PRECISION AGRICULTURE FOR CEREAL PRODUCTION

Are we all concerned?

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Pertinent questions

- Will farmers ever be able to produce sufficient products from their farm to ensure a life above the poverty line?
- Will cereal production ever be economically feasible and environmentally friendly?
- What is the site-specific ‘development’ potential?


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Introduction

- Smallholder cereal production contributes significantly to food security and rural livelihoods in Africa, but yields are often low.
- Cereal production is constrained by such challenges as decline in soil quality, high input costs, decreased availability of land for cultivation due to increasing urbanization and an increase in demand due to the growing global population.
- These challenges are exacerbated by climate change impacts.
- Profitability and sustainability of cereal production in SSA requires more effective production systems that ensures efficient inputs use in an economically viable and environmentally sensible manner.

- Smallholder farms in SSA are hugely variable in terms of soil fertility status, SOC content, soil water content and other soil biophysical properties that influence cereal yields.
- This heterogeneity exists among farms within same or different localities, and even among contiguous fields within a farm (Vanlauwe *et al.*, 2010; Tittonell *et al.*, 2011).
- This variability is not limited to soil biophysical properties, but also associated with availability of labour, income, production orientation, cultural norms and wealth.
- Furthermore, variability between fields within individual farms may be as large as those between different agro-ecological zones, with obvious consequences for cereal yields (Ojiem et al., 2006)
- Given the variability in smallholder farming systems PA strategies must be designed to optimize farming under this heterogeneity

- To produce cereal sustainably, a system approach must be adopted which will orientate the entire cereal production system towards low input, high efficiency and sustainable productivity.
- Given that variability is a common feature of smallholder farming systems, and the fact that PA can be designed to optimize farming under heterogeneity, PA principles and tools must be leveraged for the improvement of smallholder farming systems.
- A lot of the useful lessons learnt from PA use in commercial farming systems can be combined with an understanding of smallholder systems to effectively use of PA principles and tools for enhanced productivity in smallholder farms.


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Relevance f PA for cereal production in SSA

- PA has since long been practised intuitively by subsistence farmers (Vanlauwe *et al.*, 2010; Heijting *et al.*, 2011)
- Precision agriculture (PA) came of age as a technically driven means to improve industrialized agriculture in the 1990s.

- PA promised benefits to both farmers and society through increasing production efficiency while improving stewardship of the environment (Srinivasan, 2006).
- These principles explain the heightened global of interest in eco-efficiency (Keating *et al.*, 2010), driven by global food price spikes coupled with progressive concern about the degradation of agroecosystems across the world.
- These drivers have refocused global concern on the overarching aims of improving food security while protecting the environment (Godfray *et al.*, 2010; Mueller *et al.*, 2012).

