Effects of Human Population Density on Smallholder Agriculture in Kenya

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Presentation at the International Center for Tropical Agriculture (CIAT) -Kenya
Nairobi, December 3rd, 2013
Poverty and hunger

- Reducing poverty and hunger have been a critical policy concern in most of the sub-Saharan African countries for the past half-century
- Yet, despite series of governments and development agencies interventions, poverty still remains pervasive
- More than 40% of sub-Saharan Africa’s population is estimated to be below the poverty line
- Majority of the hungry and poor are the rural households who are smallholder farmers
Hunger and poverty reduction strategy

- Based on the region’s land resource endowment, an agricultural-led growth strategy has been touted as the best way for rapid and sustained reductions in food insecurity and poverty.
  - Fischer and Shah (2010) report that sub-Saharan Africa has about 202/446 million hectares of uncultivated arable land in the world.
  - The region is also reported to possess an enormous yield gap in staple grains (Fischer et al., 2009; Deininger and Byerlee, 2011).
  - Renewed interest in the “unutilized” land – “land grabs” – following food and fuel prices volatility and adverse climatic conditions.
Household landholding vs. income

Source: Jayne et al., 2003
Land abundance hypothesis
-- what do we know?--

• Newspaper headlines and household level survey data show a different picture:
  • Newspaper headlines show rising land conflicts
  • Population densities in many areas of rural Africa are much higher than they were two decades ago:
    • High populations growth rates (2.5%/year) and low urbanization rates
    • Led to declining trends in farm size and fallow rates
      • More than half of smallholder farms are less than 1.5 hectares
  • Even in countries with low population densities, there are inequalities in land access:
    • Persistently concentrated rural settlements
      • 1% of SSA’s rural areas contain 16% of its rural people
      • 20% of SSA’s rural areas contain 76% of its rural people
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Newspaper headlines show increased land conflicts
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- Causes of the wave of violence that engulfed Kenya after the presidential election in December 2007
  - Local analysts point to historical land inequalities the main cause
Land abundance hypothesis
-- what do we know?--

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Rural population growth
1960-2010

Source: World Development Indicators, World Bank
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![Graph showing arable land per capita from 1960 to 2010](image)
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### Hectares of arable land per person in agriculture (10 year average)

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia</td>
<td>0.501</td>
<td>0.444</td>
<td>0.333</td>
<td>0.224</td>
<td>0.218</td>
<td>43.5%</td>
</tr>
<tr>
<td>Zambia</td>
<td>0.643</td>
<td>0.607</td>
<td>0.398</td>
<td>0.342</td>
<td>0.297</td>
<td>46.2%</td>
</tr>
<tr>
<td>Kenya</td>
<td>0.462</td>
<td>0.364</td>
<td>0.305</td>
<td>0.264</td>
<td>0.219</td>
<td>47.4%</td>
</tr>
<tr>
<td>Uganda</td>
<td>0.655</td>
<td>0.569</td>
<td>0.509</td>
<td>0.416</td>
<td>0.349</td>
<td>53.3%</td>
</tr>
<tr>
<td>Malawi</td>
<td>0.480</td>
<td>0.466</td>
<td>0.357</td>
<td>0.304</td>
<td>0.307</td>
<td>64.0%</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>0.613</td>
<td>0.550</td>
<td>0.452</td>
<td>0.420</td>
<td>0.469</td>
<td>76.5%</td>
</tr>
<tr>
<td>Rwanda</td>
<td>0.212</td>
<td>0.213</td>
<td>0.195</td>
<td>0.186</td>
<td>0.174</td>
<td>82.1%</td>
</tr>
<tr>
<td>Mozambique</td>
<td>0.356</td>
<td>0.337</td>
<td>0.320</td>
<td>0.314</td>
<td>0.294</td>
<td>82.6%</td>
</tr>
<tr>
<td>Ghana</td>
<td>0.646</td>
<td>0.559</td>
<td>0.508</td>
<td>0.492</td>
<td>0.565</td>
<td>87.5%</td>
</tr>
<tr>
<td>Nigeria</td>
<td>0.982</td>
<td>0.860</td>
<td>0.756</td>
<td>0.769</td>
<td>0.898</td>
<td>91.4%</td>
</tr>
</tbody>
</table>
Land abundance hypothesis
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    • Persistently concentrated rural settlements
      • 1% of SSA’s rural areas contain 16% of its rural people
      • 20% of SSA’s rural areas contain 76% of its rural people
    • All arable land is either fully allocated
Figure 3: Population density in Kenya

