors that continue to constrain agriculture is the low and declining fertility of land; the problem is even more pronounced in the semi-arid areas. This study focused on developing strategies for improving adoption of soil fertility and water management technologies in the semi-arid areas of Machakos, Makueni and Kitui districts. Following the low adoption of soil fertility and water management technologies and consequent fall in yields in the semi-arid areas of Eastern province, there is need for technological recommendations that are specific to farm types. This is expected to take care of the differences between farm types. A total of 228 farmers were interviewed during the period January/February 2004 using a single-visit survey approach. Geographical Information System (GIS) guided random sampling was used to select farmers to be interviewed and the data obtained using semi-structured questionnaires. The logistic regression model was applied and the results showed that off-farm employment hired labour, maize output, agricultural extension and agro-ecological zone positively influenced fertilizer adoption, while the distance to the nearest market was negatively related to fertilizer adoption. Off-farm employment, livestock ownership, distance to the nearest market and agricultural extension positively influenced animal manure adoption, while education negatively influenced the adoption of animal manure. Hired labour, positively influenced compost manure adoption and the distance to the nearest market negatively influenced compost manure adoption. Maize output positively influenced the adoption of soil and water conservation structures, while the distance to the nearest market and agro-ecological zone were negatively related to the adoption of this practice. These factors should be incorporated in the design of policies and strategies for soil fertility improvement. As a result of the need to design specific soil management strategies, three major farm types were identified in this study, using k-mean cluster analysis. Farmers/farms were classified as socio-economically unconstrained, resource and information constrained and socio-economically constrained. The identified farm types had varying technology adoption abilities that decreased with an increase in the group socio-economic

constraints. To increase the adoption of improved soil fertility practices, short term and long-term strategies were developed for each farm type. The short-term strategy was to improve on the use of what is adoptable and the long-term strategy was to relax the constraints associated with the respective farm types. These strategies are expected to ensure better soil fertility technology adoption and higher crop yields. The study also recommended that the strategies be implemented hierarchically, starting with the socio-economically constrained group, who were only able to adopt animal manure.

Tittonell P., Vanlauwe B., Leffelaar P. A., Rowe E. C., Giller K. E. (2005). Exploring Diversity in Soil Fertility Management of Smallholder Farms in Western Kenya: Heterogeneity at Region and Farm Scale. *Agriculture, Ecosystems and Environment Journal*. 110; 149-165

The processes of nutrient depletion and soil degradation that limit productivity of smallholder African farms are spatially heterogeneous. Causes of variability in soil fertility management at different scales of analysis are both biophysical and socio-economic. Such heterogeneity is categorized in this study, which quantifies its impact on nutrient flows and soil fertility status at region and farm scale, as a first step in identifying spatial and temporal niches for targeting of soil fertility management strategies and technologies. Transects for soil profile observation, participatory rural appraisal techniques and classical soil sampling and chemical analysis were sampled across 60 farms in three sub-locations (Emuhaya, Shinyalu, Aludeka), which together represent much of the variability found in the highlands of western Kenya. Five representative farm types were identified using socio-economic information and considering production activities, household objectives and the main constraints faced by farmers. Soil fertility management and nutrient resource flows were studied for each farm type and related to differences in soil fertility status at farm scale. Farm types 1 and 2 were the wealthiest; the former relied on off-farm income and farmed small pieces of land (0.6-1.1 ha) while the latter farmed relatively large land areas (1.6-3.8 ha) mainly with cash crops. The poorest farm type 5 also farmed small pieces of land (0.4-1.0 ha) but relied on hoe wages derived from working for wealthier farmers. Both farm types 1 and 5 relied on off farm earnings and sold the least amounts of farm produce to the market, though the magnitude of their cash, labour and nutrient flows was contrasting. Farms of type 3 and 4 were intermediate in size and wealth, and represented different crop production strategies for self - consumption and the market. Average grain yields fluctuated around 1t/ha/yr for all farm types and sub-locations. Grain production by farms of types 4 and 5 was much below annual family requirements, estimated at 170 kg/person/yr. Household wealth and production orientation affected the pattern of resource flow at farm scale. In the land-constrained farms of type 1, mineral fertilisers were often used more intensively (ca. 50 kg/ha), though with varying application rates (14-92 kg/ha). The use of animal manure in such small farms (e.g. 2.2 t/yr) represented intensities of use of up to 8 t/ha, and a net accumulation of C and macronutrients.

