Soil and water conservation and nutrient use efficiencies in smallholder potato-legume intercropping systems

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What is the problem?

- Potato yield stagnates at 13 t/ha in SSA (FAOSTAT, 2017)
  - attainable yield is 30-40 t/ha (Parker et al. 2019)

- Focus given mainly on potato diseases, nutrition quality, seed systems

- Forgetting about the mother of all these: SOIL
Land Degradation in SSA

- Above 80% of cropland is degraded in SSA (FAO, 2017)

- Land degradation related strongly ($r=0.87$) with low crop productivity (Lal et al. 2014)

Source: FAOSTAT (2017)
Major causes

- Population pressure
- Inappropriate land use and soil management practices

Sub Saharan Africa Population

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>1.06 b</td>
</tr>
<tr>
<td>2050</td>
<td>2.12 b</td>
</tr>
</tbody>
</table>

Source: UNWP (2019)
Cont...

- Steady negative nutrient balances
- Hilly and mountainous terrain; exacerbated soil erosion rates
- Maximum soil disturbance; low residue return;

Source: ISRIC (2018)
Cont…

- Climate change
  - Increasing temperatures
  - Erratic rainfall
  - Recurrent droughts
dominant low-input agricultural systems
What works?

Interactions of soil and water management practices used by farmers, some of which may result in synergism leading to healthy and productive crops and agroecosystems.

- Fertilizers
- Cover crops
- Green manures
- Mulching
- Compost
- Rotations

Integrated soil fertility management practices (CIAT, 2018; Momanyi et al. 2019)

Enhanced Soil Fertility

Conservation Synergism

Healthy Crops

Healthy Agroecosystem

Capture and retention of precipitation and runoff water (e.g., zai)
- Tie ridges, trash lines, mulching
- Conservation agriculture
- Natural vegetation and cover crops
Only 5% of potato farmers in SSA practice intercropping

Where is the problem?

- lack of science-based evidence?
- more value on short-term benefits
- lack of extension information
- land tenure systems
- lack of supply of high quality legume seeds
- socioeconomic factors e.g. gender, income, legume attributes
Intercropping increases Potato DM yield

- Potato + vetch increased PEY from 12 t/ha to 19 t/ha in highland Kenya (Nyawade et al. 2019c)

- Potato + lablab increased PEY from 6 t/ha to 12 t/ha in lowland Kenya (Gitari et al. 2018)

- Potato + Lucerne intercropping increased yield by 4 t/ha over sole potato in UH AEZ (Nyawade et al. 2019b)
Intercropping controls soil erosion

Source: Nyawade et al. 2018b
Nutrient losses are reduced by up to 4 fold with intercropping

Nyawade et al. (2019)
Intercropping optimizes soil temperature and soil moisture

SWC was 26-46% greater with intercropping
Intercropping lowered soil temperature to 15-20°C
## Nutrient use efficiencies

<table>
<thead>
<tr>
<th>Agro-ecology</th>
<th>Cropping system</th>
<th>N</th>
<th>P</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kg PEY kg(^{-1}) nutrient supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midland</td>
<td>Sole potato</td>
<td>98.1a</td>
<td>109.2a</td>
<td>Gitari et al. 2018</td>
</tr>
<tr>
<td></td>
<td>Potato + lablab</td>
<td>164.8c</td>
<td>287.4c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potato + garden pea</td>
<td>131.9b</td>
<td>198.1b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potato + bean</td>
<td>128.7b</td>
<td>187.7b</td>
<td></td>
</tr>
<tr>
<td>Upper highland</td>
<td>Sole potato</td>
<td>126.2b</td>
<td>135.6a</td>
<td>Nyawade et al. 2019</td>
</tr>
<tr>
<td></td>
<td>Potato + vetch</td>
<td>198.2d</td>
<td>305.4c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potato + desmodium</td>
<td>189.3cd</td>
<td>299.8b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potato + lucerne</td>
<td>172.3c</td>
<td>295.8b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potato + lupin</td>
<td>187.2cd</td>
<td>367.5d</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potato + lablab</td>
<td>44.2a</td>
<td>298.5b</td>
<td></td>
</tr>
</tbody>
</table>
Intercropping increases radiation use efficiency

Intercropping increased RUE by 21-70%

Radiation use efficiency (MJPAR-1)
Considerations?
When the slope is greater than 20%?

- Integrate with structural SWC
- This increases soil water capture downslope
When crops differ in maturity, growth patterns?

- Do relay intercropping

<table>
<thead>
<tr>
<th>Time to Lablab introduction</th>
<th>Soil loss (t/ha)</th>
<th>PEY (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same time</td>
<td>10.6</td>
<td>11.6</td>
</tr>
<tr>
<td>2 weeks</td>
<td>17.8</td>
<td>17.8</td>
</tr>
<tr>
<td>3 weeks</td>
<td>22.7</td>
<td>22.9</td>
</tr>
<tr>
<td>4 weeks</td>
<td>19.1</td>
<td>26.3</td>
</tr>
<tr>
<td></td>
<td>17.1</td>
<td></td>
</tr>
</tbody>
</table>
➢ Adjust spatial arrangement

➢ 2:2 row ratio gave greater yield

<table>
<thead>
<tr>
<th>Intercropping system</th>
<th>Yield increment (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato + Desmodium in 2:1 row ratio</td>
<td>12.5</td>
</tr>
<tr>
<td>Potato + Desmodium in 2:2 row ratio</td>
<td><strong>30.5</strong></td>
</tr>
<tr>
<td>Potato + Lablab in 2:1 row ratio</td>
<td>8.5</td>
</tr>
<tr>
<td>Potato + Lablab in 2:2 row ratio</td>
<td><strong>16.9</strong></td>
</tr>
<tr>
<td>Potato + Lucerne in 2:1 row ratio</td>
<td>11.2</td>
</tr>
<tr>
<td>Potato + Lucerne in 2:2 row ratio</td>
<td><strong>18.2</strong></td>
</tr>
</tbody>
</table>
Integrate intercropping with Si

Crop water productivity (kg ha$^{-1}$ m$^{-3}$)

- Sole Potato
- Potato + Desmodium
- Potato + Faba bean
- Potato + Lupin

P use efficiency (kg PEY kg$^{-1}$ P supply)

- Sole Potato
- Potato + Desmodium
- Potato + Faba bean
- Potato + Lupin

Is soil P fixed, too low?
Does Potato Cultivar choice matter?

- Greater yield recorded with Unica than Shangi in midland (Nyawade et al. 2018)

- **Potato equivalent yield (t/ha)**
  - Sole Shangi: 5.6
  - Sole Unica: 10.8
  - Shangi + Desmodium: 8.5
  - Unica + Desmodium: 16.6
Way forward

- Is legume intercropping a sole replacement for fertilizer use?
- Legume intercropping vs economics?
- What constitutes a desirable combination?
- Scaling readiness? > challenges?
- CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)
- CGIAR Research Program on Roots, Tubers and Bananas (RTB)
- Syngenta Foundation for Sustainable Agriculture
- BMZ/GIZ
- CIP and University of Nairobi