Climate Change and Agriculture in East Africa (CLIP team)

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The Climate-Land “Loop”

CLIMATE DYNAMICS
- Regional
- Local

INTEGRATIVE
- Spatial and temporal scales
- Uncertainty analysis
- Feedbacks and tipping points
- Systems paradigms
- Broader impacts

NPP SIMULATIONS
- Crops
- Rangeland

LAND COVER
- Remote Sensing
- Case Studies

LAND USE CHANGE
- Case Studies
- Models
- Role Playing Games

Global Climate

Human Systems
Methodology

• Examine recent trends in climate (1950-2010)
• Calibrate regional climate model RAMS to East Africa
  – Higher resolution, better incorporates topography and landscape than global models;
• Couple RAMS and land use model to simulate effect of land use change on future climate,
• Identify impacts on crops, forage, surface water, diseases with models, fieldwork.
Recent Climate Change with Weather Station Statistics, Remote Sensing Data
Temperature Trends in Tanzania-- + 1.5º C in 25 yrs

<table>
<thead>
<tr>
<th>Location</th>
<th>Period</th>
<th>Temperature Trend</th>
<th>Equation</th>
<th>R²</th>
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<tbody>
<tr>
<td>Arusha</td>
<td>1961-2005</td>
<td>+1.1°C</td>
<td>y = 0.0248x - 29.127</td>
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<td>Zanzibar</td>
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<td>+0.7°C</td>
<td>y = 0.0248x - 29.127</td>
<td>0.5132</td>
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</tbody>
</table>

Source: Tanzania Meteorological Agency
Shift in Rainy Seasons:

Avg. Daily Precipitation, Monduli, TZ 1935-2005

Start of rains more variable
Long rains end earlier
Change in Start of Rainy Season 1982-2006; green=later, red=earlier

Analyzed GIMMS NDVI data.
Source: Qin 2011.
Trend in Vegetative Productivity
1982-2006 (green=increase; red=decline)

Change in total productivity
Change during growing season

Analyzed GIMMS NDVI data.
Source: Qin 2011.
Modeling Future Climate due to
1) Global Greenhouse Gas (GHG) Emissions and to
2) Regional Land Cover/Use Change (LCLUC)
Modeling Framework

Regional East Africa domain (18 km), and nested boxes (6 km)

- Climate: RAMS / CCSM Scenario A1B (also downscaled Hadley, ECHam) with MSU’s HPC, CLIP’s Kili cluster
- Crop: DSSAT CERES Maize
- Ecosystem: CENTURY
- Hydrology: SWAT
- Land use: ClipCover, LTM
- Land cover: GIMMS (TimeSat & other models), MODIS, Landsat.
Project Future Land Cover/Use Change (LCLUC)

Past trends from several case studies

Future trends, drivers from expert workshops and role play scenarios

LCLUC modeling of expansion of agriculture
Effects of LCLUC & GHG on Temps

ΔT_{min}

ΔT_{max}

GHG Climate Change Effects

LCLUC Effects

Combined Effects

temperature change (°C)
Wind pattern changes due to LCLUC

00 UTC (2 AM Nairobi)

06 UTC (8 AM Nairobi)

12 UTC (2 PM Nairobi)

18 UTC (8 PM Nairobi)

vertical velocity (cm/s) @ 1216 m
Effects on Precipitation

GHG Climate Change Effects

Land Cover/Land Use Change (LCLUC) Effects

Synergistic Effects

Average Annual Precipitation Difference (mm)
Impacts of Projected Climate on Crop Yields
Current Crop Yields
(kg/ha)

Maize

Sorghum

Deterministic process based simulation models (DSSAT CERES); WorldClim, low inputs.
Changes in yield, 2000-2050
(green=increase; yellow=decline)

Maize

Sorghum

Difference in maize yield (kg/ha):
- < -500
- -500 to -400
- -400 to -300
- -300 to -200
- -200 to -100
- -100 to 100
- 0 to 100
- 100 to 200
- 200 to 300
- 300 to 400
- 400 to 500
- > 500
Reasons for yield changes
warmer temps & PET, higher water demand, accelerated phenology

<table>
<thead>
<tr>
<th>MAIZE</th>
<th>2000-2009</th>
<th>2050-2059</th>
<th>Yield change</th>
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<tr>
<td></td>
<td>DUR</td>
<td>Tmax</td>
<td>Tmin</td>
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<tr>
<td>A. NE Kenya</td>
<td>73</td>
<td>28.4</td>
<td>23.1</td>
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<td>B. Mt. Kenya</td>
<td>164</td>
<td>18.8</td>
<td>11.3</td>
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<td>C. W. of Mt. Kili</td>
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<td>22.6</td>
<td>15.0</td>
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<td>25.3</td>
<td>18.1</td>
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<tr>
<td>E. SW Tanz</td>
<td>107</td>
<td>22.2</td>
<td>16.4</td>
</tr>
<tr>
<td>F. Central Ug</td>
<td>86</td>
<td>25.3</td>
<td>20.6</td>
</tr>
</tbody>
</table>

Yield change: 2000-2009 vs. 2050-2059
Agronomic implications

1. Warmer temperatures lead to accelerated phenology in nearly all cases, shortening the growing season and decreasing potential yield.

2. In some cases, the effects of warmer temperatures are offset by the impact of increasing precipitation.

3. Impacts to highland agriculture may include shifts to maize at the expense of tea, coffee.

4. Results illustrate need for development of longer season maize varieties, with greater thermal time requirements.

5. The range and spatial variability of the outcomes suggests that strategies need to be regionally specific, and that integrated regional modeling is key.
Impacts & Adaptation
Fieldwork:
Vegetation & Soil Plots
Household Surveys, Meetings, Etc.
General impact on cropping systems

- Inter-annual variability of harvests increasing, drought impact severe;
- Some abandonment of short season cropping
- Experimenting with varieties;
- Crop pests and diseases increasing
- Income diversification key;
- Impacts & coping vary highly by wealth, gender, location;
- Irrigation an important adaptation, but water availability declining.
Agro-pastoral systems

• Warmer temperatures lead to vegetation drying faster and water becoming scarce faster;
• Savanna vegetation composition changing, bush encroachment & increase in bare soil observed;
• Forage productivity and palatability declining;
• Droughts impacting faster, more severe;
• Livestock and human diseases more frequent with climatic extremes;
• Wildlife declines significant.
Implications

1. Information needed on crop response
   a. How new crop cultivars would respond to CC across region (to inform crop breeding)
   b. Potential of different management practices (yield gap)
   c. Low-risk, high return crop choice options.

2. Critical gender, nutrition, income impacts. Information needed on effects of CC on different households and ability to adopt strategies.

3. Expect increase in regional trade in agricultural commodities due to local shortages.

4. Need for regional grain, water and livestock disease strategies.

5. Capacity building, especially modeling & adaptation technologies.