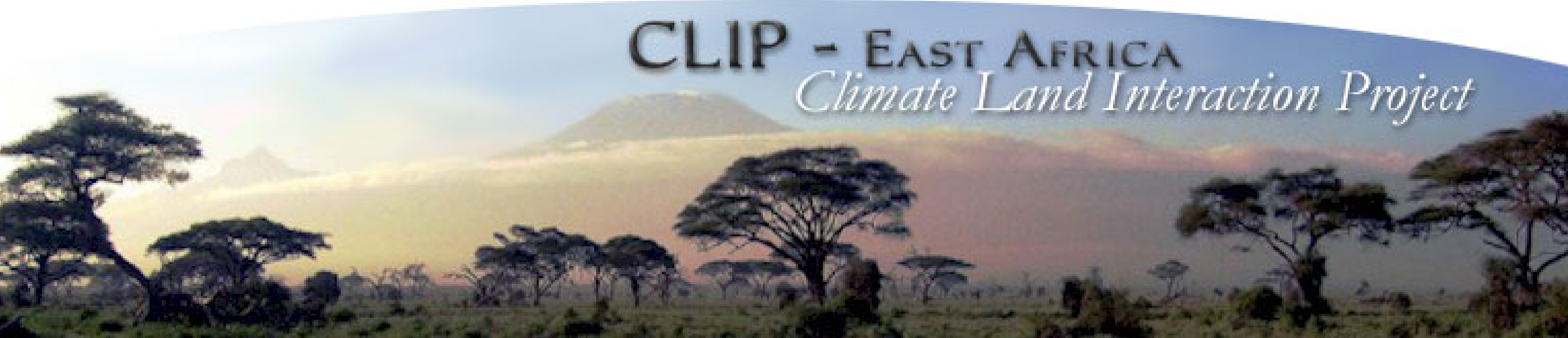


Linking Social Processes to Regional Climate Change

Gopal Alagarswamy, Jeff Andresen, David Cambell, Declan Conway, Ruth Doherty, Jianjun Ge, Ben Goodwin, Clair Hanson, Sarah Hession, Marianne Huebner, Brent Lofgren, Dave Lusch, Stephen Magezi, Joseph Maitima, Salome Misana, Nathan Moore, Sam Mugisha, John Nganga, Dave Lusch, Jennifer Olson, Bryan Pijanowski, Philip Thornton, Nate Torbick, Jing Wang, Sigismond Wilson, Pius Yanda, Lijian Yang