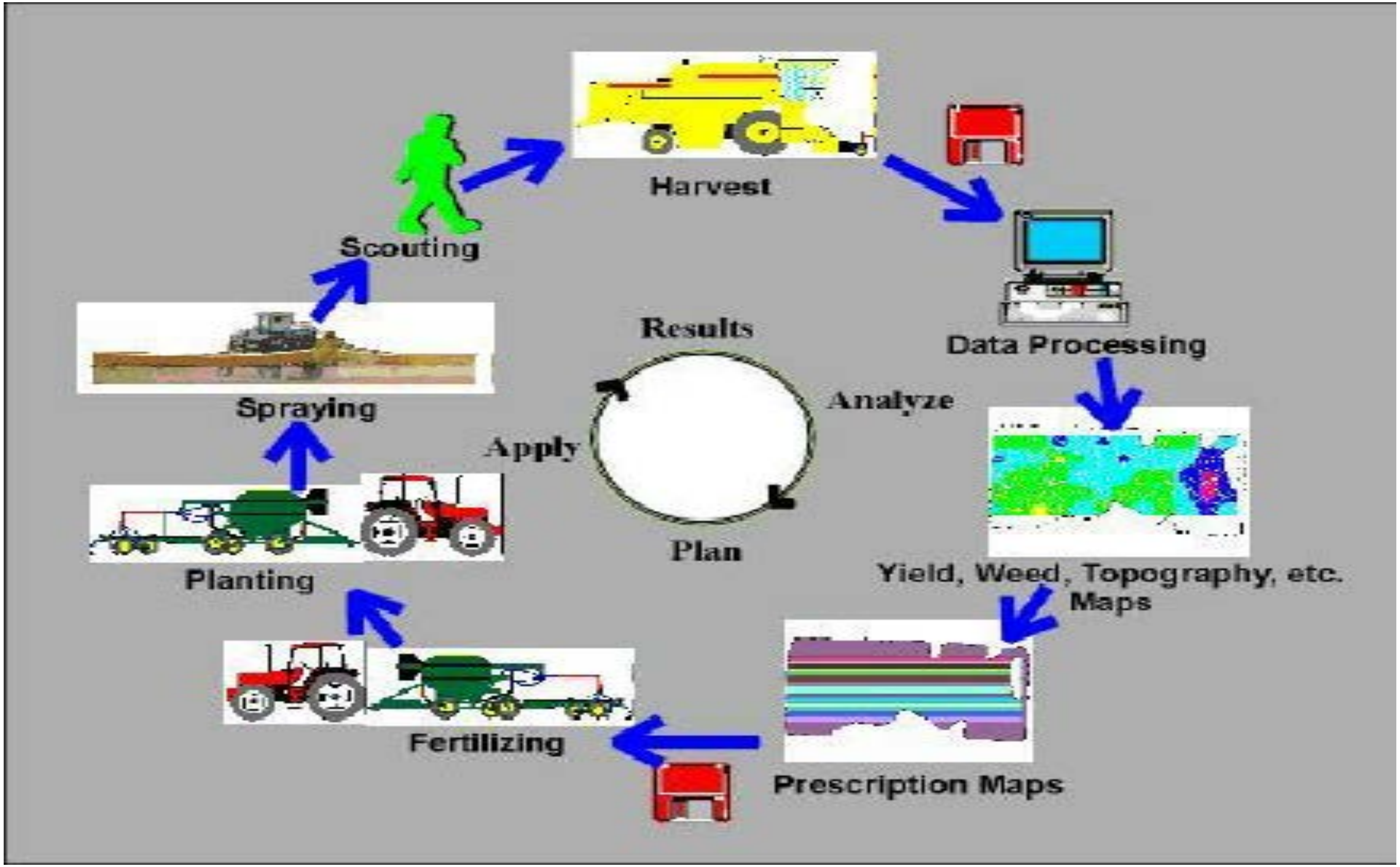
PA recognizes the fine-scale heterogeneity of agricultural fields, as many subsistence farmers have traditionally done.

Whereas subsistence farmers often have to concentrate inputs in fertile microsites as a risk-minimizing strategy (Vanlauwe *et al.*, 2010), PA focuses on optimizing farm inputs by translating site-specific crop demands into variable management practices (Srinivasan, 2006; Mueller *et al.*, 2012).

PA Principles

- Precision agriculture is based on the principle of dividing large fields into smaller sub-fields, also called site-specific fields.
- The aim is to treat the smallest possible area as a single element. For example, instead of treating a whole field with herbicide due to the presence of a few weed infestations, site specific management will provide treatment only for the required areas.
- The definition of a site is simply the smallest unit a farmer can manage with the tools available, whether it is a hectare or an individual plant.

- Large fields are divided into smaller sub-fields, management zones or site-specific zones based on the variability of crop and soil factors within the specific field. According to Zhang *et al.(*2002:114) variability can be either spatial or temporal
- The treatment of each site is determined by the needs of the specific site, as determined by soil test data, crop scouting reports and monitoring using sensors (Pfister, 1998).



Schematic diagram of PA application

Assumptions underpinning PA adoption

Experiences with PA suggest that its adoption is hinged on the assumption that :

- Cereal yield-limiting factors can be assessed with PA
- agronomic data will be readily accessible
- PA will yield considerable economic benefits in cereal production systems across scales
- extension services and or consultants will be easily accessible and affordable.

Perceptions and Challenges

- The early advocates of PA for agricultural systems were perceived as trying to mirror developments in the mobile phone industry. The critics assumed that SSA farmers were being moved from basic manual farming techniques directly to high-tech agriculture, in the same way as some mobile phone service providers started operations directly in the wireless format without ever passing through the stage of extensive landline installation.
- Others argue that precision agriculture had not yet found valuable technology options that validate the utility PA in SSA's smallholder farming including cereal systems.
- However, the rapid growth in understanding and acceptance of technologies such as the global positioning system (GPS) and mobile telephony in SSA quickly changed the narratives.

