How Do Potassium Inputs and Outputs Compare for Different Cropping Systems and Geopolitical Boundaries

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Farming Hits the Wall, But Not the Ceiling

Humankind now farms 38 percent of the earth’s ice-free land. Crops cover one-third of that area; pastures and ranges for livestock cover the rest. Little room exists for expansion because most of the remaining land is deserts, mountains, tundra or urban. Still, farms in many existing areas could be more productive (insets).

Better Breadbaskets

The world could grow much more food if the productivity of the poorest farms were raised toward the maximum possible, given climate and soil conditions. For example, the yield for maize (shown), could rise significantly across parts of Mexico, West Africa and Eastern Europe if seeds, irrigation, fertilizer and markets were improved.

Sustainable Intensification of Production Systems

- Reduction in agricultural footprint
  - Tropical forests and savannahs

- Close the world’s yield gaps
  - boost the productivity of our best farms—raising their “yield ceiling” through improved crop genetics and management
  - improve the yields of the world’s least productive farms—closing the “yield gap” between a farm’s current yield and its higher potential yield

- Use resources much more efficiently
  - far more crop output per unit of water, fertilizer and energy

Foley, 2011
Closing yield gaps through nutrient management

• Closing maize yield gaps to 50% of the attainable yield (≈ 2.3 Mg ha\(^{-1}\)) in Sub-Saharan Africa primarily requires addressing nutrient deficiencies

• 73% of underachieving areas could close yield gaps by solely focusing on nutrient inputs (with 18%, 16% and 35% increases in N, P\(_2\)O\(_5\) and K\(_2\)O application relative to baseline global consumption, respectively).

• Jointly increasing irrigated area and nutrient application could close yield gaps on all underachieving areas (with 30%, 27% and 54% increases in N, P\(_2\)O\(_5\) and K\(_2\)O application, respectively, and a 25% increase in irrigated hectares)

Potassium Balance
A simplified diagram of the K-cycle
Potassium Balance

1) Numerical difference between potassium input and output
2) Partial nutrient balance, a ratio of quantity of potassium removed to the quantity of potassium applied
Potassium Balance - Global Examples
Increase in soil test K China (1990-2012)

He et al., 2015, Field Crops Research, 173: 49-56
Partial potassium balance in China
K balance in different regions
(‘0000t, kg K₂O /ha in parentheses)

Source: China Agriculture Yearbook, 2009
Source: Shutian Li
Partial K balance in India
(\(K_2O\) fertilizer + manure – crop removal, '000 t)
Regional potassium balances in Sub-Saharan Africa

- K balances are negative across all countries in SSA
- Very low K nutrient inputs from fertilizer or organic resources
- K balances most negative in East and southern Africa
  - High potential crop production
  - High population density and intensive land use
• Manure is the only significant source of K
• Limited quantity and low quality, supplying less than 2 kg K on average
• Few farmers who own cattle concentrate manure in fields closest to homesteads resulting in positive K balances
• K balances also positive in home gardens that receive household waste, including ash from cooking firewood

Adapted from Giller et al., 2006
## Annual Nutrient Budgets for Regions in Brazil (average of 2009 to 2012)

<table>
<thead>
<tr>
<th>Region</th>
<th>Crop removal (Mt)</th>
<th>Applied (Mt)</th>
<th>Balance (Mt)</th>
<th>Removal to use ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>0.91</td>
<td>0.96</td>
<td>0.05</td>
<td>0.95</td>
</tr>
<tr>
<td>Midwest</td>
<td>1.06</td>
<td>1.29</td>
<td>0.23</td>
<td>0.82</td>
</tr>
<tr>
<td>Southeast</td>
<td>0.66</td>
<td>1.02</td>
<td>0.35</td>
<td>0.65</td>
</tr>
<tr>
<td>Northeast</td>
<td>0.30</td>
<td>0.43</td>
<td>0.13</td>
<td>0.70</td>
</tr>
<tr>
<td>North</td>
<td>0.09</td>
<td>0.09</td>
<td>0.00</td>
<td>1.04</td>
</tr>
<tr>
<td>Brazil</td>
<td>3.03</td>
<td>3.79</td>
<td>0.76</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Web tool for nutrient budget calculation at farm level: http://brasil.ipni.net/article/BRS-3293

Soybean and maize represent 84% and 87% of the land and grain production, respectively

Source: IPNI Brazil Program (2016)
Trends in K Removal to Use for the Contiguous 48 States of the U.S.

