Modeling Climate Change Impacts on Farm Households in Zambia

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Presentation at Chrismar Hotel, Lusaka, Zambia
Afternoon April 10, 2014
Objectives

• To estimate how representative farm households in Zambia will respond to effects of climate change on crop yields

• To identify the extent to which farmers can minimize the negative effects of climate change by changing crops or production technologies
How the model works

• Choose the set of crops and production technologies that best meets the household’s objectives (profit, food consumption needs)

• Taking into account:
  • Crop yields
  • Inputs required for each production activity
  • Prices of crop outputs and inputs
  • Availability of land, labor, cash
  • Household calorie consumption needs
  • Desire to maintain soil fertility
Household types

**Smallholder**
- ~1.75 hectares
- ~2.75 working-age members
- 350-500 ZMK available

**Emergent farmer**
- ~7 hectares
- ~3.25 working-age members
- 150,000-200,000 ZMK available

**Female-headed household**
- ~1.5 hectares
- ~2 working-age members
- 350-500 ZMK available

We assumed households need 2,100 calories from field crops per day per adult equivalent.
## Crops and technologies used

Based on data from Crop Forecast Survey

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seed Type</th>
<th>Tillage Method</th>
<th>Fertilizer</th>
<th>Management</th>
<th>Code</th>
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</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Local</td>
<td>Hand</td>
<td>No</td>
<td>High</td>
<td>MZ1</td>
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<tr>
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<td>Low</td>
<td>MZ4</td>
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<td>MZ6</td>
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<td>GR1</td>
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<td>Low</td>
<td>GR6</td>
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</tbody>
</table>
Climate change scenarios

• The Hadley (HadCM3) model (relatively “dry”)
  – Declines in rainfall
  – Somewhat more variable rainfall
  – Increases in temperature

• The CCSM model (relatively “wet”)
  – Increases in rainfall
  – Increases in temperature similar to Hadley model
Future yield predictions for Southern Province based on statistical yield analysis
Future yield predictions for Southern Province based on statistical yield analysis

![Graph showing proportion change in expected yield for different crops and models.](image)

- Hybrid maize with fertilizer
- Sunflower
- Hybrid maize without fertilizer
- Cotton

**Legend:**
- Blue bars: Hadley
- Red bars: CCSM
Results
Smallholder in Southern Province

CCSM outcome: 4,155 kcal/AE/day
Hadley outcome: 3,849 kcal/AE/day
Baseline outcome: 4,431 kcal/AE/day
Results
Emergent farmer in Southern Province

CCSM outcome: 10,965 kcal/AE/day
Hadley outcome: 10,440 kcal/AE/day
Baseline outcome: 11,549 kcal/AE/day
Smallholder results with and without adaptation

Hadley – with adaptation: 3,849 kcal/AE/day = -13.15%
Hadley – no adaptation: 3,656 kcal/AE/day = -17.49%
Baseline outcome: 4,431 kcal/AE/day
Emergent farmer results with and without adaptation

Hadley – with adaptation: 10,440 kcal/AE/day = -9.60%
Hadley – no adaptation: 10,135 kcal/AE/day = -12.25%
Baseline outcome: 11,549 kcal/AE/day
Main findings and conclusions

- Climate change will generally reduce crop yields.
- In response, model results to date show that farmers will choose different crops (cotton, cassava) and technologies (lower fertilizer).
- This reduces the negative effects of climate change . . . but not by much.
- Of the three household types modeled, smallholder farmers are most vulnerable to obtaining low production outcomes in a bad year.
- Larger-scale adaptation measures are needed (e.g. heat-tolerant seed varieties, agricultural investments & policies to reduce risk for small farmers).

Questions?
Slides for reference
Mathematical structure of model

\[
\text{max calories} = \sum_{j=1}^{n} K_j X_j
\]

subject to:

- Input requirements for each crop activity
- Resource constraints: \( \sum_{j=1}^{m} a_{ij} X_j \leq b_i \) → For land and biweekly labor
- Budget constraint: \( \sum_{j=1}^{n} C_{ij} X_j \leq \omega \)
- Household calorie requirement: \( K_j X_j \geq \theta \)
- Non-negativity constraint: \( X_j \geq 0 \)
- Flexibility constraints (sometimes): \( K_j X_j \geq \varphi \)
Model validation

How well do model results reflect observed farmer practices?

- 42.42% of land diverted from observed crop patterns
- 9.43% diverted
42.42% of land diverted from observed crop patterns

9.43% diverted

9.01% diverted

9.37% diverted
With/without a fertilizer subsidy

<table>
<thead>
<tr>
<th>Site</th>
<th>Basal</th>
<th>Top</th>
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<tbody>
<tr>
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<td>1,997</td>
<td>2,064</td>
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<tr>
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<td>3,452</td>
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<tr>
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</tbody>
</table>

Median fertilizer cost (per kg), including transport

- **Site 1 - Baseline - Smallholder**
  - (Maximizing total calories with 500,000 ZMK budget)

- **Without subsidy**
  - Hectares cultivated

- **With fertilizer subsidy**
  - Hectares cultivated

4,652 kcal/AE/day

4,770 kcal/AE/day
Results

Female-headed household in Southern Province

CCSM outcome: 5,379 kcal/AE/day
Hadley outcome: 5,072 kcal/AE/day
Baseline outcome: 5,714 kcal/AE/day