Sustainable Intensification and Resilient Dryland Cropping Systems: Opportunities in Sub-Saharan Africa

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1. Sustainable Intensification and Resilient Cropping Systems

2. Challenges and Opportunities: Potential and Actual Yields

3. Case Study – Results – SANREM, INTSORMIL, Africa RISING, SARI, Literature
   Focus on Ghana: Maize, Sorghum, and Soybean.

4. Conclusions and Discussion
Medium Growth Scenario: World = 9.5 billion people by 2050
Africa = 2.2 billion people by 2050.

Population in most sub-Saharan African countries will almost double by 2050.

To meet increasing world population we have increase productivity of grain crops by about 50%.

The most populous countries of Africa.
Forecast 2050: Africa will have 2 billion inhabitants.
Africa: Future Climate Change

Future Scenarios:

In SSA:

- Decrease in wet season precipitation.
- Decrease in length of wet season.
- Increased annual mean temperatures.

Fig. 3. Change in important agroclimatic variables according to GCM projections in p-2060 (top) and p-2085 (bottom) compared to b-1995 (from left to right): wet season precipitation, wet season length and annual mean temperature. The largest changes in the length and precipitation amount of the wet season per grid cell after removing the outliers and the corresponding temperatures are shown. Dark violet colors in the leftmost and middle panel indicate a reduction of 50% or more. White areas are regions with a binodal rainfall regime (eastern Africa) or desert areas (southern Africa) where no main wet season could be identified.
Maize and other grains yield will decrease (> 30%) unless climate smart resilient technologies are adopted.
Cereals grain yield will decrease, and SSA will be the hotspot region when all population increase and climate change are combined together.
Sustainable Intensified Resilient Systems
Sustainable Intensification will help improve productivity and resilience of small holding farmers.


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Sustainable Intensification: Components

Socio-Economic Intensification
- Enabling environments
- Developing markets
- Building social capital
- Creating sustainable livelihoods

Ecological Intensification
- Cropping (Farming) systems
- Efficient use of inputs
- Integrated pest management
- Integrated nutrient management
- Effective agricultural practices

Genetic Intensification
- Higher yield
- Improving nutrition
- Resilient to pest and diseases
- Resilient to climate change
- Diversified cropping systems

Creating Sustainable and Resilient Livelihoods

Resilient Systems: Components

Montpellier Panel Recommendations (2012)

Political Will
- Reduce food price volatility
- Facilitate private investment
- Build enabling environments
- Enable resilient and sustainable intensification
- Combat land and water degradation
- Build climate smart agriculture
- Scale up nutrition
- Focus on rural women and youth
- Build diverse livelihoods

Resilient Markets

Resilient Agriculture

Growth with Resilience

Resilient People

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Sub-Saharan Africa and South Asia started at the same point in 1962, but little progress is made in SSA.
Sub-Saharan Africa has relatively low adoption of improved varieties due to lack of extension programs and also strong breeding programs and capacity.

It is improving. Need to invest in Extension Services and Engagement of farmers and seed production and seed distribution systems.
In SSA we have achieved only about 30% of the attainable yields. This is very low compared to other parts of the world.
Crop Productivity: Attainable vs. Actual

<table>
<thead>
<tr>
<th>Crops</th>
<th>Reported Yield Range</th>
<th>Good Farmers Field</th>
<th>National Average</th>
<th>Yield Gap</th>
<th>Potential Yield Increase</th>
<th>Approx. Genetic Potential*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>1.5 – 8.2</td>
<td>5.5</td>
<td>2.3</td>
<td>3.20</td>
<td>139</td>
<td>10</td>
</tr>
<tr>
<td>Maize</td>
<td>0.5 – 7.2</td>
<td>5.8</td>
<td>1.6</td>
<td>4.20</td>
<td>262</td>
<td>14</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.8 – 5.5</td>
<td>4.5</td>
<td>1.17</td>
<td>2.33</td>
<td>280</td>
<td>10</td>
</tr>
<tr>
<td>Millet</td>
<td>0.5 – 4.5</td>
<td>3.0</td>
<td>1.02</td>
<td>1.98</td>
<td>294</td>
<td>7</td>
</tr>
<tr>
<td>Cowpea</td>
<td>0.8 – 2.6</td>
<td>2.1</td>
<td>0.60</td>
<td>1.50</td>
<td>250</td>
<td>2.5</td>
</tr>
<tr>
<td>Soybean</td>
<td>0.60 – 2.6</td>
<td>2.4</td>
<td>0.90</td>
<td>1.50</td>
<td>166</td>
<td>4</td>
</tr>
<tr>
<td>Cassava</td>
<td>12.5 – 40</td>
<td>28.4</td>
<td>12.5</td>
<td>15.9</td>
<td>127</td>
<td>80</td>
</tr>
<tr>
<td>Yam</td>
<td>3.4 – 30</td>
<td>22.0</td>
<td>14.5</td>
<td>7.5</td>
<td>90</td>
<td>27</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>10.5 – 30</td>
<td>13.0</td>
<td>7.8</td>
<td>5.2</td>
<td>66</td>
<td>15</td>
</tr>
</tbody>
</table>