Mutegi J., Mugendi D. N., Kungu J., Otor S., Mugwe N. J., Micheni A. (2003). Farmers' evaluation of on-farm contour hedges for soil conservation and nutrient cycling: A case of Central highlands of Kenya. *Proceedings of the 20th Conference of soil science society of East Africa*, Pp.82-87

Decline in soil fertility, soil erosion and insufficient fodder production are some of the major problems facing agricultural production in central highlands in Kenya. Researcher-designed but farmers managed trials were started on farms of 32 willing farmers with an aim of exploiting the multipurpose attribute of agro-forestry species to address these problems. The selected farms arable lands with a slope of between 5 and 33%. The set up consisted of double *Calliandra calothyrsus, Leucaena trichandra* and napier grass hedges planted in a zigzag pattern at an intra-row spacing of 0.25m or 0.5m and a variable inter-row spacing, and arranged as 2×3 complete factorial. Farmers were allowed to continue with their normal farming operations after setting up the trial. Nine months later, both the trial and the non-trial farmers evaluated the impact of hedgerows on the farms. The trial farmers reported a yield of 0.6 and 0.4 kg of Calliandra and Leucaena leaf biomass, respectively, per metre of hedge and an average increment of 1.5 litres of milk/day/animal feed on the leguminous species. 61 and 59% respectively reported the ability of hedges to control soil erosion and enhance soil fertility at a relatively low cost with 46% and 34% citing lack of labour and planting materials as the major constraints to full use of these technologies. At the end of evaluation, 100% of trial farmers expressed their willingness to continue with the technology, while 93% of non-participating farmers showed interest in joining the trials.

Nanok T. (2003). Assessment of the adoption and dissemination of improved fallows and biomass transfer technologies in western Kenya. Msc. thesis. Egerton University, Kenya

In the highlands of Western Kenya, land productivity is very low due to continuous cropping with little or no organic or inorganic fertilizers. International Centre for Research in Agro forestry (ICRAF) and partner organizations together with farmers developed low cost agro-forestry technologies to help improve soil fertility. A lot of agro-forestry information on improved fallows and biomass transfer technologies has been disseminated to farmers but the spread and impact has not been adequately assessed in Western Kenya. The purpose of this study was to assess the adoption and dissemination of biomass transfer and improved fallows technologies in Western Kenya. The

study was carried out among 56 organizations dissemination the technologies in western Kenya and 99 farmers who were randomly chosen from ICRAF's test villages in Siaya and Vihiga districts. The survey of organizations indicated out that female farmers were increasingly practicing improved fallows and biomass transfer technologies. The most important benefits of improved fallows were: The increase in yields, cheap biomass and improvement of soil fertility. The limitation of improved fallows were land scarcity, pests and disease, and seed in availability while biomass transfer was labour availability and unavailability of biomass. Organizations and farmers also modified original technologies they learnt to suit their needs. The weaknesses in assessing dissemination activities were that it involved time and physical resources for organizations involved, little follow up from ICRAF, and no accurate records kept by some organizations. Data from the farmer survey were analysed to assess factors influencing farmers' decisions to continue planting improved fallows following initial testing. The result of the logit and multiple regression models showed that farm size (positive effect) and use of mineral fertilizer (negative effect) were the socio-economic factors significantly influencing the decisions to continue improved fallows improved fallows practice appears to be gender neutral, and especially appropriate for low-income farmers.

