Progress Report Year 1

Improved Modeling of Household Food Security Decision Making And Investments Given Climate Change Uncertainty

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Outline of presentation

• Overview of project
• Field visits
  – Zambia
  – Zambia/Kenya
• Climate and crop yield analysis
• Household modeling
• Next steps

Photo: P. Grabowski
Overview of project

• Sponsor: BFS/ART
• $700,000 over 3 years (10/1/11 to 9/29/14)
• PIs and MSU colleagues:
  – Eric Crawford, Ayala Wineman (Ag, Food, and Resource Econ)
  – Jennifer Olson (Telecommunications, Information Studies, and Media)
  – Jeffrey Andresen, Nathan Moore, Aaron Pollyea (Geography)
  – Gopal Alagarswamy (Center for Global Change and Earth Observations)
  – Brian Mulenga (Zambia), Joseph Maitima (Kenya)
Project purpose

• Purpose: to link multiple-year household survey data and climate, crop, and farm household production models, in order to improve understanding about:
  – how rural households are adapting to climate change
  – the impacts of anticipated future climate scenarios on farm household production, income, and food security
  – implications for vulnerability assessments and planning for adaptation programs
Project activities

1. Historical analysis of rainfall patterns: Zambia (starting FY2012), Kenya (starting FY2013)
2. Analysis of impact of past climate variability and changes on maize yields (using climate-crop models) and on household food security and income, using the multiple-year household data.
4. Farm household models incorporating projected future climate change and maize yield scenarios, to identify impacts on future household production, farm and off-farm incomes, and food security.
5. Use of farmer and key informant focus groups to guide the design and interpretation of (1) and (2), and to discuss the outcomes of (3) and (4).
6. Outreach to key stakeholders in Zambia, Kenya, and the U.S.
Field visits

• November 2011 (Zambia)
  – Main collaborator: FSRP/IAPRI
  – Hiring of Brian Mulenga (IAPRI)
  – Collaboration with UNZA, ZMD

• February 2012 (Kenya)
  – Meetings with REDSO, ICRAF, KARI, Rockefeller Foundation, Tegemeo Institute
  – Collaboration with Ecodym Africa
Field visits, cont.

- **February 2012 (Zambia):**
  - Focus group meetings in Chipata
  - Meetings with IAPRI, UNZA, ZMD, ZARI, ZAMSEED

- **August 2012 (Kenya):**
  - Meetings with Tegemeo, KARI, Rockefeller
  - Planning focus group meetings with Ecodym
Climate analysis: Observed trends

• Using meteorological (weather) station data, identify recent trends in rainfall amounts and timing with particular reference to potential agronomic impacts.

• Data: Daily rainfall data available for 2 stations (Lusaka and Chipata), so results illustrated for those sites.
Lusaka Climograph (mean max & min temperatures, precip by dekad)
1981 - 2010
Annual Precipitation by Year
Lusaka, 1950-2002

Minor decreases, 50mm/yr
Annual Precipitation by Year
Chipata, 1945-2002

10-15% decline, 150mm/year
Changes in Seasonal Precipitation (3 month periods)
Chipata, 1945-2002

MAM

SON

DJF: largest decreases

JJA
Changes in Precipitation by Month
Chipata, 1951-2010

Monthly Precipitation (mm)

Month
Impact of Climate on Crop Production

• What is the impact of climate change and variability on crop production?
• What is the relative importance of climate, compared to agronomic practices, affecting yields?
• How examined? Observed climate data run through a crop model (DSSAT)
Crop model calibration for Zambia

- **Soils**: FAO (1:5 million) database, plus observed soil profiles from World Inventory of Soil Emission Potentials (WISE). Zambia has many soil profiles so using profiles to inform crop modeling for Africa.
- **Weather**: Met. station daily data for sites. GIS data from WorldClim to represent current period (1960-1990s) with MarkSim to generate daily data.
- **Maize model** in Decision Support System for Semi Arid Tropics (DSSAT)
- **Maize cultivar** selection: data base developed for DSSAT by Dr Durand, ARC - Grain Crops Institute Potchefstroom, RSA. Cultivar C3549 to represent 7 series silking in 70-75 days; matures in 140-150 days after planting.
- **Maize yield & agronomic practices**: model calibrated to Zambia based on yield trials conducted by Golden Valley Agricultural Trust (GART) in Zambia 2009-2010, and on information from Dr. Verma, ZAMSEED. Fertilizer rate application, cultivars, yield, etc. from household survey data.
- **Fertilizer rates**: 3 levels of basal fertilizer rates representing small, medium and larger farms (0, 15 and 30 Kg N/ha applied in the form of compound fertilizer 100 and 300 kg/ha) selected based on household survey. An additional treatment to apply 100 Kg/ha of Urea as top dressing was selected.
Improving Use of FAO Soils Database in Crop Models with Soil Profile Data