* Genetic potential not corrected for environment

In SSA (e.g. Ghana) we have opportunities to more than double yield of most cereals and legumes; and by > 60% for tubers.
Objectives of SANREM and INTSORMIL

- Develop and demonstrate locally available sustainable agricultural production systems for smallholder rain-fed farmers that improves food security, productive capacity and ecosystems services of degraded and productive agricultural lands.

- The new practices, knowledge and technological innovations should address food security, economic and social (including gender) viability, soil quality, water productivity, and other ecosystems services.
Resilient Dryland Cropping Systems

Improve productivity and resiliency of cropping systems for rainfed small holding farmers

Focus was on above components.

Crop Residue  Cover Crop  Minimum Tillage

Crop Rotation  Water Harvesting  Nutrient Management
Farmers Driven Research Approach

Farmers should be the key component at all stages of research and development

Farmers should feel the ownership of research.
Approach and Road Map

1. Needs Assessment: Problem Diagnosis with Farmers
2. Collecting baseline information on socio-economic and biophysical conditions
3. Gender Sensitization
4. Community Engagement / Network Building with all Stakeholders
5. Collaboratively identified practices for evaluation
6. On-Farm (5-10 villages) and On-Station (2-3) Demonstrations (Mother-Trials)
7. Farmers led and managed: single / multiple CAPs in their own fields (Baby-Trials): 10 – 25 in each village
8. Technical and Impact Assessment
9. Methodology Assessment and Gender Impact Analyses
10. Extend and Scale-up in other villages within and outside the region (Baby trials)
Case Study: Maize – Value Chain – Ghana
Maize: Improved Genotypes and Hybrids

Grain yield increased by 400% by hybrids, and by 200% by open pollinated varieties.

Grain yield increased by 400% by hybrids, and by 200% by open pollinated varieties with drought tolerance and striga resistance.
Maize planted on tied ridges increased grain yield in all treatments compared to flat bed systems.
Maize: Response to Nitrogen Fertilizer

Fertilizer application of about 80 to 90 kg ha\(^{-1}\) of nitrogen can increase grain yield in the range of 80 to 300%.

<table>
<thead>
<tr>
<th>Nitrogen Levels (kg ha(^{-1}))</th>
<th>Maize Yield (t ha(^{-1}))</th>
<th>% increase over control</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Control</td>
</tr>
<tr>
<td>30</td>
<td>31</td>
<td>31%</td>
</tr>
<tr>
<td>60</td>
<td>56</td>
<td>56%</td>
</tr>
<tr>
<td>90</td>
<td>81</td>
<td>81%</td>
</tr>
</tbody>
</table>

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</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Control</td>
</tr>
<tr>
<td>40</td>
<td>193</td>
<td>193%</td>
</tr>
<tr>
<td>80</td>
<td>263</td>
<td>263%</td>
</tr>
<tr>
<td>120</td>
<td>333</td>
<td>333%</td>
</tr>
<tr>
<td>160</td>
<td>435</td>
<td>435%</td>
</tr>
</tbody>
</table>

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<tr>
<td>0</td>
<td>0</td>
<td>Control</td>
</tr>
<tr>
<td>40</td>
<td>233</td>
<td>233%</td>
</tr>
<tr>
<td>80</td>
<td>341</td>
<td>341%</td>
</tr>
<tr>
<td>120</td>
<td>434</td>
<td>434%</td>
</tr>
<tr>
<td>160</td>
<td>294</td>
<td>294%</td>
</tr>
</tbody>
</table>

(2) Annual Report of Africa RISING project - subprojects carried out by CSIR-SARI, 2013.
Maize: Integrated Nutrient Management

A detailed meta-analysis of published papers in SSA on response of maize to inorganic and combination of inorganic and organic sources showed positive responses to combinations (INM).

