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

Year 3 -- Latest Results

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Main project activities

- Analysis of historical climate (rainfall, temp) patterns for Kenya (East Africa) and Zambia
- Downscale GCMs for current and 2050 periods: 4 AR4 and 4 AR5 GCMs
- Calibrate DSSAT crop models for maize, groundnuts, beans for East Africa and Zambia
- Model crop yields under current and future climates at various fertilizer levels
- Farmer focus groups: perceptions, impacts, adaptations

Main project activities, cont.

Linking crop and farm household models

- Zambia (3 zones: Northern, Eastern, Southern)
    1. Estimation of statistical crop yield models
    2. Linear programming models of farm households
    3. Modeling of household crop production under current/future climate scenarios for 3 HH types
    4. Analysis of minimum tillage options
    5. Comparison of farmer perceptions to met. data
    6. Impact of climate change on food security index
- Kenya (3 zones: Meru, Machakos, Uasin Gishu)
    - Preliminary: steps 1 to 3 as for Zambia, 2 HH types

Main results & implications

- Climate trends and variability more complex in East Africa than Zambia
- More certainty about future temperature trends than rainfall trends and patterns
- On-farm adaptation will mitigate but not completely offset climate change impacts
- Larger-scale public investment and policy measures will therefore be needed
- Modeling results informative, but linking climate/crop & household models more difficult than expected

Methodological lessons

- Crop modeling can be very helpful tool. Need:
  - Data on wider range of crops and crop cultivars
  - Improved rainfall and temperature data
    - Wider network of meteorological stations
    - Links with satellite imagery and ground-based sensors
- Farm HH models can be helpful tool. Need:
  - Improved data on area by crop and field, and labor inputs
  - Tradeoff between simplicity and complexity
- Household surveys helpful but:
  - Panel periods too short to observe climate impacts
  - Data gaps on crop-specific inputs and outputs

Observed Climate Trends: How are rainfall and temperatures already changing?

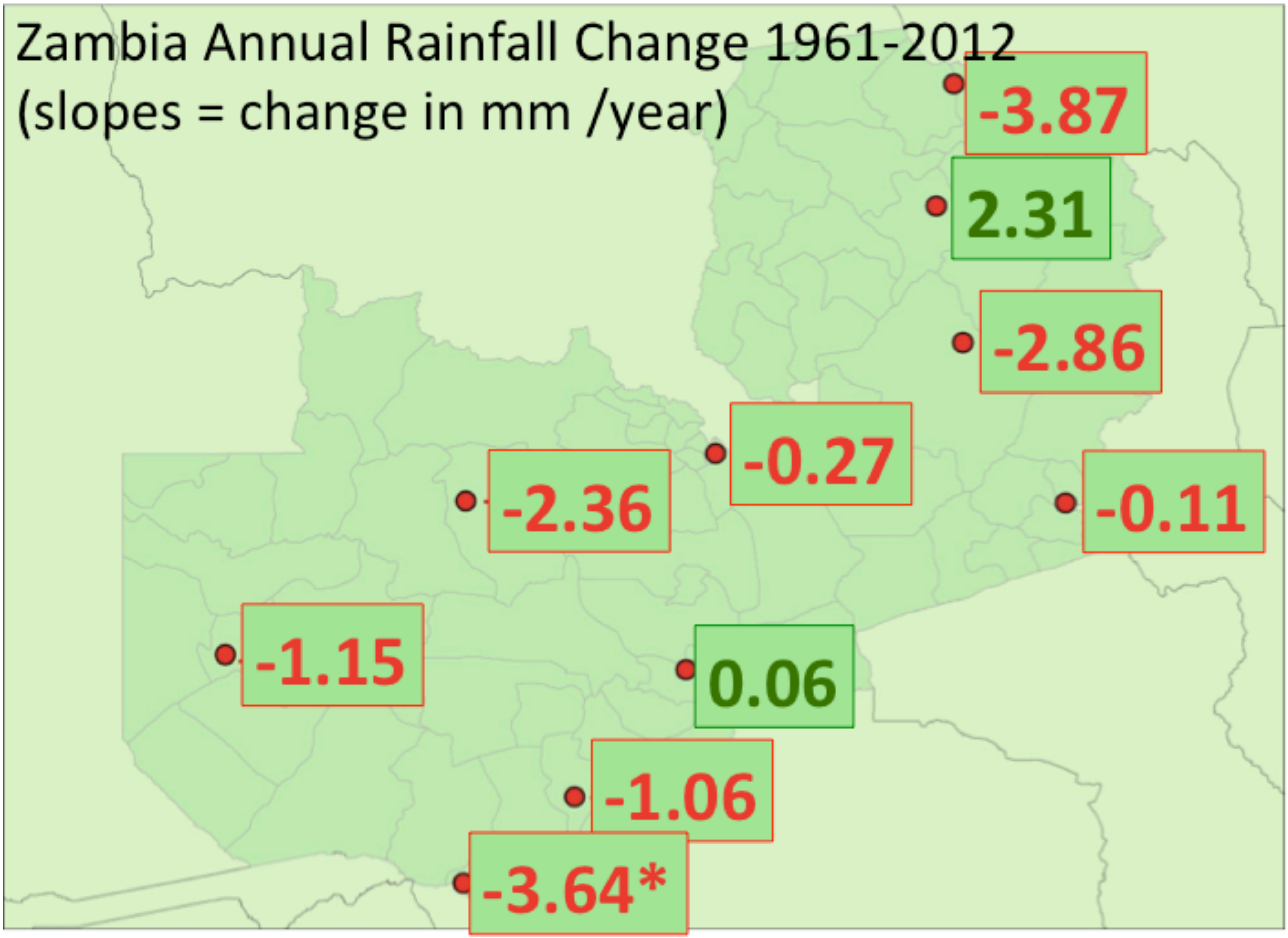
- Meteorological station data (daily)
- Mixed datasets (station + satellite imagery)