Conclusion: Soil water holding capacity or soil texture is a good proxy for selecting FAO soil.
Simulated & Station Yields versus Farm Yields

- Poor quality seeds, “recycled” hybrids
- Soil degraded
- Pests & diseases
- Weeds
Simulated Maize Yields in GIS: Current Climate, Moderate N Application

Spatially distributed yield under current weather conditions (1960-1990) in AEZs. 6 km resolution
Effect of Weather on Yields:
Same for Chipata

Q’s: Why dips in yield in wet years? Why similar years but different yields? What is role of top dressing N?
Seasonal Hydroclimatic Variables and Yield by Year
Farmers’ Views, Focus Groups

- 2 Districts in each of 3 AEZ’s selected
  Sinazongwe and Siavonga representing zone 1; Chipata and Petauke representing zone 2, and Mpulungu and Mungwi representing zone 3.

- Men & women interviewed separately.

- Key informant interviews (extension, researchers, etc.) in each District.
Main Findings 1

“I’m confused especially with the rainfall pattern, which is now unpredictable. So I have resorted to planting maize in stages like an experiment so as not to lose out completely in case I plant at a wrong time. I plant some of the maize at the beginning of the rain season, some after a few weeks and so on, so that if the first planted maize dies out I will still have the other maize that I planted at some other dates…”.
Main Finding 2

1. Farmers experiencing changes in rainfall (season onset is later, often a gap in the middle (Jan-Feb), more variable).
2. Crop yields declining, less grass & water for livestock
3. Farmers are changing their practices due to changes in rainfall (early maturing maize, planting in phases, rotation, etc.) but to the detriment of production.
4. Off-farm activities important.
5. Important differences between men and women, & by wealth category, in impact of climate change and adaptation / coping practices.
Social Differentiation:
Fertilizer application, cultivar & yields in AEZ IIB (2008 household survey data).

Yield ranges from 767 to 2745 kg/ha depending on amount of fertilizer applied, and type of seed.
Preliminary Findings & Hypotheses Re: Vulnerability & Adaptation

Vulnerability appears to be high where:

   a) High rainfall variability, declining rainfall, and gap of rainfall during the growing season
   b) Soil degradation
   c) Low fertilizer application, especially top dressing
   d) Poor quality seed (recycled hybrid seed)
   e) Dependence on maize
   f) High social differentiation affecting farming practices (e.g., weeding).
Household modeling: overview of activities

• Literature review
• Exploration/assessment of data sources
• Initial model development:
  – Simulation/math programming
  – [Systems dynamics]
Farm-Household Model

• **Motivation:** To translate the climate projections more directly into possible food security outcomes.
  – Choices among crops and cultivars, given relative profitability
  – Other adaptation strategies (autonomous or planned)
  – Deal with climate-related risk at farm level.

• **Main questions:**
  – For a given GCM, what are the likely changes in production and land use?
  – What will be the likely impacts on economic welfare and food security of farming households?
Data sources for model (Zambia)

• Panel household survey 2001, ‘04, ‘08: crop yields
• Rural Ag Livelihoods Survey 2012 (RALS 12): household structure & endowments
• Crop Forecast Survey (CFS): crop yields and labor requirements
• Ministry of Ag and Livestock: crop budgets
• Zambia Meteorological Department (ZMD): climate data
• Previous models by Siegel & Alwang, and Haggblade
• Output of the MSU climate team’s analysis and maize crop growth modeling
Relating climate and crop yields

• 3-wave panel household survey (‘01, ‘04, ‘08)
  – Panel analysis allows us to control for ‘unobservables,’ such as farmer ability
  – Precipitation records from ZMD
  – Wider range of rainfall variables included
  – Analysis still in progress; preliminary results disappointing as for previous studies
  – Need daily data; include breaks in rainy season; use insights from crop model

– Plan to use 2000-2012 Crop Forecast Survey data to allow analysis over longer time period
Model design