Gachangi A., Maina M. P. D., Lelgut D. K., Kinyua M. G., Macharia E., Kamwaga J., Luvonga J. (2002). Cassava-Grain Legume Inter-Crop: Its Feasibility and Implications on Household Food Security in Kenya. Kenya Agricultural Research Institute, Njoro. *Annual report*. PP: 1-7

Cassava adapts to a wide range of ecological conditions and it is known for its tolerance to drought. However, a sole crop of cassava, which is considered a long-season crop, does not efficiently use the available land light, water and nutrients during its early growth stages due to its slow initial development. A short-duration second crop may be inter-planted to make more efficient use of land and these growth factors. Five grain legumes, soybeans, cowpeas, beans, pigeon peas, and dolichos were evaluated in two sites to determine their production potential; and effect on cassava in a cassava intercrop. Trials were laid in a RCBD with 3 replications. The research intends to determine biophysical compatibility of selected grain legumes and cassava intercrop as well as the optimum production attainable from intercrop-based cropping system. Cassava was planted as a monoculture and also intercropped with various grain legumes. Plant growth parameters and legume yields were established and significance of their mean production differences tested using ANOVA. Results indicated that some cassava crop growth parameter had not been significantly affected by intercropping. In all plots, greater numbers of whiteflies were noted on plants with larger leaves for example dolichos and pigeon peas.

Omamo S. W., Williams J. C., Obare G. A., Ndiwa N. N., (2002) Soil fertility management on small farms in Africa: evidence from Nakuru District, Kenya. *Food policy Journal*. (27) 159-170

This paper uses data from a 1998 survey of farming households in Nakuru district, Kenya to explore factors influencing soil fertility management decisions of small holder farmers in Africa. The modelling strategy builds on results of research in soil science that point to the joint determination of inorganic and organic soil nutrients stocks and flows on-farm. Farmers' decisions on levels of inorganic and organic fertilizers use are hypothesized to be similarly mutually dependent, and to be further influenced by various farmer-specific socioeconomic factors. Econometric estimations indicate that once the effects of cropping patterns, farm-to-market transport cost, and labour availability are taken into account. Small holder applications of inorganic and organic fertilizers appear to be substitutes. Implications for research and policy are drawn.

Makokha S., Kimani S., Mwangi W., Verkuijl H., and Musembi F. (2001). Determinants of Fertilizer and Manure Use in Maize Production in Kiambu District, Kenya. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Kenya Agricultural Research Institute (KARI).

Farms in Kiambu District are very small owing to high population pressure and need to be intensively farmed to provide enough food for consumption and sale. Since soil nitrogen levels are low, the use of inorganic fertilizers and manure needs to be increased to improve land productivity. This study identified the socioeconomic factors influencing the use of inorganic fertilizers and manure for maize production in Kiambu District. A multistage sampling procedure was used to select divisions and farmers to be included in the study. Three divisions were randomly selected, from which a sample of 97 farmers was obtained. Data were collected at the farm level using a structured questionnaire. Soil and manure samples were taken from sample farms for laboratory analysis. The soil analysis showed that soils in Kiambu District have high organic carbon content (3-4%), which reflects high levels of applied organic matter, most likely coupled with low rates of mineralization. Soils are low in nitrogen (N), indicating that more N needs to be added. Phosphorus (P) levels are not severely limiting, which might reflect a build-up of previously applied P. The logistic regression showed that extension and off-farm income were significant factors influencing the adoption of manure. Age of household head, extension, membership in an organization, and off-farm income significantly influenced the use of inorganic fertilizer. The use of both inorganic fertilizer and manure was significantly influenced by extension, membership in an organization, household size,

hired labor for manure application, livestock ownership, and off-farm income. Extension, the most significant factor affecting the use of manure and fertilizer, should promote adoption by providing advice on improved on-farm manure management and fertilizer recommendations, particularly in terms of crop suitability and timing and method of application. Also, the extension service should advise fertilizer dealers to supply the packages required by farmers. To further aid adoption, capital (credit) constraints faced by farmers need to be relieved. Improved market information will assist farmers in securing the best prices for their outputs and inputs.

Soule M. J., Shepherd K. D. (2000). An ecological and economic analysis of phosphorus replenishment for Vihiga Division western Kenya. *Agricultural systems, Vol.* 64: 83-98

Soil scientists have identified soil deficiency as a major constrain to improved maize and beans yields in highland areas of western Kenya. This study evaluated the economic cost and benefits as well as ecological impacts for different phosphorous replenishment strategies from both a farm level and a regional perspective using an economic-ecological stimulated model. The study associated soil properties with representative farm types and showed the impact of soil fertility replenishment depends on initial soil conditions as well as the resource endowment level of the farmer. Two hundred and ten different strategies for phosphorous replenishment with different sources of phosphorous applied at various levels were analysed for seven farm types. The farm level analysis showed that phosphorous replenishment was generally profitable for farms with low and medium pH (4.9-6.2) soils, but not farms with high pH (6.2-7.0) soils. A regional analysis showed that benefits were higher when phosphorous replenishment was targeted to farmers with low and medium resource endowments on low and medium pH soil rather than spread evenly across all soil and farm types