U.S. Contiguous 48 States

\[ y = e^{-25.334 + 0.013 \times x} \]

\[ R^2 = 0.825 \]

Annual change: 1.3%

Changes in potassium relative frequencies over time: Multiple locations

Average change in percent of samples from 2001 to 2015

Ammonium acetate equivalent soil test level, ppm
Potassium balance by production in Uruguay

![Graph showing potassium balance by production in Uruguay. The x-axis represents K₂O balance (tonnes) ranging from -40,000 to 30,000. The y-axis lists different crop categories: Soybean, Other field crops, Other crops, and Other productions. The graph indicates the potassium balance for 2010, 2000, and 1990.]
Addressing Negative K balances in Soils
Mineral Sources of Soil K

- **Mica**: Dioctahedral, and Trioctahedral,
  - Trioctahedral micas are more weatherable than Dioctahedral micas

- **Feldspar**: Sanidine, Orthoclase & Microline
  - Contributes to a much lesser extent of available K in soils than micas

<table>
<thead>
<tr>
<th>Soil fraction</th>
<th>Concentration in soils (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral</td>
<td>5,000 – 25,000</td>
</tr>
<tr>
<td>Non-exchangeable</td>
<td>50 - 750</td>
</tr>
<tr>
<td>Exchangeable</td>
<td>40 - 600</td>
</tr>
<tr>
<td>Solution</td>
<td>1 - 10</td>
</tr>
</tbody>
</table>

Release of K from structural positions to the soil solution is a very slow process besides having several competitive processes working simultaneously so there is no 1:1 congruence.
Our global soil resource

Soils behave differently to K demand under intensive cropping: Mean exchangeable K (mg/kg) in different soils of West Bengal, initially ($I_0$) and after each successive cropping with maize

<table>
<thead>
<tr>
<th>Location and soil type</th>
<th>$I_0$</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>Difference between $I_0$ and minimal exchangeable K level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gangetic alluvium</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hariharpura</td>
<td>100</td>
<td>90.0</td>
<td>70.0</td>
<td>45.0*</td>
<td>45.0</td>
<td>45.0</td>
<td>55.0</td>
</tr>
<tr>
<td>Daulatabad</td>
<td>130</td>
<td>105</td>
<td>85.0</td>
<td>55.0</td>
<td>55.0</td>
<td>55.0</td>
<td>75.0</td>
</tr>
<tr>
<td>Chinsura</td>
<td>95.0</td>
<td>60.0</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>40.0</td>
<td>55.0</td>
</tr>
<tr>
<td>Memari</td>
<td>130</td>
<td>85.0</td>
<td>55.0</td>
<td>35.0</td>
<td>35.0</td>
<td>35.0</td>
<td>95.0</td>
</tr>
<tr>
<td><strong>Coastal saline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canning</td>
<td>350</td>
<td>265</td>
<td>185</td>
<td>115</td>
<td>85.0</td>
<td>85.0</td>
<td>265</td>
</tr>
<tr>
<td><strong>Acidic alluvium</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birpara</td>
<td>30.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>5.00</td>
</tr>
<tr>
<td>Talipara</td>
<td>40.0</td>
<td>33.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>10.0</td>
</tr>
<tr>
<td><strong>Vindhyan alluvium</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deshra</td>
<td>100</td>
<td>75.0</td>
<td>50.0</td>
<td>20.0</td>
<td>20.0</td>
<td>20.0</td>
<td>80.0</td>
</tr>
<tr>
<td>Garbeta</td>
<td>50.0</td>
<td>42.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Contribution of Non-exchangeable K in a long-term experiment after 13 crop cycles

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Total change in available K in two depths of sampling (kg/ha)</th>
<th>K added</th>
<th>K removed by crops</th>
<th>Contribution of Non-ex K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1985-86</td>
<td>1997-98</td>
<td>Change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-15 cm</td>
<td>15-30 cm</td>
<td>0-15 cm</td>
<td>15-30 cm</td>
</tr>
<tr>
<td>NP</td>
<td>157</td>
<td>160</td>
<td>83</td>
<td>80</td>
</tr>
<tr>
<td>NPK</td>
<td>168</td>
<td>168</td>
<td>136</td>
<td>91</td>
</tr>
<tr>
<td>NPK + FYM</td>
<td>155</td>
<td>166</td>
<td>156</td>
<td>122</td>
</tr>
</tbody>
</table>

Pasricha & Bansal, 2002
How farmers perceive the benefit of potassium

- Lustre/Shine/Quality/ Good color/ Shelf Life: 67%
- Higher Yield: 51%
- Fruit Size: 32%
- Better Root/ Shoot Development/Better Nutrient Absorption: 20%
- Disease/Pest Resistance: 19%
- Vegetative Growth or Prolonged Greenery: 18%
- No. of Fruits/Pods/Flowers: 7%
- Drought Resistance: 3%

Slide courtesy Mosaic India, 2017
Farmers’ apply potassium in crops according to their perception and resource endowment: Example from Kenya

- K used predominantly in flower and tobacco production
- Very low K fertilizer is used in production of cereal crop
- K deficiencies increasingly occurring in cereal production regions

Source: Ministry of Agriculture, Kenya
Thank you

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