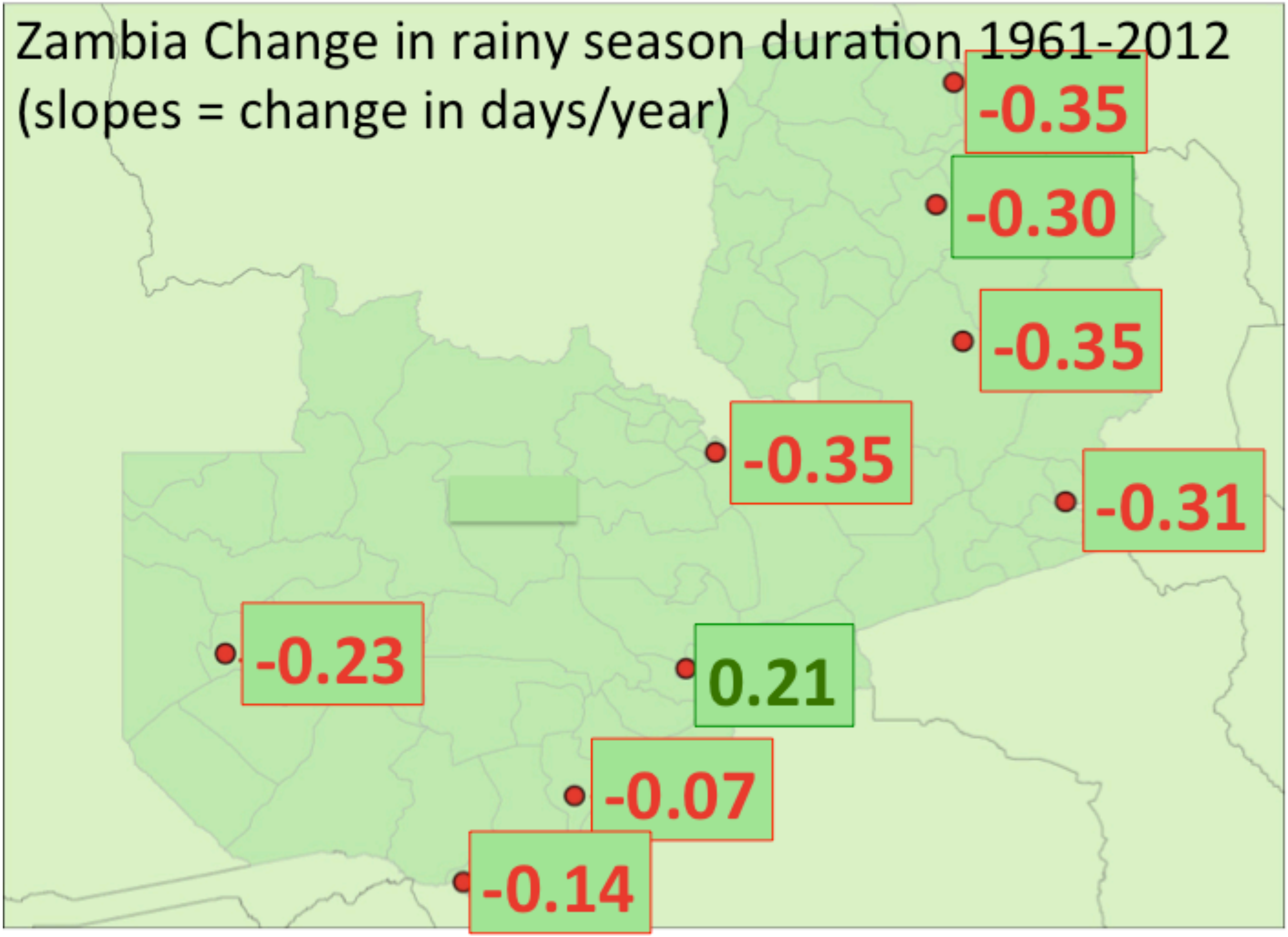
Zambia Temperature Trends

1. Daily minimum temperatures showed a rising trend every month, with 100 of the 108 station-month combinations showing statistical significance. This is a common trend across Zambia.

2. Daily maximum temperatures showed an increasing trend in temperature, with 88 of the 108 station-month combinations showing significance.

3. The number of days over 35°C (critical for crops) is generally increasing in the warmer stations.


Zambia Annual Rainfall Change 1961-2012
(slopes = change in mm /year)
-3.87
2.31
-2.86
-0.27
-2.36
-0.11
-1.15
0.06
-1.06
-3.64*


Zambia Change in rainy season duration 1961-2012
(slopes = change in days/year)
-0.35
-0.30
-0.35
-0.35
-0.31
-0.23
0.21
-0.07
-0.14

Zambia: Summary of Climate Change for Agriculture

1. Current trends:
   a. Temperatures warming. More frequent hot days. Higher evapotranspiration, plants need more water.
   b. Trend towards declining rainfall & shorter seasons.
   c. Evidence towards fewer, but intense rainy days.
2. Projected changes:
   a. Continued warming temperatures.
   b. Projected *average annual* precipitation changes are not large. However there will be more frequent precipitation and temperature <u>extremes</u>, and more precipitation <u>variability</u>.

Kenya/ East Africa Trends

- Warming: persistent in atmosphere, and surface of Indian Ocean.
- Precipitation: question of whether precipitation is increasing or decreasing in northern Kenya & area. Observations (maybe) vs. GCMs (yes).

East Africa Rainfall Trends

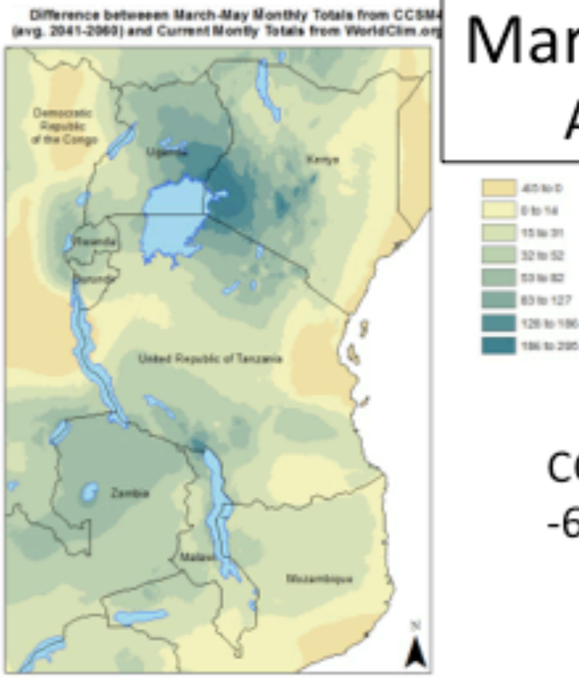
(met station data analysis)

1. Rainfall has remained steady or declined during the past several decades.
2. The decreases were in unimodal and in bimodal regions for both long and short seasons.
3. Largest decreases were found in southern Tanzania and central Kenya.
4. Northern Kenya shows increases (but needs more analysis)
5. Western Uganda trends suggest increasing long season rainfall since 1960, although there have been decreases in that region during the most recent decade.