![Population density in Kenya](image-url)
Diminishing land sizes
--smallholder intensification--

• So, what do diminishing landholding sizes mean for a feasible poverty reduction strategy in sub-Saharan Africa?
  • In the middle of increased smallholder inaccessibility to land?
  • Limited off-farm opportunities and migration?
• The **Asian green revolution** was a small farm phenomenon (Johnston and Kilby, 1975; Mellor, 1976)
  • Over 80 percent of farms in India, Bangladesh, Indonesia, China, Japan and Viet Nam are less than two hectares
  • Is there a potential for similar forms of inclusive smallholder-led agricultural growth in SSA?
Boserup (1965): Land use intensity responds to population density

- Value output per hectare cultivated
- Potential forms of intensification:
  - Modern inputs use
    - Fertilizers
    - High yielding seeds and quick maturing crops
  - Soil quality improvements
    - Terracing, mulching, etc.
  - Irrigation – water availability allowing
  - Improved crop choices – shift to higher value crops
  - Reduced fallow / continuous cultivation
Study objectives and approach

- Effects of increasing population density on smallholder agricultural intensification in Kenya
- Conceptual framework—utility maximization problem
  - Household problem is to maximize its utility
  - Derive factor inputs and output supply functions
  - Estimate the impact of rising population densities on these variables
Effects of population density on smallholder-intensification - analytical framework

- **Observed**
  - Population density
  - Land prices
  - Non-market institutions
  - Landholding
  - Expected output prices
  - Input prices
  - Information flow, institution development, transaction costs
  - Input demand
  - Output supply
  - Income

- **Unobserved**
  - DIRECT EFFECTS
  - INDIRECT EFFECTS
Data and econometric issues

- **Diversified production systems:**
  - Aggregate outputs in some manner – use value per unit of land
- **Unobservable output price:**
  - Output price observed after production decisions are undertaken
  - Expected maize prices model
    - *Dependent variable:* maize price received per kg by household
    - *Explanatory variables:* maize price in regional market; distances to regional markets, lagged NCPB prices, transportation and storage facilities, distances to motorable roads, and buyer types, etc.
- **Population density variable is potentially endogenous:**
  - *Control function* estimation approach
    - Instruments: lagged population density, rainfall, soil quality, elevation, ethnicity, etc.
Econometric models

\[
\ln q(p_{it}, w_{it}) = \alpha_{1i} + \beta_1 \ln \hat{p}_{it} + \sum_{j=1}^{M} \gamma_{1j} \ln w_{jit} + \rho_1 \ln \varphi_{it} + Z_{it} \kappa_1 + V_{it} \nu_1 + \delta_1 \hat{u}_{it} + \tau_1 \hat{\delta}_{it}^2 + \varepsilon_{1it} \quad (1)
\]

\[
\ln x_j (p_{it}, w_{it}) = \alpha_{2ij} + \beta_{2j} \ln \hat{p}_{it} + \sum_{j=1}^{M} \gamma_{2j} \ln w_{jit} + \rho_2 \ln \varphi_{it} + Z_{it} \kappa_2 + V_{it} \nu_2 + \delta_2 \hat{u}_{it} + \tau_2 \hat{\delta}_{it} + \varepsilon_{2ijt} \quad (2)
\]

- **Dependent variables**
  - \( q \): value of gross and net outputs per unit of land; income per adult equivalent
  - \( x \): intensity of fertilizer use; intensity of cash inputs use
Data sources

- Household Survey Panel Data:
  - Nationwide Egerton University (Tegemeo Institute) rural household survey panel dataset