- to many people especially in SSA, the overall impression of PA is one of an intensive crop management system, served by high- end technology (Cook *et al.*, 2003; Gebbers and Adamchuk, 2010).
- In developed countries, precision farming uses the internet of things, robotics, blockchain, big data, artificial intelligence and drones to improve yields.
- These large-scale innovations are often not suited to African smallholders, whose farms are generally less than two hectares. Illiteracy and lack of connectivity

- Low rates of PA adoption by smallholder cereal farmers can be linked to the lack of awareness of PA technology, lack of access to sources of information, insufficient quality of information, time requirements, lack of technical knowledge, problems with the incompatibility of different hardware devices and the high cost of the technology (Kutter et al., 2011; Tey and Brindal, 2012).

- A critical challenge facing PA use for cereal production in SSA is the need to develop tools and build capacity to effectively use information in farmer decision-making to tailor intervention options to sites and farmer specific conditions.

- However, there are examples of knowledge- based systems tools that can be used to customize extension messages to local circumstances, but mainstreaming the development and use of such tools is still rudimentary in many areas in SSA.

Benefits of PA

- The benefits of PA can be clearly seen when it is analysed in a holistic systems approach that includes placing values on environmental protection, food safety and other external benefits.

- At the farm level, the costs are considered to outweigh perceived benefit if these added values are not included in the analysis (Lowenberg-DeBoer, 2001; Srinivasan, 2006).

Applicability of PA to smallholder cereal farmers

- Precision agriculture is not exclusive to the modern, western farmers.
- Smallholder farmers in West Africa can also use precision agriculture to improve their harvest and labour productivity.
- Farmers in the semi-arid part of West Africa have to deal with poor plant growth, varying precipitation, low soil fertility and a lack of labour, and they have little money and resources to solve these problems. That is why they benefit from cultivation measures that make efficient use of the available resources and diminish the risks of poor harvest.

- PA technologies seem to be especially appropriate tools for agriculture in developing countries, where policies that promote management of land and water resources for sustainable intensification have remained elusive (Gebbers and Adamchuk, 2010; Godfray *et al.*, 2010).

- The gap between average yields presently achieved by farmers and yield potential is determined by the yielding ability of available crop varieties or hybrids and the degree to which crop and soil management practices allow expression of this genetic potential (Cassman, 1999; Mueller *et al.*, 2012).

- Supporting the expression of this genetic potential while increasing the efficiency of use of farm resources by adjusting crop management according to field variability and site- specific conditions is intuitively appealing to most agricultural practitioners

Recipe for PA adoption for cereal production

The standard recipe for PA is a stepwise process that entails:

- defining the yield-limiting factor or factors at a given time;
- mapping these factors across the region of interest;
- designing a variable-rate management strategy that addresses the spatial variability of these factors and
- assessing and monitoring environmental and economic benefits of implementing variable-rate management strategies.

- For PA to improve yields successfully, the yield-limiting factors need to be clearly defined and responsive to agronomic practices. The yield potential of a crop variety grown by a farmer does not only depend on its genetic makeup, but also on the inherent agronomic potential of the site. No increase in yield can be expected if the field chosen for planting is not suitable for the growth of the crop.
- Site-specific nutrient management (SSNM) aims to record and predict the spatial variation of the nutrient supply in fields and to address this with variable fertilizer rates (Srinivasan, 2006).
- The principles of SSNM were developed for rice through more than a decade of research beginning in the mid 1990s and involving countries across Asia and in Africa.
- The experiences with rice were subsequently used to develop SSNM principles for maize and wheat, which were ready for delivery by 2010.

- Delivery of SSNM for rice from 2002 to 2008 focused on developing and promoting printed guidelines for large rice-growing regions. Uptake by farmers was limited because of the amount and sophistication of knowledge required to use the printed materials to develop field-specific guidelines for individual farms (Timsina *et al.*, 2010; Global Rice Science Partnership, 2010

Some SSA friendly PA technologies

Effective and efficient implementation and use of precision agriculture systems requires technology.