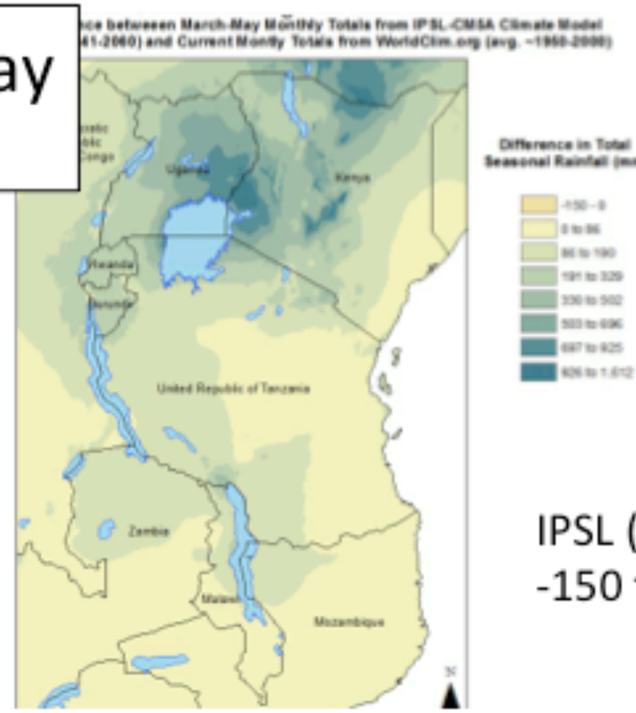
Future Climate Projections (IPCC AR5)

- Most models project a warmer, wetter East Africa partly as a result of stronger low-level moisture transport across the Indian Ocean during boreal Spring.
- But, this wetting trend may be unrealistic due to stronger deep convection over the Indonesian Warm Pool counteracting winds over the Indian Ocean (Williams and Funk 2011).

