Potential for Cropland Expansion in Africa: Estimates under Alternative Assumptions

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Land and people in SSA

FACT #1

• Despite urbanization trends, rural populations still growing at 1 to 2.5% per year

• Arable land resources are generally taken to be abundant, but indicators of declining land availability in high-density areas:
  – Declining trends in farm size & fallow rates
  – Persistently concentrated rural settlements
Growth of rural populations in SSA

These patterns are true for both high and low density countries
Clustering of rural populations in SSA

<table>
<thead>
<tr>
<th>Region</th>
<th>top 1%</th>
<th>top 5%</th>
<th>top 10%</th>
<th>top 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>East/Central</td>
<td>17%</td>
<td>44%</td>
<td>61%</td>
<td>76%</td>
</tr>
<tr>
<td>Southern</td>
<td>14%</td>
<td>37%</td>
<td>53%</td>
<td>73%</td>
</tr>
<tr>
<td>West</td>
<td>13%</td>
<td>36%</td>
<td>51%</td>
<td>70%</td>
</tr>
<tr>
<td>SSA</td>
<td>16%</td>
<td>42%</td>
<td>58%</td>
<td>76%</td>
</tr>
</tbody>
</table>

Rural populations are highly spatially concentrated

Source: AfriPop (rural areas only)
Clustering of rural populations in SSA

<table>
<thead>
<tr>
<th>Region</th>
<th>top 1%</th>
<th>top 5%</th>
<th>top 10%</th>
<th>top 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>East/Central</td>
<td>15%</td>
<td>40%</td>
<td>57%</td>
<td>74%</td>
</tr>
<tr>
<td>Southern</td>
<td>12%</td>
<td>32%</td>
<td>47%</td>
<td>66%</td>
</tr>
<tr>
<td>West</td>
<td>10%</td>
<td>29%</td>
<td>43%</td>
<td>60%</td>
</tr>
<tr>
<td>SSA</td>
<td>14%</td>
<td>36%</td>
<td>52%</td>
<td>70%</td>
</tr>
</tbody>
</table>

Source: AfriPop (rural areas only)

even after throwing out areas with <400 mm rainfall
Land and people in SSA

FACT #2

• Increased intensification (Headey and Jayne) but soil fertility/SOM declining in densely populated areas with continuous cultivation (e.g. Dreschel *et al.* 2001)
  – incl. evidence of low crop response to inorganic fertilizer application with low SOM (e.g. Marenya & Barrett 2009)

FACT #3

• Rising investor interest in large-scale land acquisitions
  – ostensibly in surplus land
Facts → Policy questions

• What is the appropriate response to stagnant productivity in densely populated areas?
  1. Intensification  Viable? Sustainable?
  2. Extensification  Limited possibilities
  3. Rural-urban migration / NFRE
  4. Rural-rural migration  via public investments…

• How much surplus land is there in SSA?
  – Resolving this question is critical
  – Suggests tradeoffs to land-oriented FDI
How much land is there really?

• Recent assessments have been widely commented on
  – 200 million ha, half of which in just 4 countries...

• We revisit this work & seek to update it with
  – Newer, alternative datasets on landcover, pop, etc.
  – Refined assumptions about profitability
Our approach

• Builds on earlier work
• Incorporates newer data, higher resolution
  – Rural population distributions
  – Cultivated area, forest cover information
• Argues for a more nuanced approach to viewing the economics of expansion
  – Agronomic potential $\rightarrow$ potential yields
  – Economic remoteness $\rightarrow$ spatial prices
• Not the definitive answer! Incremental advance in how best to address the question
5” spatial database for SSA

- Land cover
  - Cultivated area
  - Forest cover
- Population
- Potential yields
- Accessibility
- Prices
Defining “available” land

1. **Criteria for determining expansion envelope:**
   - Unpopulated, uncultivated, non-forest, non-PA

2. **Criteria for determining economic viability:**
   - For each grid cell: economic returns to expansion calculated for 9 crops (rainfed, low & med. inputs)
   - Returns calculated for gross margins from most profitable crop mix in a particular grid cell

\[
\text{[yield (MT/ha) } \times \text{ output price ($/MT)]} - \text{ variable production costs ($/ha)}
\]
Potential yields