Gitari J. N., Kanampiu F. K. and Murithi F. M. (1996). Maize yield gab analysis for mid altitude areas of eastern and central Kenya region. *Proceedings of the 5th KARI Scientific Conference held in Nairobi*, PP 645-657

Trials were conducted for three seasons starting 1994/5 at agro-ecological zone. Upper Midland 2 of Kenya to quality maize (*Zea mays* L.) yield gap obtained in research plots and farmer's fields. Three factors tested were fertilizer application, planting density and choice of variety. Plant density of 53,333 plants/ha increased maize grain yields compared to 37,037 in all seasons. High fertilizer rate increased grain yields during 1994/1995 short and 1995 long rains. However, using H512 increased grain yield only during long rains 1995. If finances are limiting, investing in improved plant density is more profitable compared to the use of hybrid seed and higher plant density was more profitable rather than using higher fertilizer application. If finances are not adequate, the farmers are advised to invest in preparations for a better plant density which has higher returns than either the use of hybrid seed or higher dosage of fertilizer application.

Irungu J. W, Warren G. P and Sutherland A. (1996). Soil fertility status in small holder farms in the semi-arid areas of Tharaka Nithi District: Farmers' assessment compared to laboratory Analysis. *Proceedings of the 5th KARI Scientific Conference held in Nairobi*, PP 645-657

A diagnostic farming systems survey was conducted by a multi-disciplinary team of agricultural research and extension staff in the semi-arid areas of Tharaka-Nithi District, Kenya in 1993. A participatory appraisal of soil fertility status was conducted with the aim of assessing the soil fertility as experienced by farmers. This was done by farmers identifying the poor and good fields of their farms. In addition to soil fertility management histories for each field, a composite soil sample was taken from the plough layer (0-10 cm). A total of 62 soil samples were taken from 30 farms in 2 villages. The soils were analysed for extractable phosphorus (Olsen method), total carbon and pH (H_2O and 0.01M $CaCl_2$. The overall mean for extractable soil P was 10.7mg/kg soil. However, there was a wide variation with values ranging from 1.6 to 53.7 mg/kg soil. Total soil carbon mean was 0.60% and soil pH was around neutral. The laboratory analysis results generally agreed with the farmers experiences in categorizing the land within their farms. Total soil carbon levels compared well with the farmer's perception of good and poor soil fertility status. Results were also used to prioritise the aspects of soil fertility that are most pressing in terms of research needs for sustainable soil fertility management and enhanced crop productivity in semi-arid areas.

Mellis D., Matsaert H. and Micheni A. (1996). Demand-led research: integrating farmers and researchers experiments in surface water management in a semi arid area of Kenya. *Proceedings of the 5th KARI Scientific Conference held in Nairobi*, PP 645-657

Surface water management techniques were studied (1:1 runoff-run-on, strip tillage and tied ridges) from 1988-93 with a combination of on-farm and on-station trials, but farmer uptake remained very low. Subsequently, in 1993, the Dryland Applied Research and Extension Project (DAREP) started with an approach intended to involve farmers in all stages of the technology development process, from identification to research and extension. DAREP carried out participatory diagnostic surveys looking at the whole farming system and out of these, farmer focus

groups were started to identify and develop solutions to the identified moisture constraint. A range of options were presented through pictures, descriptions and farmer tours, and farmers selected technologies such as Zai pits, planting furrows, cambered beds, earth basins and external water harvesting. After designing and evaluating their own trials, with assistance from researchers (over 5 seasons), over 30 farmers continue with the techniques and have recommended certain techniques and management options to other farmers at open days. Controlled trials were carried on station (over 2 seasons) according to farmers' demands allowing a quantitative understanding to be obtained of the hydrological processes at work. Integrating farmers and researchers' experiments has enabled data to be collected on techniques preferred by farmers for the wide range of conditions existing in their fields and their diverse management techniques. All the surface water management techniques tried appear to have potential for use by farmers in the area to improve their productivity. Tied furrows appear to be particularly popular with farmers, needing lower labour inputs and giving higher yields than the control. Both the farmers and researchers experiments highlight the need for studying fertility aspects of the structures as well as their hydrology.