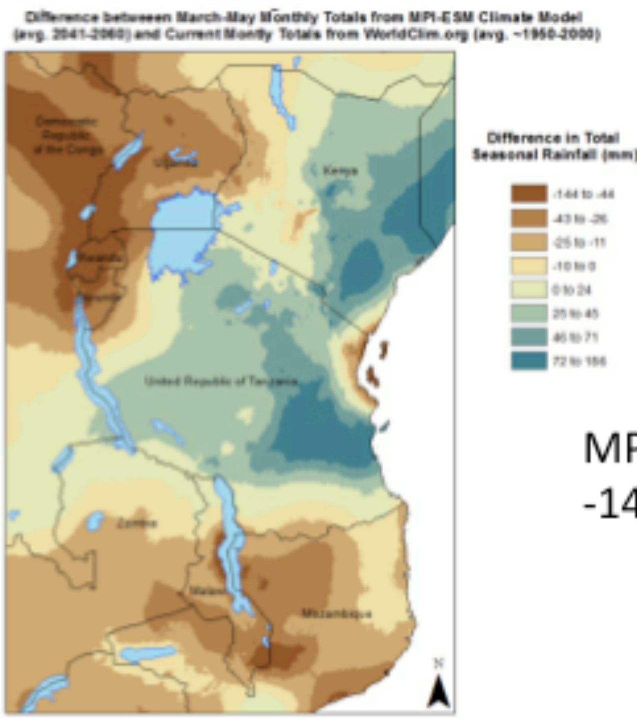
March-April-May
AR5; RCP8.5



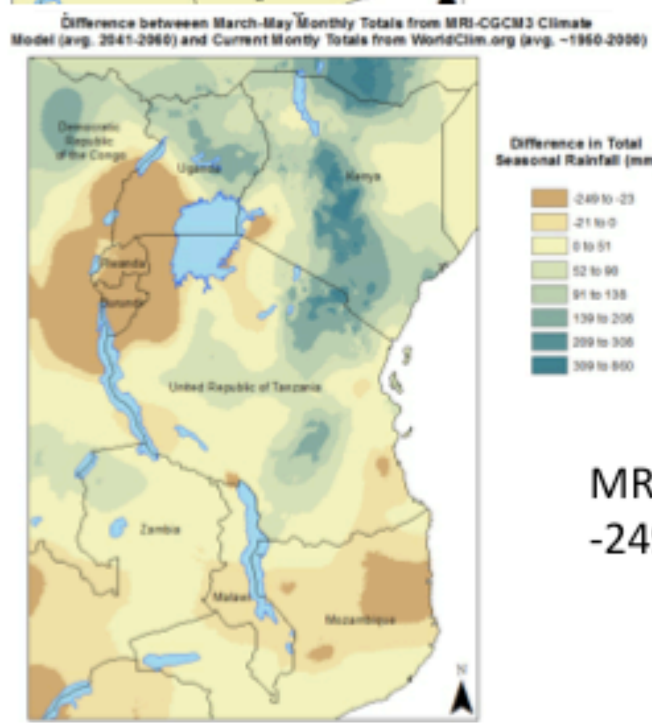
CCSM (USA)
-65 to +295 mm



IPSL (Fr)
-150 to +1612 mm

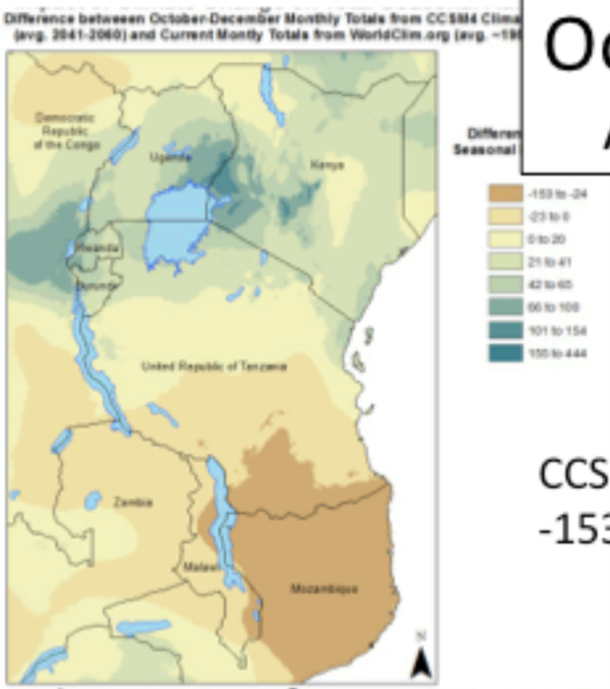


MPI (Germ)
-144 to +186

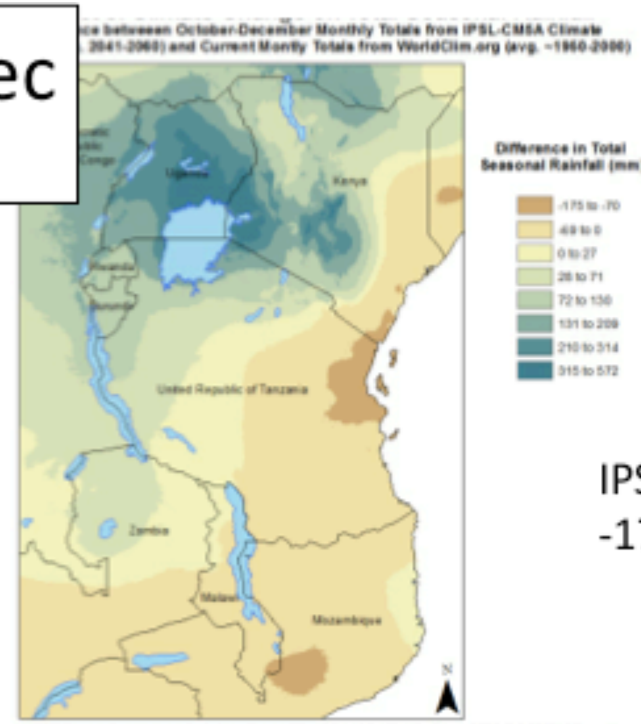


MRI (Japan)
-249 to +860

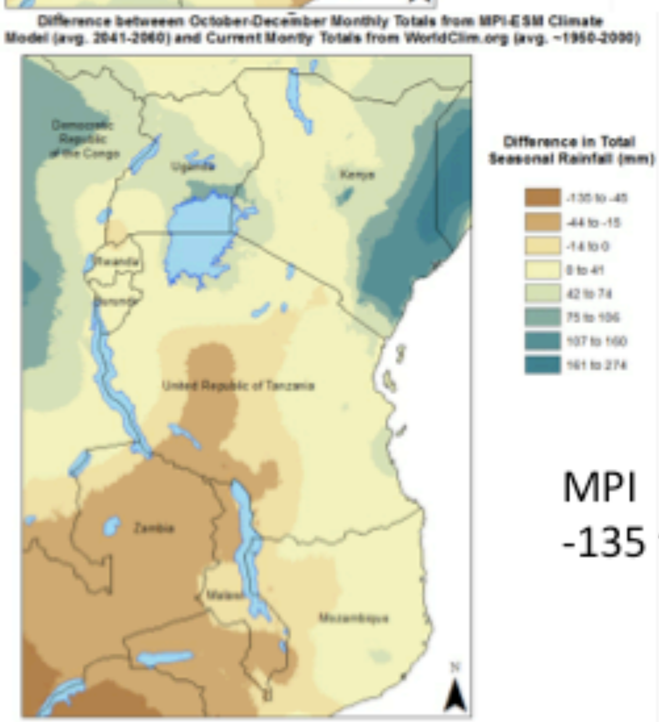
Oct-Nov-Dec
AR5; RCP8.5



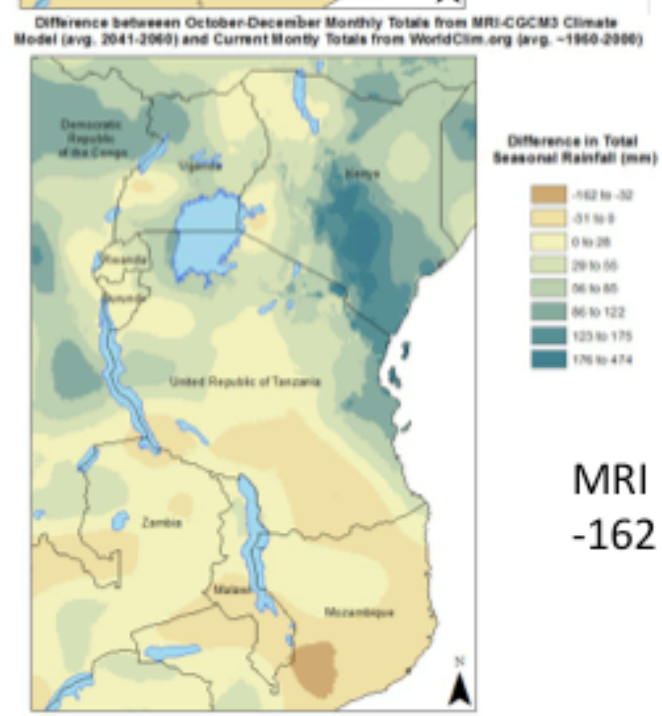
CCSM
-153 to +444



IPSL
-175 to +572



MPI
-135 to +274



MRI
-162 to +474

Kenya/ EA: Summary of Climate Change for Agriculture (1)

1. Temperatures have risen approx. 0.2-0.4˚C/ decade since 1960
   a. More frequent hot days affect crops.
   b. More rapid phenology reduces maize yields
2. Rates of potential evapotranspiration and vegetation water needs have increased. This has led to declining vegetation productivity across large areas.

Kenya/ EA: Summary of Climate Change for Agriculture (2)

3. <u>Drought</u> frequency and intra-<u>seasonal dry spells</u> has been increasing across some southern sections but decreasing across the north.
    a. Interruptions during maize flowering time
    b. Failed harvests
4. <u>Shorter rainy seasons</u> and fewer but more more intense rainfall events will affect crops
    a. Leaching, shorter duration varieties.