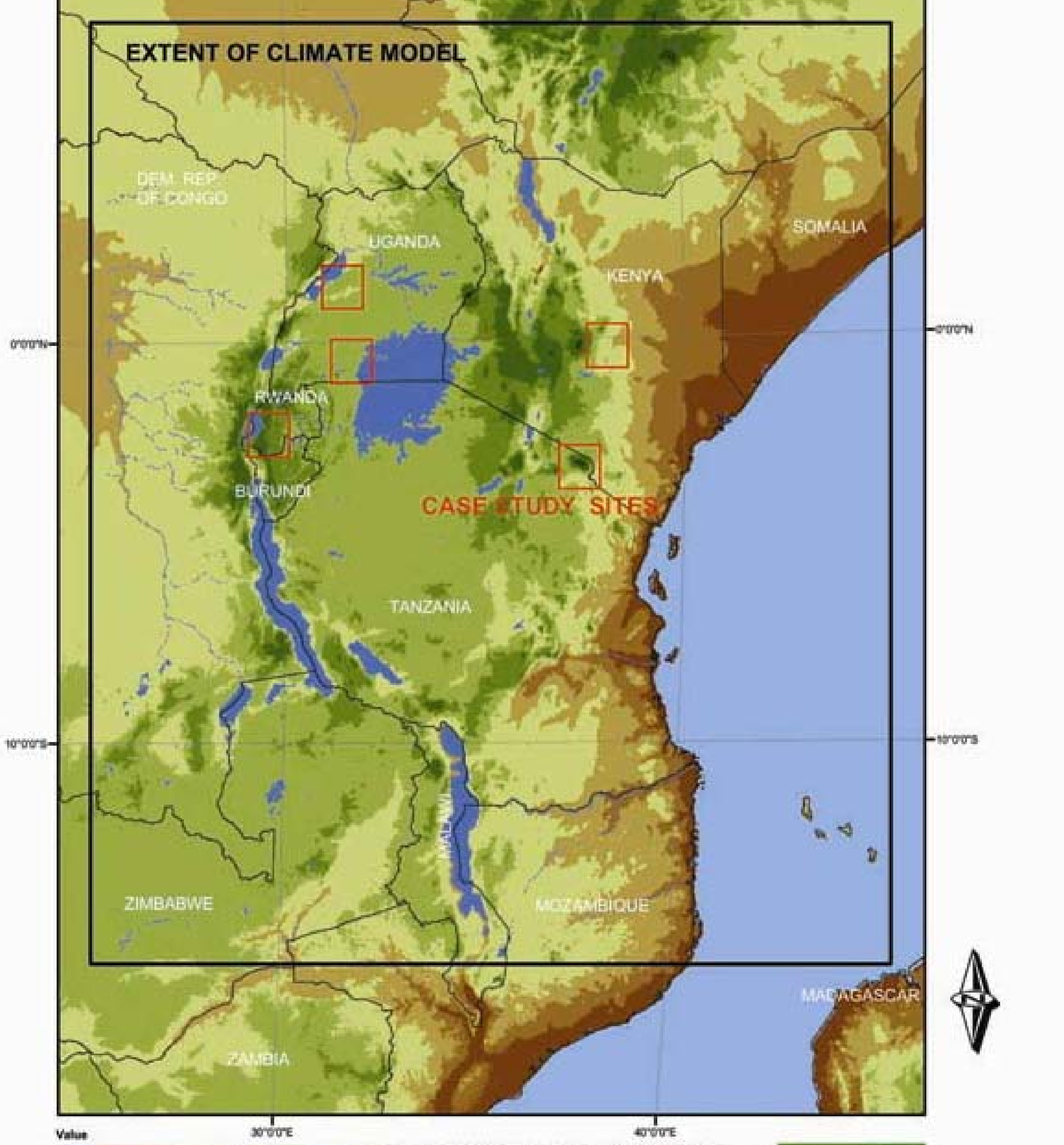
Michigan State University
NOAA
ILRI International Livestock Research Institute
University of Nairobi
The University of Dar es Salaam
The University of Edinburgh
UEA Norwich
Purdue University
Makerere University

Overarching Research Question

What is the nature and magnitude of the interaction between land use and climate change at regional and local scales?

Extent of Analysis:

Kenya, Tanzania, Uganda, Rwanda, Burundi and parts of 6 other countries.



High variability in land uses, covers.