Muyekho F. N, Wandera J. L (1996). Forage legume seed production, opportunities and challenges for research and on-farm production in Kenya. *Proceedings of the 5th KARI Scientific Conference held in Nairobi*, PP 645-657

Forage legumes are important in the smallholder farming systems in Kenya in terms of improving the quality of the pastures and agricultural by-products fed to livestock, as well as improving soil fertility. Inadequate supply of affordable seed has however, limited the use of forage legumes in the farming system. This paper reviews the seed yield of various forage legumes in the farming system. This paper reviews the seed yield of various forage legume species in Kenya. The data documented suggests that Kenya can produce its own legume seed for some species, however, there are still large gaps in the knowledge of production of high seed yield on a large scale. Lack of information on suitable sites for legume seed production of specific species, inadequate understanding of the vegetative and reproductive growth and identification of correct management practices are the main factors that limit seed production. The research recommendations already generated at KARI centres have not been adopted by farmers/seed companies. Poor technology transfer from research centres to seed companies and farmers is identified as constraint to adoption of the technology are discussed and methods of technology transfer to promote both commercial and farm to farm sales of forage legume seed are proposed.

Nyangito L. O. and Mugunieri (1996). An economic analysis of the determinants of fertilizer use among smallholder maize producers in Western Kenya. *Proceedings of the 5th KARI Scientific Conference held in Nairobi*, PP 645-657

Attainment of food security is a major objective of the government of Kenya. Fertilizer is an important input necessary to achieve this objective. However, a wide range of socio-economic factors affect its use. This study was formulated to identify the major determinants of fertilizer use from a random sample of 120 farmers using structured questionnaire over the 1995 major maize growing season. The study found out that the amount of fertilizer used vary in these districts. The results of the analysis indicate that the factors which determine fertilizer use included the normalised price of fertilizer, farm size, extension, liquidity position of farmers and on-farm employment.

Onyango M. A., Njue E. K., Ogecha J. O., Nzabi A. W., Tana P. O., Makworo S., Kuaya F. (1996). RRC-Kisii on-farm research experience with soil fertility management in S. W. Kenya. Kenya Agricultural Research Institute, Kisii. *Annual report*. pp 421-434

South West Kenya is comprised of diverse agro-ecological zones ranging from LH1-LM5. Participatory research was initiated in this region to diagnose soil fertility related constraints and evaluate identified interventions. From the participatory rural appraisal (PRA) exercise which was undertaken, several constraints were identified by farmers. In the high potential sites (Kisii, Nyamira), the constraints were low crop yields due to use of inappropriate varieties, declining soil fertility, bean pests and diseases, and inadequate livestock feed. In the lower potential sites (Homa Bay district), striga infestation, soil erosion and livestock diseases were the major problems. Preliminary results of the evaluation of organic manure and inorganic fertilizers using maize and vegetables as test crops show that a mixture of organic manure plus reduced rates of di-ammonium phosphate (DAP) fertilizer may be a promising alternative to use of recommended rates of inorganic fertilizers. A study on farmer recommended non-chemical control techniques for Striga in sorghum is currently being conducted. This paper highlights problems identified, feasible and sustainable solutions as perceived by farmers and discusses some results of initiated on-farm research activities. Results of farmers' evaluation of the maize and vegetable trials, introduced soil conservation grasses, and fodder grasses and legumes are presented. Further work is being done to draw practical recommendations.