- GAEZ database: estimates of agroclimatically attainable yield
  - Distill large amts of biophysical production info
  - Crop-specific
  - 3 input management levels, water management
- Rainfed production: low & medium inputs
  - Estimates are (much) higher than observed
- We define scaling factors for attainable share of potential yields
  - Low inputs: 40%; medium: 32% of potential yields
Output prices

- Transfer costs imply spatial prices
- Output prices decline with remoteness
- Start with wholesale prices in urban markets
- Distance decay function
  \[ P_{i}^{farmgate} = P_{j}^{market} \cdot e^{-d_{ij}/\max(d_{ij})} \]
Output prices

WB Pink Data
• Maize
• Sorghum
• Rice
• Barley
• Wheat
• Banana
• Coffee
• Cotton
• Soybean
## Cost of production

<table>
<thead>
<tr>
<th>Costs (USD/ha)</th>
<th>Low inputs</th>
<th>Medium inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family labor</td>
<td>251.43</td>
<td>251.43</td>
</tr>
<tr>
<td>Hired labor</td>
<td>0</td>
<td>32.22</td>
</tr>
<tr>
<td>Animal traction</td>
<td>12.95</td>
<td>31.60</td>
</tr>
<tr>
<td>Basal fertilizer</td>
<td>0</td>
<td>30.66</td>
</tr>
<tr>
<td>Top dressing</td>
<td>0</td>
<td>31.39</td>
</tr>
<tr>
<td>Herbicides</td>
<td>0</td>
<td>0.34</td>
</tr>
<tr>
<td>Seed</td>
<td>0</td>
<td>37.82</td>
</tr>
</tbody>
</table>

**Total variable costs**  
- Low inputs: 264.39 USD/ha  
- Medium inputs: 415.47 USD/ha

- Based on Zambia household data
Baseline
Replicate DB/FS estimates:
- suitable
- unforested
- not protected
- low density

Refined economic criteria
1. Gross margins > 0, assuming agroclimatically attainable yield
2. Gross margins > 0, realistically attainable yield
3. Gross margins > 250, realistically attainable yield
4. Gross margins > 500, realistically attainable yield

Alternative data sources
- Currently cultivated land
- Forest cover
- Population distributions
<table>
<thead>
<tr>
<th>Country</th>
<th>baseline</th>
<th>v1</th>
<th>v2</th>
<th>v3</th>
<th>v4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angola</td>
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<td>1,873</td>
<td>1,873</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Cameroon</td>
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<td>1,658</td>
<td>730</td>
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<td>CAR</td>
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<tr>
<td>Chad</td>
<td>4,642</td>
<td>561</td>
<td>561</td>
<td>561</td>
<td>561</td>
</tr>
<tr>
<td>DRC</td>
<td>27,200</td>
<td>26,700</td>
<td>26,700</td>
<td>22,800</td>
<td>900</td>
</tr>
<tr>
<td>Congo, Rep.</td>
<td>14,200</td>
<td>14,200</td>
<td>14,200</td>
<td>12,500</td>
<td>220</td>
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<tr>
<td>Ethiopia</td>
<td>7,030</td>
<td>1,662</td>
<td>1,662</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Gabon</td>
<td>2,161</td>
<td>2,161</td>
<td>2,161</td>
<td>1,639</td>
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<tr>
<td>Kenya</td>
<td>4,767</td>
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<tr>
<td>Madagascar</td>
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<tr>
<td>Mali</td>
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<td>Mozambique</td>
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<tr>
<td>Sudan</td>
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<td>3,438</td>
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<td>153</td>
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<td>Tanzania</td>
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<tr>
<td>Zambia</td>
<td>4,656</td>
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<tr>
<td>East/Central</td>
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<td>60,045</td>
<td>37,889</td>
<td>1,835</td>
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<tr>
<td>Southern</td>
<td>55,239</td>
<td>25,746</td>
<td>25,746</td>
<td>10,315</td>
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<tr>
<td>West</td>
<td>43,403</td>
<td>10,683</td>
<td>10,683</td>
<td>6,456</td>
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<td>SSA</td>
<td>200,343</td>
<td>96,474</td>
<td>96,474</td>
<td>54,660</td>
<td>3,868</td>
</tr>
</tbody>
</table>