Climate Impacts on Crop Yields

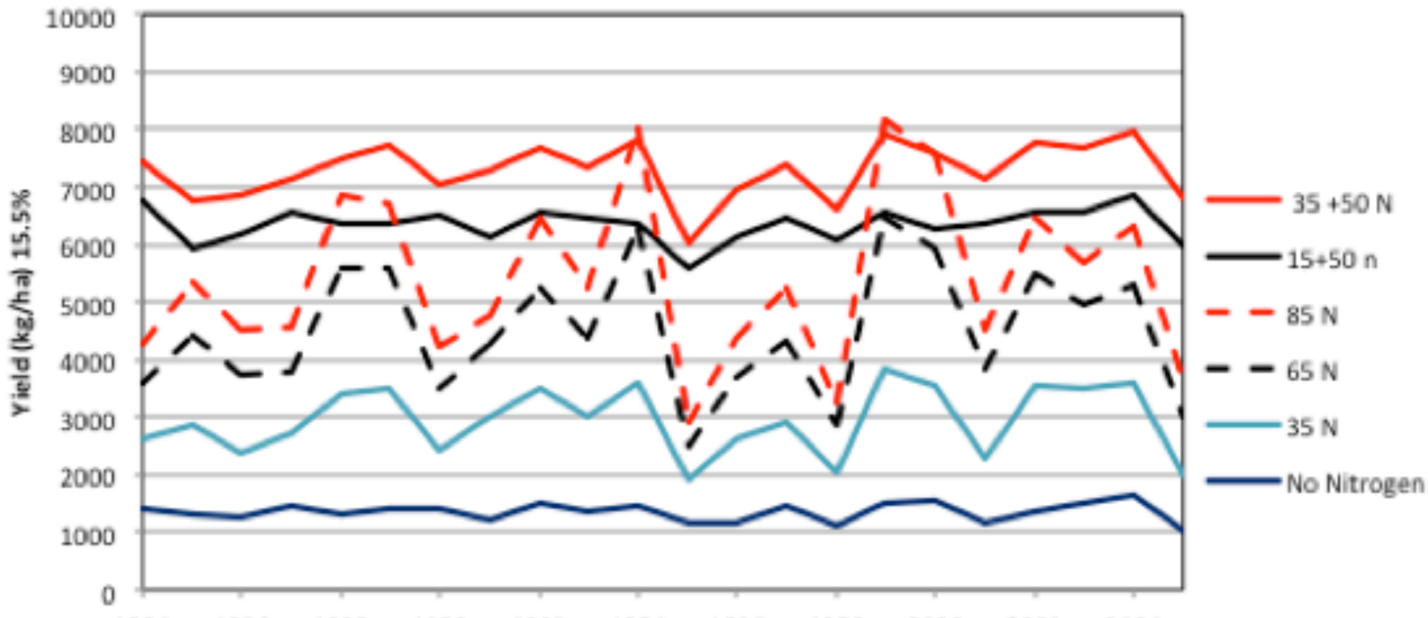
Question: How will crop yield change with climate variability and change? What variety, and what level of fertilizer, is best under climate variability and change?

- Process-based crop model (DSSAT) calibrated for region for maize, beans, groundnuts, rice. Simulated effect of fertilizer, climate, cultivars.
- Climate data used: meteorological station data, CHIRPRS and downscaled GCM data.

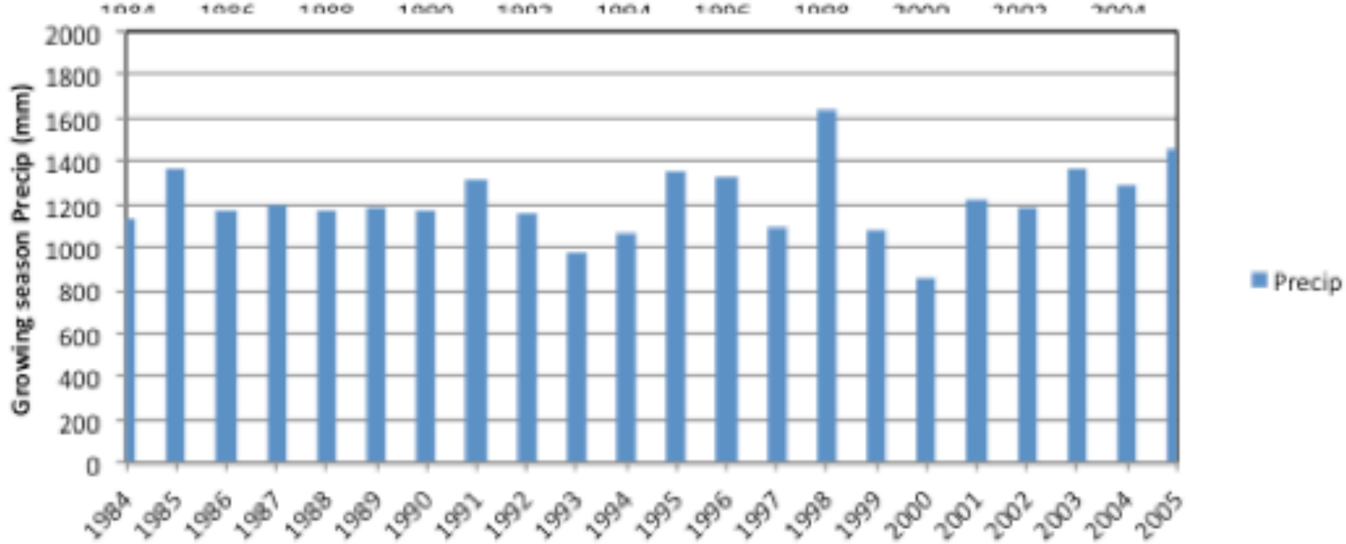
Kasama Simulated Yield of Long Duration Maize