Andre Desaules (1986) The soils at Mount Kenya semi-arid northwestern footzone and their agricultural suitability. PhD Thesis, University of Berne, Switzerland

The survey area roughly 36,000 ha is located on the north western footzone of Mt. Kenya between the towns of Naro Moru and Timau in a semi-arid and tropical cool and temperate environment, where the most large-scale farms and ranches are of low population densities but high but high technology have been subdivided into densely populated small-scale farms of fairly low technology which are often below subsistence capacity. The socio-economic transition is causing vital problems of increasing population pressure on the marginal land and agricultural land use intensification, along with the declining level of technology. The objectives of the present report are to establish an inventory of the physical environment by means of a semi-detailed soil survey, to proceed to a land evaluation for agriculture and to end up by land use and management recommendations, with emphasis on small scale farming. The findings of the soil survey and the land evaluation are presented in a concentrated form in the four appendices in folder. The physical environment is described by various components: The average annual rainfall figures range between 500mm for the driest parts of the lower footzone up to almost 1000mm for the wettest parts of the upper footzone. The rainfall pattern is generally bimodal and the rainy seasons occur around Mid-March to May and late October to the beginning of December. There is, however, a tendency of a third rainy season (continental rains) from June to August in the northern part on the other hand, the dry season from late December to the beginning of March is less pronounced in the southern part of the survey area. The probabilities of drought occurrence compared to the average rainfall are around 50% for most of the survey area. The mean annual temperatures are between 14 to 17^{0}C.Two main agro-climatic zones (IV and V) divide the survey area which is of semi-arid to semi-arid and cool-temperate to warm-temperate character. The landforms of the upper footzone are volcanic footridges separated by parallel and steep v-shaped valleys. The lower footzone consists of plateaus and high-level structural plains with oriented, smooth interfluves which are separated by minor valleys and bottomlands. The geology is dominated by basic rocks with volcanic ash admixtures which are deeply weathered or weakly consolidated. The drainage pattern includes nine small perennial watercourses of which Ewaso-Nyiro is the main river. The mean low discharge is assessed to be roughly 1300 litres per second for all watercourses together. Preliminary investigations on groundwater estimate difficulties in its quality and renewal. The natural vegetation has been greatly influenced by bush clearing and other land use. The upper footzone is covered today by wooded bush-grass-land with scattered trees, typically dry cedar but no acacia. Remains of forests occur on steep valley sides. The lower footzone is dominated by Acacia with partly evergreen bush-grassland to dense bushland and Themeda-grassland on the back of the interfluves. Land use has changed with few expectations from large-scale mixed farming of wheat, dairy cattle and beef production and ranching into scattered small-scale arable and mixed farming of rather low technology with emphasis on interplanted maize and bean production including potatoes for the upper footzone and some livestock production. The soils as the physical component on which is laid emphasis on are divided into 29 different soil classification units. The general soil pattern is mainly determined by the kind of bedrock, climate and topography. All soils are fairly deep, fine textured and free of stones except for the eroded soils on valley sides and the organic matter content of the top soils is commonly around 2%.The soils on the wetter upper footzone are dominated by moderately acid, well drained, reddish brown, friable clay soils (chromic luvisols and intergrades). On the lower footzone the soil pattern is more complex .There is a tendency that interfluve backs are occupied by near neutral to moderate alkaline, well drained that interfluve backs are occupied by near neutral to moderately alkaline, well drained brownish friable clay soils (Phaeozems) which intergrades into slightly alkaline, imperfectly drained, brownish black, firm clay soils (Phaeozem/vertisols intergrades) on the interfluve sides, plateaus and bottomlands. On plateaus, the topsoils are sometimes degraded to moderately acid, poor drained greyish, friable to hard clay loams (Planosols).In the minor bottomlands, the river terraces consist of deep reddish brown, friable clay soils (Luvisols) derived from eroded soil material from the upper footzone and the marshlands and swamps bear more or less waterlogged, greyish, heavy clay soils (Gleys and intergrades) and in places bog soils (Histosols). For agricultural use, the soils are generally seriously deficient in phosphorous and often nitrogen. The firm clays which crack when dry and are sticky when wet (vertic properties) are a constraint to drainage and tillage. The soils and other components of the physical environment are integrated into 11 distinct soil-land units and presented by a 1:50,000 scale map as a special basis of reference for the subsequent land evaluation. The land quality assessment converts the physical components of the soil land units into 13 land qualities of relevance for agriculture and identifies general physical constraints. The major all over limitations are related to moisture availability because of low and unreliable rainfall and to chemical soil fertility, through deficiency in phosphorus. The limitation related soil workability due to firm clays includes about 50% and the one related to serious erosion hazard roughly 10% of the survey area. The land use requirements and yield levels of 29 crops species included 53 varieties which are grown in the area of potential interest for a semi-arid environment, have been compiled mainly from literature, so that they can be compared to the above mentioned land qualities. The land suitability assessment consists in matching the land qualities identified with specified requirements of 40 crops including crop varieties and to assess as a first step crop suitabilities for each soil-land unit separately. Promising crop alternatives adapted to the prevailing semi-arid and tropical cool conditions were found to be selected varieties of barley, sorghum, *triticale Quinoa* and Amaranth grains, potatoes (var. Anett), early maturing sweet potatoes, bonavist beans, garden peas, chickpeas, linseed, rapeseed and sunflowers. The subsequent suitability assessment includes 8 further land utilization types with emphasis on small-scale farming, compared to large scale farming, ranching and protective