A brief outline of the available technology as described by Zhang *et al.* (2002):

- Sensors: Yield, field, soil, crop and anomaly sensors.
- Controls: Variable rate technology agro-chemical applicators, automatic guidance systems (incorporating global positioning systems), robotic harvesting systems, network systems and remote sensing systems.
- GIS (geographic information systems).

PA strategies that work for cereal production

- Enough evidence exist which confirm the applicability of PA in SSA cereal production systems. Most of these examples have already shown the benefits associated with PA across scales.
- There are some documented examples of PA being applied to smallholder farms in developing countries.

Fertilizer microdosing

- Fertilizer microdosing or “micro-fertilization” consists of the application of a small quantity of mineral fertilizer together with seeds of the target crop in the planting hole at sowing or 2-4 weeks after sowing.
- Recent scientific developments on fertilizer micro-dosing revealed that this technology has given promising results in respect of crop yields improvement, fertilizer use efficiency and economic returns.

Ghana experience

- Fertilizer microdosing technology can complement traditional fertility management strategies,
- Microdosing increased maize yield by more than 50% as it increased fertilizer use efficiency by 2 fold compared to recommended broadcast rate.
- However, maize response to fertilizer microdosing appeared to decrease with increasing soil fertility.

- There are examples which show clearly that remote sensing and information technology can be used to provide fine-scale data on biophysical and socio-economic variables to farmers and research and extension work.
- For instance, in recent times, farmers are able to obtain information such as produce price alerts, bids and offers, and news and advisories via telephony. A typical example is the Esoko platform established in 2005. It is a very reliable source of information for smallholder farmers.

- The Africa Soil Information Service (AfSIS, http://africasoils.net) is a pioneering effort funded by the Bill and Melinda Gates Foundation (BMGF), and the Alliance for a Green Revolution in Africa (AGRA) to fill one of the major gaps in spatial information worldwide.

- The AfSIS produces timely, cost- effective, soil health surveillance maps at a scale useful to smallholders and rural development practitioners (Terhoeven-Urselmans *et al.*, 2010).

- The Grameen Foundation has built a self-sustaining, scalable network of rural information providers through the Community Knowledge worker (CKw) initiative.
- The CKw provides access to up-to-date information on best farming practices, market conditions, pests and disease control, weather forecasts and market access by collecting and disseminating relevant information via mobile phones.
- The CKws are trained to use mobile phones to access actionable information that meet farmer needs. For instance In Uganda, CKws have proved to be a vital link between farmers, government programmes, non-governmental organizations and other entities (e.g. Kiiza and Pederson, 2012).

- The Seeing Is Believing – west Africa (SIBwA) project offers real-time data about the spatial and temporal variation of the landscape on which the farmers operate.
- In this project trained persons verify data acquired from the landscape, use it to update databases of information for the development of accurate maps of each farm.
- The SIBwA partners translate the information into local languages to enable easy effective delivery of detailed maps to individual farmers to enable them plan and manage their crops during the growing season (Traore, 2009).
- In accordance with the well-established view that farmers are naturally capable of actively observing and experimenting, farmers’ knowledge is increasingly becoming dynamic and explanatory, (Shiferaw *et al.*, 2009; Cerdan *et al.*, 2012).
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- Based on hydrological regimes (rainfed, tidal and rainfall combined with marine tides) and soil properties, Senegalese and Gambian farmers recognize six micro-environments Carney (1991). Consequently, the farmers adapt rice cultivation in different agro ecological zones to the differing moisture regimes and edaphic properties.
- Thus, the farmers often adjust their cultivation schedules, agronomic practices and seed selection to the specific characteristics of each micro-environment.

- Women farmers in Diola in southern Sene and Mandinka in central Gambia grow as many as 15 and 30 local and introduced rice varieties, respectively, throughout the production zones due to soil or climate variability at patch, field and landscape scales
- Farmers also understand the positive effects of nutrient transfers made via livestock at landscape scales to concentrate fertility on crop fields (Vanlauwe *et al.*, 2010).
- Many farmers have clear understanding of agroforestry regarding how interactive effects of different species affect crop yield and other ecosystem services, and their variability in space and time (Cerdan *et al.*, 2012).