(700 series), 1984-2005 Weather

Yield



Rainfall

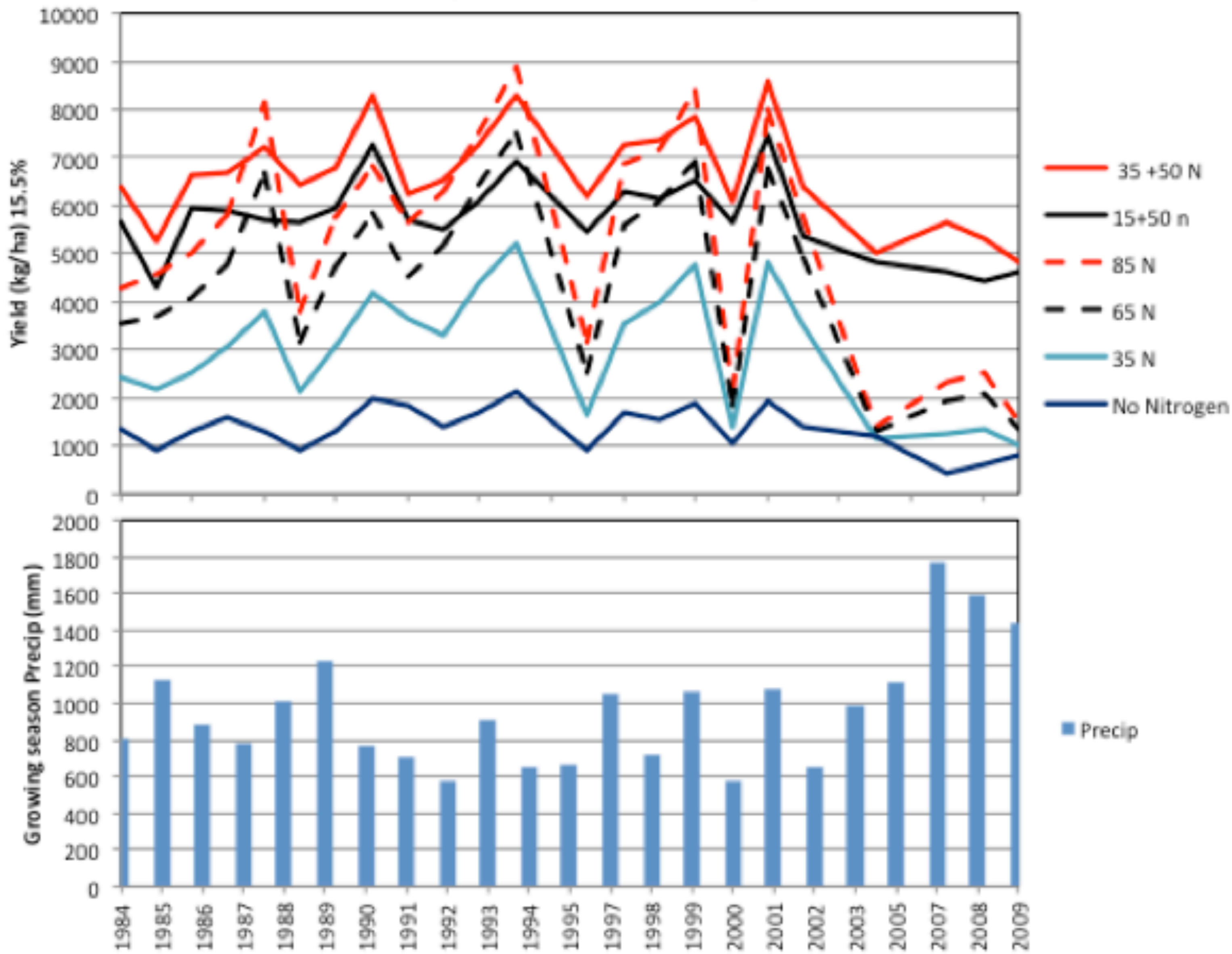


Chipata Simulated Yield of Long Duration Maize

(700 series), 1984-2009 Weather

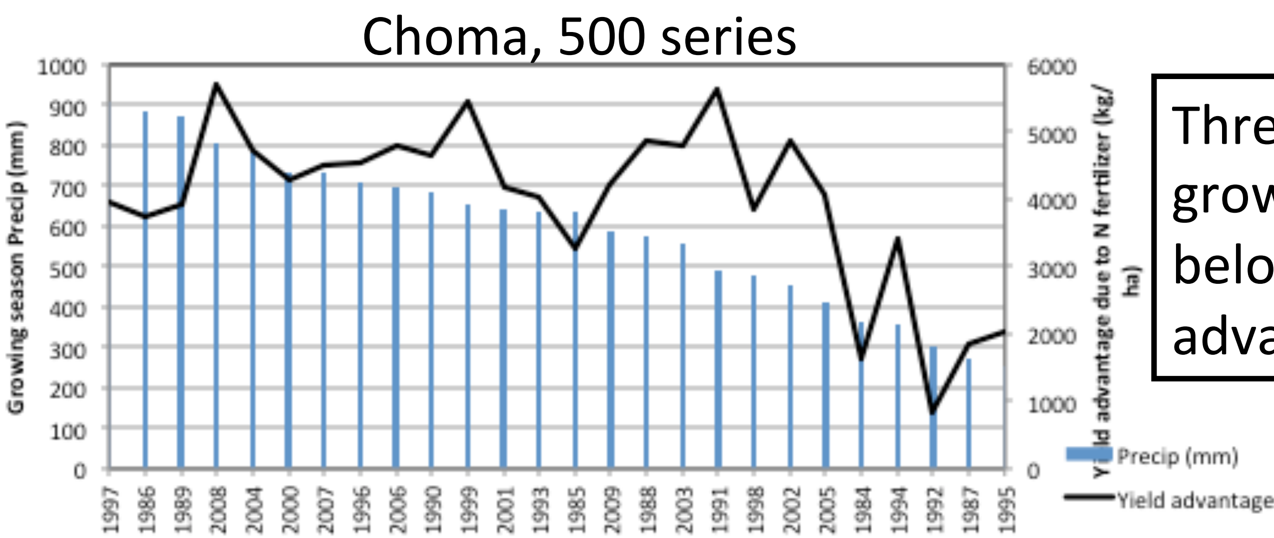
Yield

Rainfall

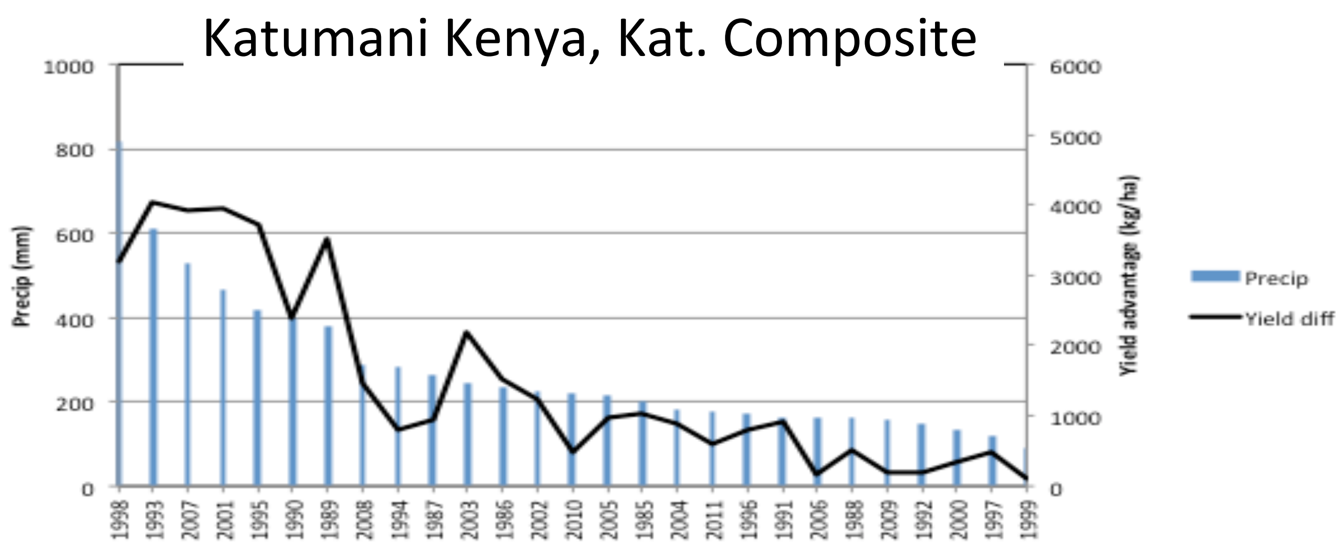


Yield Advantage of Adding Nitrogen Fertilizer

Short Duration Maize, 1984-2009 Weather