forest. Protective forest is affected by the hazards of erosion and possible flooding. Ranching is the most drought resistant land use. Large-scale rain-fed arable and mixed farming proved to be competitive under low population density. As a general statement, only small-scale rain-fed arable and mixed farming of advanced technology and adequate farm sizes which are non-existent at present within the survey are likely to reach a similar level of suitability. The river terraces are the most promising for small-scale irrigation. The recommendations for land use management are guided towards improvements and the better use of land qualities in which they occur are conditional with regard to the socio economic conditions. The land use recommendations are synonymous to the promising land suitability assessments and emphasize the propagation of drought and cold tolerant crops and the improvement of the technical level, especially concerning dry farming. The management recommendations plead for better husbandry and indicate a series of practical measures to reduce the limitations by moisture availability and further land qualities. The outlook reports on the representativeness and extrapolation of data and findings. The survey area represents a cool as well as dry environment which includes about 30% of the highlands of Kenya and 13% of its soils. The socio-economic conditions are estimated to be generally those within the area of the former 'White Highlands' where the subdivision of large-scale farms is taking place. Attention is drawn to the fact that the present report does not include a socio-economic analysis and to the key role of the agricultural Extension services which transmit recommendations into the farmer's reality.

Chui J. N., Waweru E. S., Kungu N. K., Bendera N. (1983). Crop rotation. Kenya Agricultural Institute. *Annual Report*. pp.27-28

In all these cropping systems, maize and cowpea populations remained at 55,000 plants/ha whereas that of beans was 110,000 plants/ha in sole-crop and 55,000 plants/ha in the intercrop systems. Pigeon pea population remained constant at 22,500 plants/ha for both sole-crop and intercrop systems. These systems were not applied nitrogen fertilizer or farmyard manure. However, they all received 17.5 kg P/ha as triple superphosphate, each season. To determine the contribution of legumes to maize in terms of nitrogen nutrient; a continuous function line was developed from partial land equivalent ratio (LER's) of continuous maize fertilizer trial which was adjacent to the crop rotation plots. Economic evaluation of the systems was done using estimates of gross values of returns since labour for harvest, usually provided by the family is the only major variable cost. Data indicated that rainfall total and distribution were the major factors influencing the results. The differences between seasons were highly significant. The two previous seasons of short rains 1981/82 and Long rains 1982 suggested that the incorporation of legumes in the cropping system, either as intercrop or as part of a rotation generally resulted in a higher value of production than that obtained from continuous sole maize production. The long rains (March-May) 1983 season were very poor and no harvest was done. There was no planting in the short rains 1983/84 due to lack of rain. However, the rainfall conditions were favourable during the short rains 1982/83. Hence the data reported is that of short rains 1982/83. Intercropping systems indicated some advantages over the continuous sole-crop maize by giving greater land use efficiency (land equivalent ratio-LER). Also, by virtue of intercropping maize with cowpeas (1c) or pigeon peas which had been (4a) or cowpea (4b) intercrop in the previous season, maize yields and value were raised above those of continuous sole-crop maize. Although yields of maize intercropped with beans were 28 and 44% lower than that of continuous sole-crop maize, the increase in total LER's ranged between 6% for the continuous maize/bean intercrop (1b) and 42% for a one-season maize/bean intercrop (2c). The gross values of all intercropping systems were higher than that of continuous sole-crop maize. The beneficial effects of rotating sole-crop legume and/or maize/legume intercrop with sole-crop maize was reflected in the yield of maize. The yield increase of maize succeeding a sole-crop legume ranged between 22 and 109%. The total gross values of all cropping systems were higher than that of continuous sole-crop maize except in the case of sole-crop beans which was 4% lower. The contribution of legume to several cropping systems was found by using maize partial LER's and short rains 1982/83 maize fertilizer trial (Table 12)>beans had the highest contribution, 44 Kg N/ha, to maize in sole-crop rotation system while pigeon peas were the highest contributors, 9 Kg N/ha, to the intercrop system. A cowpea crop intercropped with maize in the previous season contributed highest, 26 Kg N/ha, to the succeeding sole-crop maize as compared to the other intercrop of pigeon peas,15 Kg N/ha and beans,10 Kg N/ha. These results indicated that any cropping system that had a legume in the preceding season could save some fertilizer to the succeeding sole-crop maize. The amount saved is that estimated to have been contributed by the legume. The N fertilizer would have required cash outlays and the amount to substitute sole-crop legume contribution was Kshs. 480 and Kshs. 262 for beans and cowpeas respectively.