- National Population Census Data:

- Gridded Population Data:
  - High-resolution gridded estimates of rural population distributions -GRUMP (Global Rural-Urban Mapping Project)
    - Population density: persons/km² of arable land
    - Land quality – agricultural potential
## Results: Smallholder intensification

<table>
<thead>
<tr>
<th></th>
<th>Fertilizer use kg/ha</th>
<th>Purchased inputs KSh/ha</th>
<th>Crop production kg/ha</th>
<th>Income KSh/ae</th>
<th>Off-farm income KSh/ae</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct partial effects</strong></td>
<td>0.129***</td>
<td>0.097***</td>
<td>0.135***</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Indirect partial effects</strong></td>
<td>-0.023***</td>
<td>-0.021***</td>
<td>-0.037***</td>
<td>-0.035***</td>
<td>0.014*</td>
</tr>
<tr>
<td><strong>Total partial effects</strong></td>
<td>0.107***</td>
<td>0.077***</td>
<td>0.098***</td>
<td>-0.035***</td>
<td>0.014*</td>
</tr>
<tr>
<td><strong>Turning point</strong></td>
<td>617</td>
<td>729</td>
<td>713</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Number of observations</strong></td>
<td>5845</td>
<td>5845</td>
<td>5845</td>
<td>5845</td>
<td>5845</td>
</tr>
<tr>
<td><strong>Number of households</strong></td>
<td>1169</td>
<td>1169</td>
<td>1169</td>
<td>1169</td>
<td>1169</td>
</tr>
</tbody>
</table>
Results: Farm intensification thresholds

Figure 1: Fertilizer quantities applied per hectare cultivated

![Fertilizer quantities applied per hectare cultivated](image1)

Figure 2: Total value of cash expenditures per ha cultivated

![Total value of cash expenditures per ha cultivated](image2)

Figure 4: Net crop income per hectare cultivated

![Net crop income per hectare cultivated](image4)

Figure 5: Net crop income per family labor (resident adults)

![Net crop income per family labor (resident adults)](image5)
Results overview

• Literature has not considered what lies beyond the smallholder intensification
  • Intensification not possible beyond some population density thresholds
  • Soil fertility is declining in densely populated areas due to nutrient mining with continued cultivation and reduced fallows (Dreschel et al., 2001)
  • Literature show low crop response to inorganic fertilizer application due increased soil acidity as a result of inorganic fertilizer overuse (Marenya & Barrett, 2009)
Areas of further research

• Studying the linkages between rising population density, effects on farm behavior, e.g.
  • More continuous cultivation and reduced fallow
  • Impacts on soil fertility/carbon
  • Crop response to fertilizer application
  • Feasible options for sustainable intensification in light of these trends

• Teasing out these relationships at least in some countries
Policy suggestions

• Sustainable intensification in densely populated areas
  • Public investment in agricultural research focusing on new land-saving farm technologies and practices appropriate for small farms

• Rural-rural migration
  • Incentives for people owning more land than they need to release what they don’t need to land-poor groups
  • Physical infrastructure investment in less populated areas e.g. roads and irrigation

• Rural-urban migration
  • Off-farm employment opportunities in urban center
  • Invest in education to equip students necessary skills
Acknowledgements
THANK YOU

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Assistant Professor, AFRE, Michigan State University
Senior Research Fellow, Tegemeo Institute, Egerton University
Food Security Group: http://fsg.afre.msu.edu/
Econometric models [2]

• **Explanatory variables**
  
  • Output price—expected maize prices (time-varying)
    - Predicted maize prices
    - Square of residual from the first stage regression of maize prices to capture expected maize prices variability
  
  • Input prices – wage rate, land rent, fertilizer prices (time varying)
  
  • Village level population density (time varying)
    - Population density variable
    - Residuals from the first stage population density regression
    - We also test for potential non-linear relationships
  
  • Household level variables
    - Demographic, distances to infrastructural facilities and services
  
  • Village level variables
    - Rainfall quantity and variability
  
  • Unobserved heterogeneity
  
  • Regional and survey year dummies