Example: agriculture--

Large scale

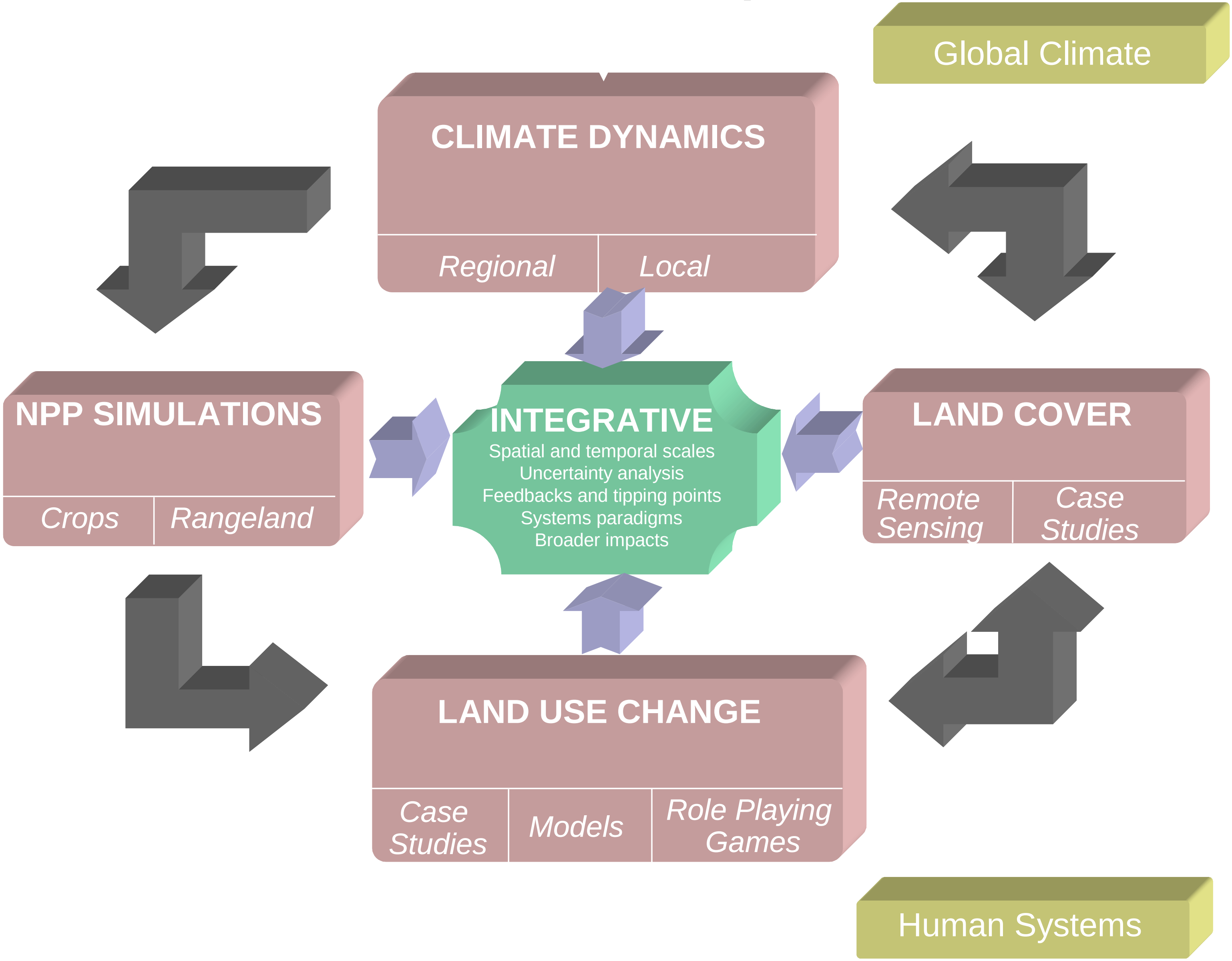
Pineapple

Rice paddy

Tea plantation

Small scale. Mixed livestock, agro-forestry

The Climate-Land “Loop”



Key Components of Research

Main goal: Understanding the coupled land-climate system

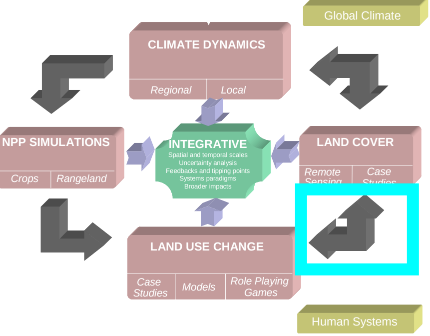
- Historical basis of future scenarios
- Multiple temporal & spatial scales
- The connections between components address key integrative issues.

This presentation:

- Challenges in calibrating models, datasets for East Africa;
- Initial findings.