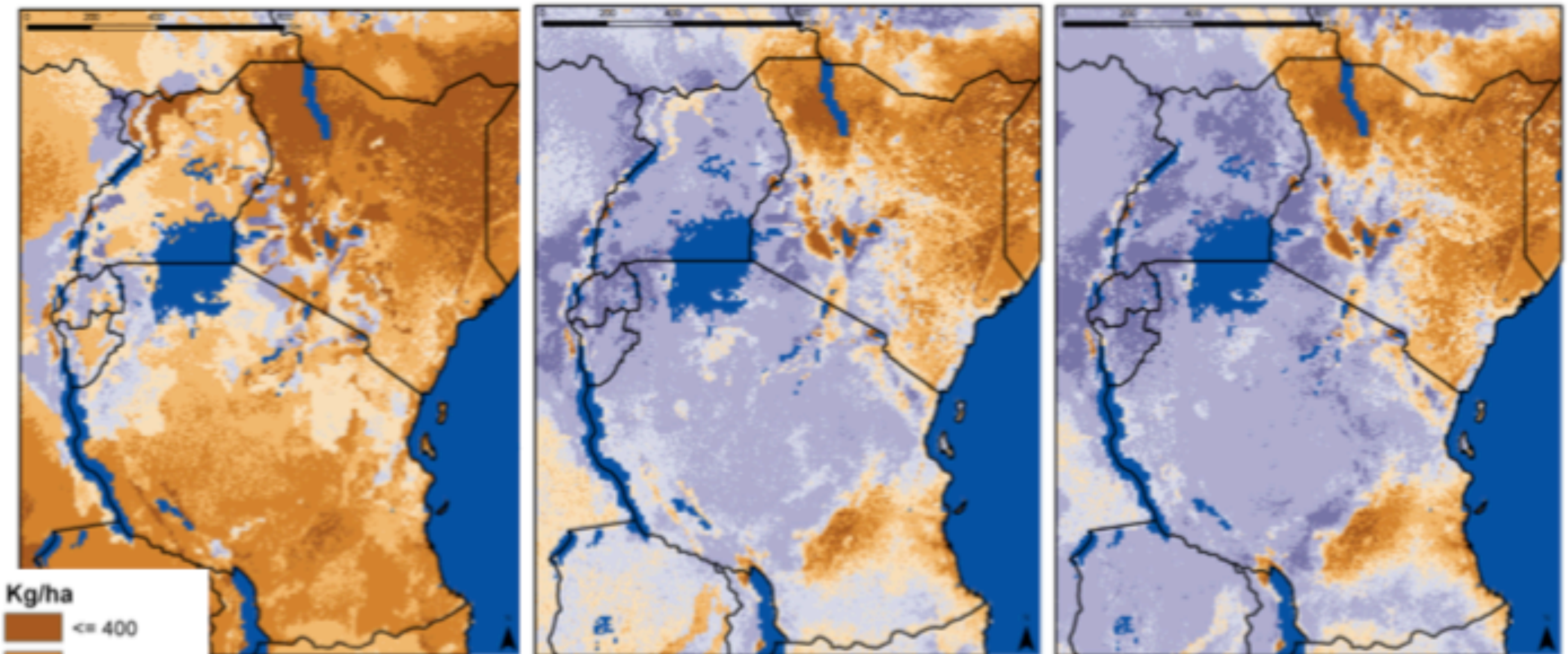
Threshold of ~450 mm growing season precip. below which little yield advantage to N.

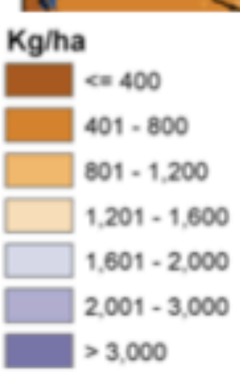


Maize Yield, *Current* Climate

Katumani comp.

5 kg/ha 2000 | 35 kg/ha 2000 | 85 kg/ha 2000





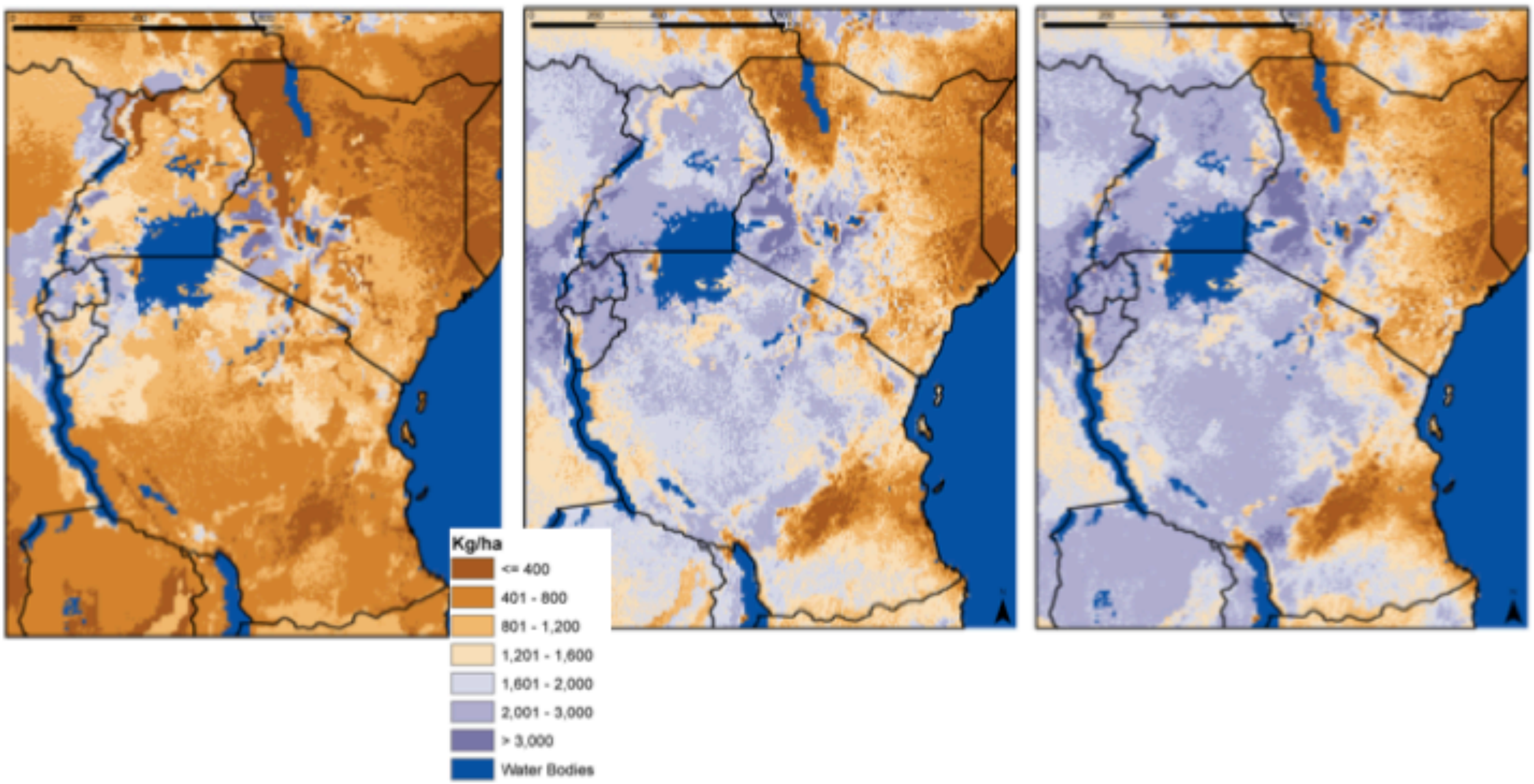
Limiting factor
is soil nutrients
(except No. Kenya)