Precision conservation agriculture

- Precision conservation agriculture (PCA) assists farmers to be successful by tailoring practices to local circumstances (Jerich, 2011).
- Conservation agriculture (CA) is defined by three simple principles: (1) minimizing soil disturbance, (2) using crop rotations and or associations and (3) keeping soil covered with crop residue (Giller *et al.*, 2011).
- An example of PCA land preparation could include hand-dug planting holes, precise lime application around the root zone of each plant and precise spatial positioning of plants (Jerich, 2011).
- The universal applicability of CA principles for smallholder farmers in Africa has been questioned.
- More tailored approaches that adapt some or all three principles for different circumstances are seen as critical to their appropriateness (Giller *et al.*, 2011).

Precision manuring

- Results indicate that farmers can improve management of manure applied to cropped areas simply by rotating the night-time tethering sites of their animals.
- Through this strategy of precision manuring, they can concentrate manure application on the ‘bad spots’ or ‘tired soils’ that are most in need of nutrients and organic matter.
- Deliberate application of manure, compost and other fertilizers to low-yielding parts of fields is a common strategy employed by smallholder farmers (Vanlauwe *et al.*, 2010).
- The practice is especially useful for poor farmers, since they do not have enough land to ignore areas of declining soil fertility.
- Village-level management of precision manuring shows promise for enabling dryland communities to fine-tune the management of agro-pastoral systems across whole landscapes, resulting in larger and more sustainable yields (Taddesse *et al.*, 2003).

Supplementary irrigation

- Supplementary irrigation (SI) is the addition of water to essentially rainfed crops during times of serious rainfall deficits.
- The combined use of rainfall and irrigation water is a potentially valuable management principle under conditions of water scarcity.
- The aim is to reduce the risk of crop failure and to stabilize yields where rainfall is normally sufficient, but vulnerability to drought is considerable.
- In our biochar amended soils, we found substantial increases in maize yield in response to the application of relatively small amounts of irrigation water

Tools for PA in cereal production

- Precision Agriculture use for cereal production is based on observing, measuring and responding to inter and intra field variability in crop performance.
- The PA tools are aimed at matching farm practices closely to crop need, protecting and limiting environmental risk and boosting competitiveness through efficient practices.
- To this end geospatial technologies involves capturing farm data and undertaking a characterization of variability for effective decision-making and implementation practices at the farm level.

Examples of PA tools used in cereal production

- GPS provides location and time information in all weather conditions, anywhere on or near the Earth.
- Remote Sensing facilitates the acquisition of information without physical contact: Example; meteorological data, chemical concentrations in the atmosphere, soil water, soil minerals, land cover, land use, plant and crop health, etc.
- GIS is designed to capture, store, manipulate, analyse, manage and present all types of geographical data: where things are, quantities and densities and finds what’s inside and what’s nearby.

- Other benefits of deploying geospatial technologies include determining the location of agri-businesses including tractor, storage, aggregation points, et al being guided by a reliable geo-database.
- In addition, it is very essential for private enterprises venturing into rain-fed large scale commercial grain farming to effectively make use of geospatial information otherwise it will be suicidal for them.
- One of the advantages of current planting equipment is that it enables farmers to plant at variable seed rates. The rate is programmed according to the data available (for example field conditions and soil composition) for a specific site.
- The selection of the best seed variety for the specific set of conditions is also of critical importance.
- The biotechnology era has resulted in a wide variety of genetically enhanced cultivars. Farmers need to make informed choices with regards to the potential advantages that can result from choosing varieties that will perform best under his specific conditions (Pfister, 1998).

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- The development of automated sprayers that use VRT (variable rate technology) and VRA (variable rate application) has become a very important tool in precision agriculture.
- The practice of whole-field application of chemicals has been replaced by site-specific treatments with VRA equipped sprayers. Data obtained from crop scouting and analysis of field conditions are used to program these sprayers to deliver the exact amount of a specific chemical according to the field requirement.

- Yield monitoring is one of the most critical aspects of precision agriculture. Traditionally, yield was determined by weighing harvested batches of crops. However, precision agriculture has resulted in methods that provide instantaneous yield monitoring. The modern yield monitor utilizes sensors in the combine that continuously log grain flow during harvesting together with the speed of the combine (Pfister, 1998).