Challenges and Progress

1. Calibrating models and datasets to East Africa.
   a. Global datasets and models do not represent African, equatorial region well
   b. Limited primary data available.
2. Coupling different approaches and models to close the “loop” requires creative, innovative approaches.



Linking land use and land cover

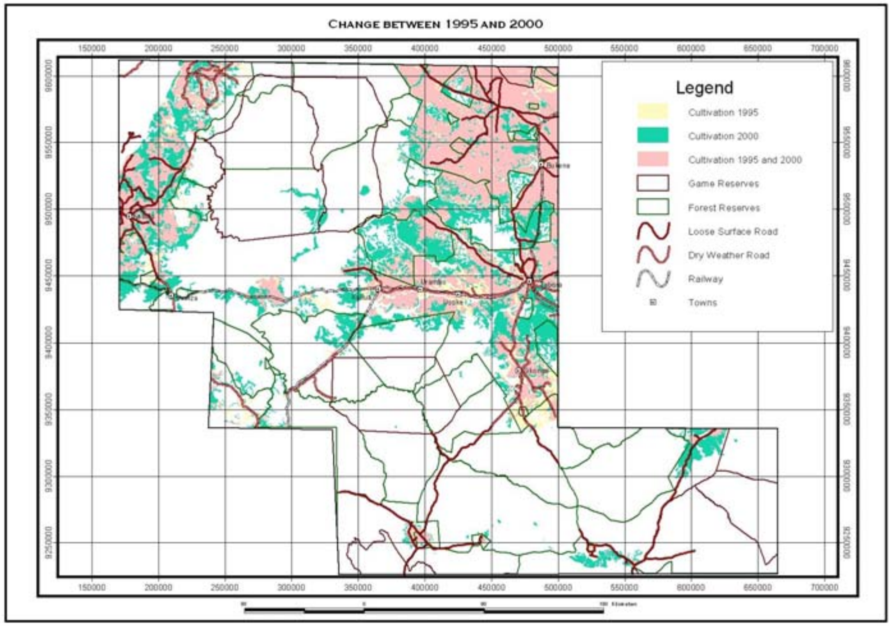
Challenge: identify past and future land use patterns and drivers; and how changes affect land cover.

David Campbell, Amélie Davis, Ben Goodwin, Dave Lusch, Jennifer Olson, Joseph Maitima, Salome Misana, Sam Mugisha, Bryan Pijanowski, Sigismond Wilson, Pius Yanda.

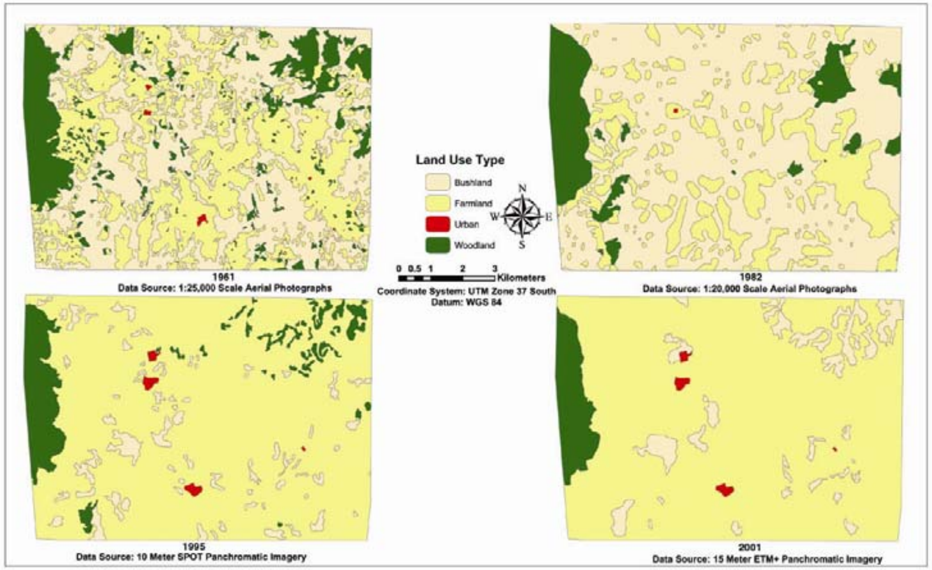
Approach:

1. Historical LUC analyses from many case studies

(drivers and patterns are input to spatial model)



Tobacco expansion into woodlands. Tanzania, 1985-2000



Expansion of cultivation into savanna following land tenure policy. Kenya, 1985-2002

Current LUC patterns across East Africa

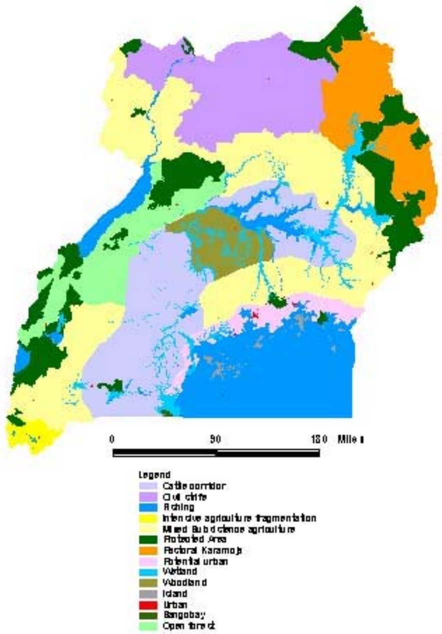
1. Expansion of cropping into savannas
2. Expansion of irrigated agriculture
3. Woodlands and forests: declining outside protected areas, little change within
4. Intensification of agriculture in humid areas.

Drivers:

1. Policy is a major driver, and changes often
2. Economic changes including markets
3. Migration and local population growth
4. Some drivers, such as war, result in land abandonment.

Difficult to forecast future policies and other “shocks.”

2. Land Use Expert Workshops to identify Future Patterns, Drivers
(input to spatial allocation model)



Major LUC is expected in certain zones due to:

- Infrastructure development
- Agricultural modernisation policy
- Urban market for fuelwood, meat, milk and crop production
- Structural adjustment, globalization
- Migration
- Sedentarisation of pastoralists.

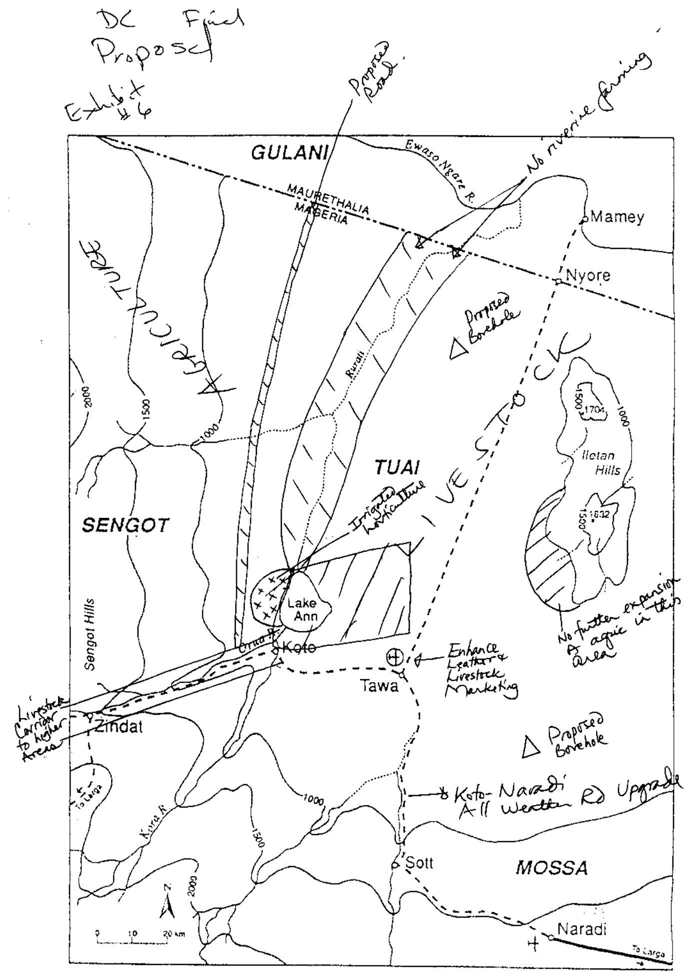
Large role of policies.