Limiting factor
is mostly water stress.

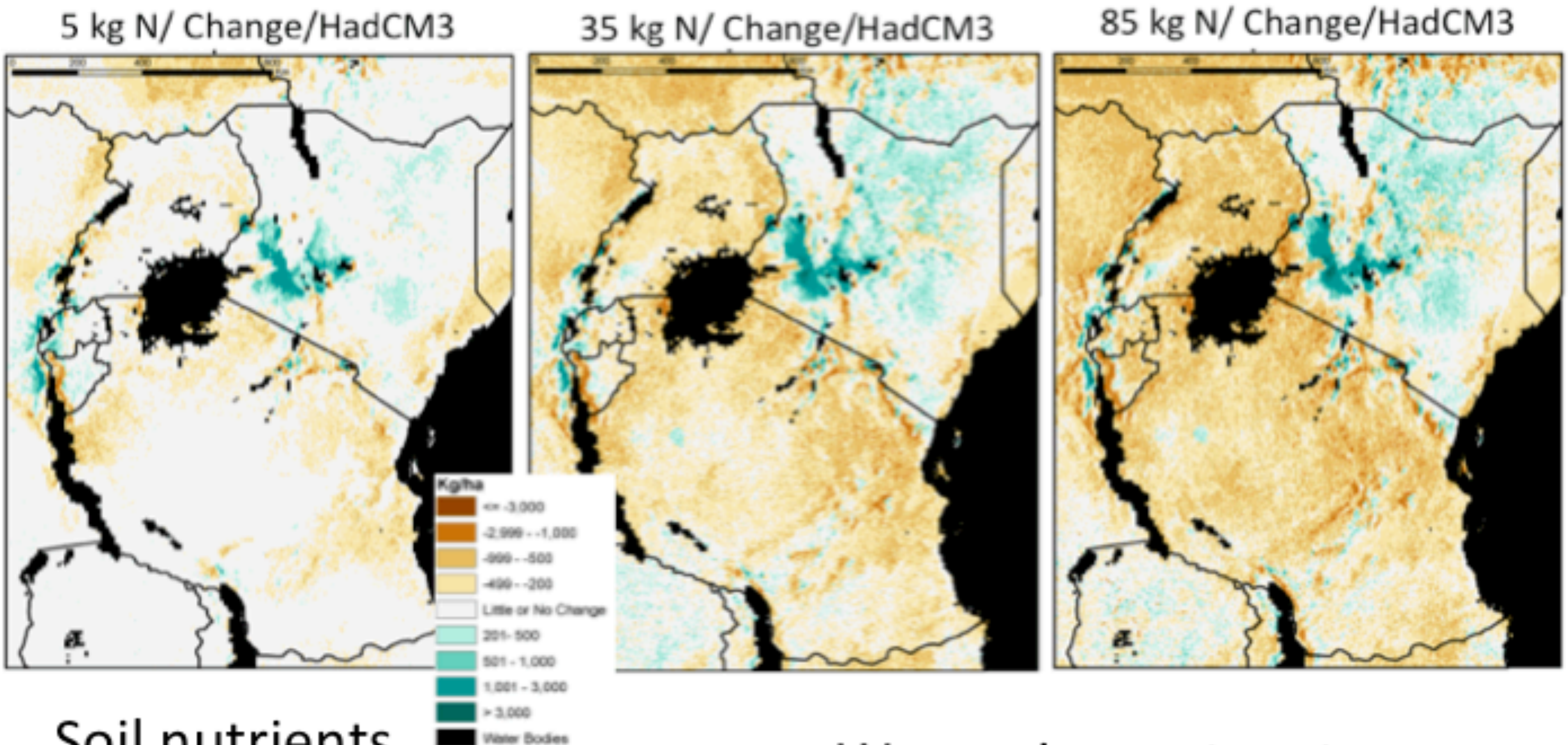
Maize Yield, *Future* 2050 Climate

(HadCM3)

5 kg/ha 2050 | 35 kg/ha 2050 | 85 kg/ha 2050



Change in Maize Yield, 2000 to 2050



Soil nutrients
still limiting
factor

Worsening water stress
is the limiting factor

Summary 1: Effect of Adaptation Techs

1. Low fertilizer levels severely limit current yields. Fertilizer applications will remain a critical management practice.
2. Highlands may see increased maize yields with the warming, but at the expense of cool-weather crops such as coffee.
3. In wetter areas, longer-duration varieties may remain preferred.
4. In areas of low and declining precipitation, drought-resistant varieties will produce more reliably over time and at less risk to the grower.

Summary 2: Effect of Adaptation Techs

6. However, higher fertilizer levels and new varieties will not entirely compensate for the lack of water (water stress will overwhelm the potential effects of fertilizer and possibly new varieties). Additional adaptation strategies (e.g., improved land & water management, irrigation, switching crops) could mitigate some of the impact of climate change.
7. The range and variability of the outcomes suggests that future technologies need to be locally specific.

Possible Next Steps (1)

1. Test new drought-resistant maize varieties (modeling):
   – fertilizer response rate,
   – how fertilizer response varies across region,
   – how yields compare to other cultivars across region (where is its comparative advantage?).
2. Identify causes of yield and yield change across region, and role of adaptations—interaction of climate change, soil, initial climate, varieties, agronomic practices (statistical analysis of spatial crop simulation results).

Possible Next Steps (2)

3. Identify causes of changes in veg. productivity across region – what is role of climate change? So how can we expect climate to affect productivity in the future? (spatial statistical analysis of satellite imagery, CHIRPS & other datasets, compared to crop model results).
4. Capacity building / collaboration of crop modeling linked to climate model data, GIS.