- Household-level analysis
- Incorporates the decision-making process of farmers
- Math programming solves for optimal resource allocations, subject to a set of constraints
- Accounts for extent of adaptation by farmers (not just 100% or zero %)
Model Structure

‘Observations’ of future climate

DSSAT-CERES maize yield projections

Non-maize crop yield functions

\[ Y = f(x, \beta) + \varepsilon \]

Farm-household model

Socio-economic information on households

Crop budgets

\textit{Simulation optimization or EV analysis}

Model output

- Optimal (likely) production mix
- Distribution of crop income
Probabilistic model analysis

• Climate outcomes will enter the farm model as random variables:
  – Incorporates climate variability into the farm model
  – Not a single “best guess” model result
  – Allows us to talk about probabilities of outcomes
  – Risk profiles of crop production → distribution of food security indicators and income

• Framework can be used to assess vulnerability to climate change, and the impact of adaptation options on the risk farmers will face
Expected model outputs

• Likely land use patterns and production levels
• Probability distributions of cropping income
• Likely adaptation strategies/constraints to adaptation
• We can explore:
  – Which households are most likely to fall short of meeting their food needs?
  – Will simple farm-level adaptations be enough to offset expected losses?
  – How might recommendations be tailored to households according to location, resource endowment, and gender of household head?
Next steps

• Revise work plan for Year 2
• In Zambia and Kenya:
  – Complete analysis of observed climate data and climate modeling in Zambia; initiate analysis/modeling in Kenya
  – Link climate data to crop model to identify impacts on crop production
• In Zambia:
  – Refine household model, extend to Zones 1 and 3
  – Statistical analysis of rainfall and crop yields using 12 years of Crop Forecast Survey data.
• In Kenya:
  – Focus group interviews
  – Initial development of household model
• Outreach on project progress: Kenya, Zambia, Washington, DC
Questions?
Abbreviations

CFS  Crop Forecast Survey
FSRP  Food Security Research Project (Zambia)
IAPRI  Indaba Agricultural Policy Research Institute
ICRAF  World Agroforestry Center
KARI  Kenya Agricultural Research Institute
MSU  Michigan State University
RALS  Rural Agricultural Livelihoods Survey
REDSO  Regional Economic Development Services Office
UNZA  University of Zambia
ZAMSEED  Zambia Seed Company
ZARI  Zambia Agricultural Research Institute
ZMD  Zambia Meteorological Department
Background papers prepared


Background papers, cont.


Kenya, East Africa Climate Model
Results: Change in Precipitation

Change in annual average precipitation (mm) from 2000 to 2050 from 4 GCMs downscaled to 6 km.
Kenya, East Africa Climate Model
Results: Change in Temperature

Change in average annual maximum temperature (°C) from 2000 to 2050 under 4 GCMs downscaled to 6 km.
Kenya, East Africa Climate Model
Results: Change in Maize Yields

Simulated change in maize yield (kg/ha) from 2000 to 2050 under 4 climate scenarios (4 downscaled GCMs).
Grabowski Model: Methods

- Bio-economic system dynamics model
- Key stocks: Food, Money, SOM and Soil N
- DSSAT crop model for maize production using historical weather data
Grabowski Model Diagram

1. **Loop 1**
   - **Food**
   - **Household Money**
     - Selling
     - Buying
   - **Consumption and Losses**

2. **Loop 2**
   - **Soil Organic Matter**
   - **Crop Residues**
   - **Tillage**

3. **Loop 3**
   - **Residual Nitrogen**
   - **Rainfall**

**External Connections**
- **Other cash needs**
- **Wage Labor**
- **Credit**
- **Back**
Year 1 work plan

1. Initial contacts with USAID and research consortium members
2. Travel to Zambia to initiate research activities
3. Revision and approval of work plan
4. Compile and evaluate existing Zambia weather data
5. Calibration and initial use of crop-climate models
6. Initiate collection of data to supplement existing surveys:
   a. Cost and price data
   b. Crop-specific production input use
7. Focus groups on climate trends and adaptation measures
8. Analysis of Zambia weather station and African RFE data
9. Design of gender analysis and integration
10. Initial design of household models
11. Design of procedures to link climate-crop-household models
12. Downscale and calibrate GCMs for future scenarios for Zambia
13. Testing/initial use of models
14. Outreach on project progress Zambia and Washington, D.C.
15. Review discussions, budgeting and work plan for Year 2