Customizing smallholder cereal farmer interventions with PA

- In order to address heterogeneity in smallholder farming systems researchers and extension workers have to identify any capacity gaps that limits their ability to match interventions to sites and farmer circumstances as well as any risks that farmers are likely to face if they adopt them (Tittonell *et al.*, 2011).
- The challenges in PA development can be tackled at a fine scale if practitioners decided to take risks through local experiments and observations so that farmers will use the lessons learnt to build on their local knowledge and expertise.
- African governments need to adopt policies that ensure more demand-driven and market-orientated agricultural services. a trend of paradigm shifts from centralized extension systems to decentralized, demand-driven agricultural advisory systems.

Success stories

- The University of Cape Coast has implemented the use of drone technology, as a means to improve security, boost productivity and help reduce escalating costs.
- According to farmers’ organisation Agri Eastern Cape,. More and more farmers are starting to use drones to do quick spot-checks on their farming operations without having to waste time trekking to remote areas on foot. This ranges from checking that boundary fences are secure, to checking on livestock, watering points and other critical operational issues
- New planting and harvesting techniques have transformed the fortunes of rice farmers in Nigeria’s agricultural belt, turning family-run plots into thriving businesses. Many have doubled or tripled their profit with higher yields and better-quality rice that gives smallholder farmers access to a wider market.
- A shared-cost initiative between Parrot Drones and the Technical Centre for Agriculture and Rural Cooperation (CTA) has been launched for the deployment of drones for agriculture in sub-Saharan Africa.

Leveraging on PA application to enhance smallholder cereal productivity

- Build on farmers’ knowledge and expertise by facilitating local experimentation, observation and learning.
- Use of high-resolution spatial and temporal data to inform farmers and target interventions.
- Match extension methods to local circumstances and demand.
- Manage social and economic factors within the PA framework at a range of scales.

Conclusion

PA provides an incredibly exciting opportunity for farmers, consumers and businesses because, for the first time in more than a 100 years, it's possible to improve production and bring a certain degree of confidence to transparency and traceability operations.

Traceability and transparency that blockchain bring will help organic farmers and local producers finally get the premium they deserve.

Drones can make it easier to produce more per hectare, feeding more mouths than ever before.

However, as easy as it sounds, the reality is that the digital transformation of agriculture is still a few years away.

- Countries in Sub-Saharan Africa can benefit from advanced farming technologies that mitigate the effects of climate change and protect environmental resources.
- Water scarcity is an issue that can be overcome by adopting climate-smart technologies such as micro-irrigation.
- There are several precision agriculture investment opportunities available to the private sector, including agricultural extension via digital advisory services, drip irrigation, solar pumps, and crop and soil monitoring.
- Developing technologies will positively impact food production and food security in emerging markets. According to the International Food Policy Research Institute (IFPRI), the largest yield gain potential across the world's key staple crops—maize, rice, and wheat—in percentage terms are in Africa, South Asia, and parts of Latin America

- PA provides invaluable opportunities for intensifying cereal production in a sustainable manner, in value addition and value chain development.
- It also has inherent potential for improved local economies and livelihoods.
- The establishment of viable cereal based business enterprises including processing, transport services, and so forth in Africa, is crucial to creating employment and income opportunities and, thereby, enhancing the demand for farm produce.
- PA can contribute significantly to enabling the growth of commercial cereal production systems and the efficiency of post-harvest handling, processing and marketing operations, and as such can be a major determinant in the availability and accessibility of food, the food prices paid by urban and rural poor, as well as contributing to increased household food security.

- PA is applicable all scales of cereal farming and processing technologies, from simple and basic hand tools to more sophisticated and motorized equipment.
- It eases and reduces hard labour, relieves labour shortages, improves productivity and timeliness of agricultural operations, improves the efficient use of resources, enhances market access and contributes to mitigating climate related hazards.
- PA can help farmers in Africa boost their yields, while adding the additional benefits of improved nutrition, greater employment opportunities, and advancement towards global food security. Precision agriculture technologies feature as a key component.

We are all involved

THANK YOU FOR YOUR ATTENTION