Imposing economic criteria & more realistic attainable yields leads to declines >90% in area estimates!
More recent land cover data indicates greater % of land already under cultivation

Cultivated area data from GAEZ

~20% reduction in estimates of surplus land
Sensitivity of estimates

Assumptions about attainable yields are important (particularly in Eastern/Central)

low-input management

medium-input management
Sensitivity of estimates

Change in estimated land availability as a function of forest cover within candidate areas

![Graphs showing surplus land (ha) and deviation from baseline as a function of % forested (grid cell) for different regions (East/Central, Southern, West).]
Sensitivity of estimates

At what population density threshold should a grid cell be considered “available”?

![Graph showing Surplus land (ha) vs. pop density threshold and Deviation from baseline vs. pop density threshold. The baseline for both graphs is set at 25.]
Concentrated surplus under all scenarios

<table>
<thead>
<tr>
<th>% of total</th>
<th>baseline</th>
<th>v1</th>
<th>v2</th>
<th>v3</th>
<th>v4</th>
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<tbody>
<tr>
<td>20%</td>
<td>&lt;1</td>
<td>1</td>
<td>1</td>
<td>&lt;1</td>
<td>1</td>
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<tr>
<td>40%</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>60%</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
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<tr>
<td>80%</td>
<td>13</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>5</td>
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</tbody>
</table>

**Rank**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>v1</th>
<th>v2</th>
<th>v3</th>
<th>v4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Madagascar</td>
<td>DRC</td>
<td>DRC</td>
<td>DRC</td>
<td>DRC</td>
</tr>
<tr>
<td>2nd</td>
<td>DRC</td>
<td>Madagascar</td>
<td>Madagascar</td>
<td>Congo-Brazz.</td>
<td>Madagascar</td>
</tr>
<tr>
<td>3rd</td>
<td>Sudan</td>
<td>Congo-Brazz.</td>
<td>Congo-Brazz.</td>
<td>Madagascar</td>
<td>Chad</td>
</tr>
<tr>
<td>4th</td>
<td>Congo-Brazz.</td>
<td>CAR</td>
<td>CAR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th</td>
<td>CAR</td>
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<td>Tanzania</td>
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<td>6th</td>
<td>Mali</td>
<td>Sudan</td>
<td>Sudan</td>
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<td>7th</td>
<td>Mozambique</td>
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</tr>
<tr>
<td>8th</td>
<td>Tanzania</td>
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<tr>
<td>9th</td>
<td>Angola</td>
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<tr>
<td>10th</td>
<td>Ethiopia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

• Earlier estimates (DB/FS) appear very optimistic
  – Sensitive to input data
  – Sensitive to assumptions about prices & costs
• With few, very *conservative additional assumptions* about economic feasibility, the estimate of suitable surplus land *declines by up to 90%*
  – Note that we are almost certainly underestimating true costs of expansion
Meanwhile, back on the farm...

- Evidence that continuously cultivated lands in high-density rural areas are experiencing a reduction in responsiveness to standard intensification recipes (Dreschel et al. 2001)
- Reduced fallow $\rightarrow$ soil organic carbon losses $\rightarrow$ reduced responsiveness to inorganic fertilizer
- Soil rehabilitation in severely mined areas is expensive and lengthy
- Upshot: bringing new land may be cheaper than intensification as a development pathway – but with potentially major global environmental costs
Fertilizer response rates in degraded areas

Maize yields as a function of plot soil carbon content

Source: Marenya & Barrett 2009
Fertilizer response rates in degraded areas

Estimated marginal value product of nitrogen fertilizer conditional on plot soil carbon content

Source: Marenya & Barrett 2009
Policy implications

• Reducing barriers to economic exploitation of remote [waterlogged, disease-prone, etc.] land may enable spontaneous re-settlement
  – E.g. white gold of Gokwe, Zimbabwe
• Under conditions of land constraints, the political process of land allocation will influence whether smallholder agriculture has a future
• The limited scope for extensification, absorption by non-farm sector, and sustainable intensification → suggests the importance of keeping the rural-rural pathway available