Kwambai T.K., Nyambati E.M., WanjekecheE., Kamau J.N., Ngure J. and M. Kamidi Participatory Evaluation of Climbing Bean Varieties for Integration into the Cropping Systems in Smallholder Farms in North Western Kenya. *Proceeding 10th Kenya Agricultural Research Institute Biennial Conference* PP: 1-5 Kenya

The maize (*Zea mays* L.), common bush bean (*Phaseolus vulgaris* L.) intercropping system in the major source of cash and food for smallholder farmers in north-western Kenya. However, low grain yields of the common bush bean caused by low soil fertility and susceptibility to pests and diseases is a major constraint to increased food security in the region. The productivity of climbing bean varieties was assessed under on-station and on-farm

conditions compared to the currently grown common bush bean. The varieties evaluated were: Flora, Umubano, Puebla, Gisenyi and 4) control (GLP 2 or Wairimu common bush bean). In 2001 climbing bean varieties yielded 0.86 and 0.99 tha^{-1} more grain than the GLP2 common bush bean in the on-station and on-farm experiments, respectively, which suggested that they could be a better alternative to the currently grown bush beans. The yields of the best 3 performing varieties ranged from 1.2 - 3.61 t/ha and control 0.97 - 1.76 t/ha over the period of experimentation. The performance of the climbing beans on low soil fertility farmer's fields were in the order of Puebla >Flora>Umubano but not significantly different. Upon evaluation farmers preferred Umubano on basis of its red colour and early maturity. However Puebla was least preferred due to its relative susceptibility to disease and a brown colouration of its creamy grains with excess rainfall. The results indicated that these varieties could be included as alternatives to common bush bean in the design and development of sustainable cereal/vegetable - legume cropping systems in the sub-humid highlands of North Western Kenya.

Kenya Soil Health Consortium
Collating, harmonizing, Disseminating
Soil Health Innovations

The Kenya Soil Health Consortium (KSHC)

The Kenya Soil Health Consortium was formed in 2013 under the leadership of the former Kenya Agriculture Research Institute (KARI), currently Kenya Agricultural and Livestock Research Organization (KALRO), with funding from the Soil Health Program of AGRA. The objectives of KSHC are to:

1. Improve access by smallholder farmers and other stakeholders to ISFM innovations
2. Enhance the generation and dissemination of ISFM innovations by harmonizing the approaches, recommendations and protocols by key institutions engaged in agricultural research
3. Advance the dissemination of ISFM innovations by developing and hosting the national ISFM database and appropriate knowledge products

The Consortium has a national stakeholders' forum that draws representation from national and international research organizations, policy, extension, national farmer organizations and the private sector (input and credit providers, agricultural output market players). KSHC provides a forum for lobbying and advocacy support through development of policy instruments and technical papers aimed at improving linkages with policy makers at national and county levels.

AGRA
Growing Africa's Agriculture

IPNI
International Plant Nutrition Institute

KALRO
Kenya Agricultural & Livestock Research Organisation