Chivenge et al. (2011). Plant and Soil 342:1-30
Crop rotation with legume (soybean or cowpea) or fallow and Mucuna increased grain yield of maize by about 60%.

Maize: Response to Crop Residue

Rotation and incorporation of leguminous crops / residue provided about 75 to 100% of nitrogen needs, and doubled yields.

Savanna Transition Zone of Ghana

Treatments

Minimum Tillage – Maize – Soybean Systems

Upper West Region

Nyoli: 2011

Source: Naab et al. SANREM CRSP Research Activities

Use of minimum tillage in on-farm mother and baby test had similar yields to that of conventional tractor tillage in all cropping systems. Economics showed beneficial response.
Maize: Response to Tillage Practices

Minimum tillage with improved management (fertility and herbicide) increased yield (>300%) and also had economic benefits.

Case Study: Ghana - Sorghum and Millet
Sorghum: Tillage – Genotype - Fertilizer

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Stover (kg ha(^{-1}))</th>
<th>Grain (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tillage System</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional Tillage</td>
<td>3797 a</td>
<td>1379 a</td>
</tr>
<tr>
<td>No Tillage</td>
<td>3161 a</td>
<td>1641 a</td>
</tr>
<tr>
<td><strong>Varieties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kapala</td>
<td>2218 a</td>
<td>1941 a</td>
</tr>
<tr>
<td>Dorado</td>
<td>2555 a</td>
<td>1694 a</td>
</tr>
<tr>
<td>Local (Chere)</td>
<td>5663 b</td>
<td>895 b</td>
</tr>
<tr>
<td><strong>Fertilizer Rate (N kg/ha)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1973 a</td>
<td>912 a</td>
</tr>
<tr>
<td>30</td>
<td>4112 b</td>
<td>1395 a</td>
</tr>
<tr>
<td>60</td>
<td>3832 b</td>
<td>1462 a</td>
</tr>
<tr>
<td>90</td>
<td>3632 b</td>
<td>2276 b</td>
</tr>
<tr>
<td>120</td>
<td>3848 b</td>
<td>1506 a</td>
</tr>
</tbody>
</table>

Tillage: No difference
Genetics: >100 % Increase
Nutrients: >100 % Increase

Naab et al. INTSORMIL Project

Sorghum on various managements had higher yields (>100%).
Use of contour ridging (ACN), inorganic fertilizer and crop residue increased crop yields (>40%) and soil carbon. Tillage practice did not influence yield and soil carbon.
Application of nitrogen and phosphorus significantly increased grain yield of sorghum. N = ~80% increase; P = ~400% increase.
Soybean
No difference in tillage systems for maize residue or grain yield. Minimum tillage improved soybean residue and grain yield (30%).
Application of P (26 kg/ha) increased grain yield of soybean (>30%) in all tillage systems and crop rotations.

NPK (37:16:31 kg/ha)
Remarks and Conclusions
Various Yield Gaps and Approaches

Different yield gaps can be achieved by improving extension services, facilitating inputs and market opportunities, and enhancing research capacity and international partnerships and cutting edge genetics and improved efficient technologies.
We Need to Build Integrated Programs; and Not Short Term Individual/Independent Projects
Conclusions

- There are opportunities to more than double (~200%) yield of major cereals and legumes in through use of intensive sustainable and climate smart technologies.
- Engagement of farmers and value chain partners is critical.
- NARS should develop sustainable programs and not be contained with limited short-term projects. Capacity building should be integral part.
- Research and donors should increase communication and work as team and complement each others programs.
Acknowledgements

- **Farmers**
- **Savanna Agricultural Research Institute, NGOs, MOFA**
- Ghana: SARI: J.B. Naab and R.A.L. Kanton (SARI) and their team.
- Mali: IER, M. Doumbia, S. Traore, M. Kone, O. Samake, P. Sissoko
“You can’t eat the potential yield, but need to raise the actual by combating the stresses”

Norman E. Borlaug
(Nobel Peace Laureate)