3. Role Playing Simulations
(input to agent based model)

How do farmer and herder groups decide who gets what land?

How do they respond to government mandates?

What is the land use outcome of the competition over land?



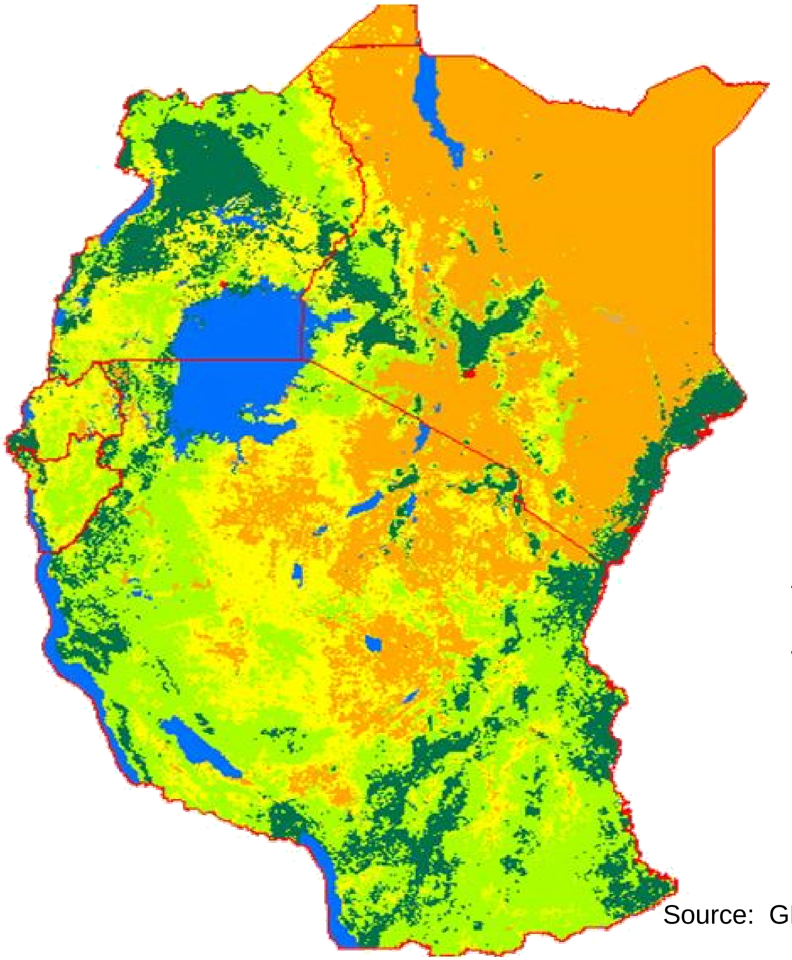
4. Study of competition over land, water resources in SE Tanzania

- Kilosa has rapid in-migration by pastoralists from the north dispossessed of their land
- Dual system of land rights
- Expanding irrigation schemes, large ranches
- Limited resources
- Result: competition, conflict, and re-adjustment of land use and social system.

5. Link land use change to cover

Savannas: Dominant land cover in East Africa, with the most rapid land use/ cover change.

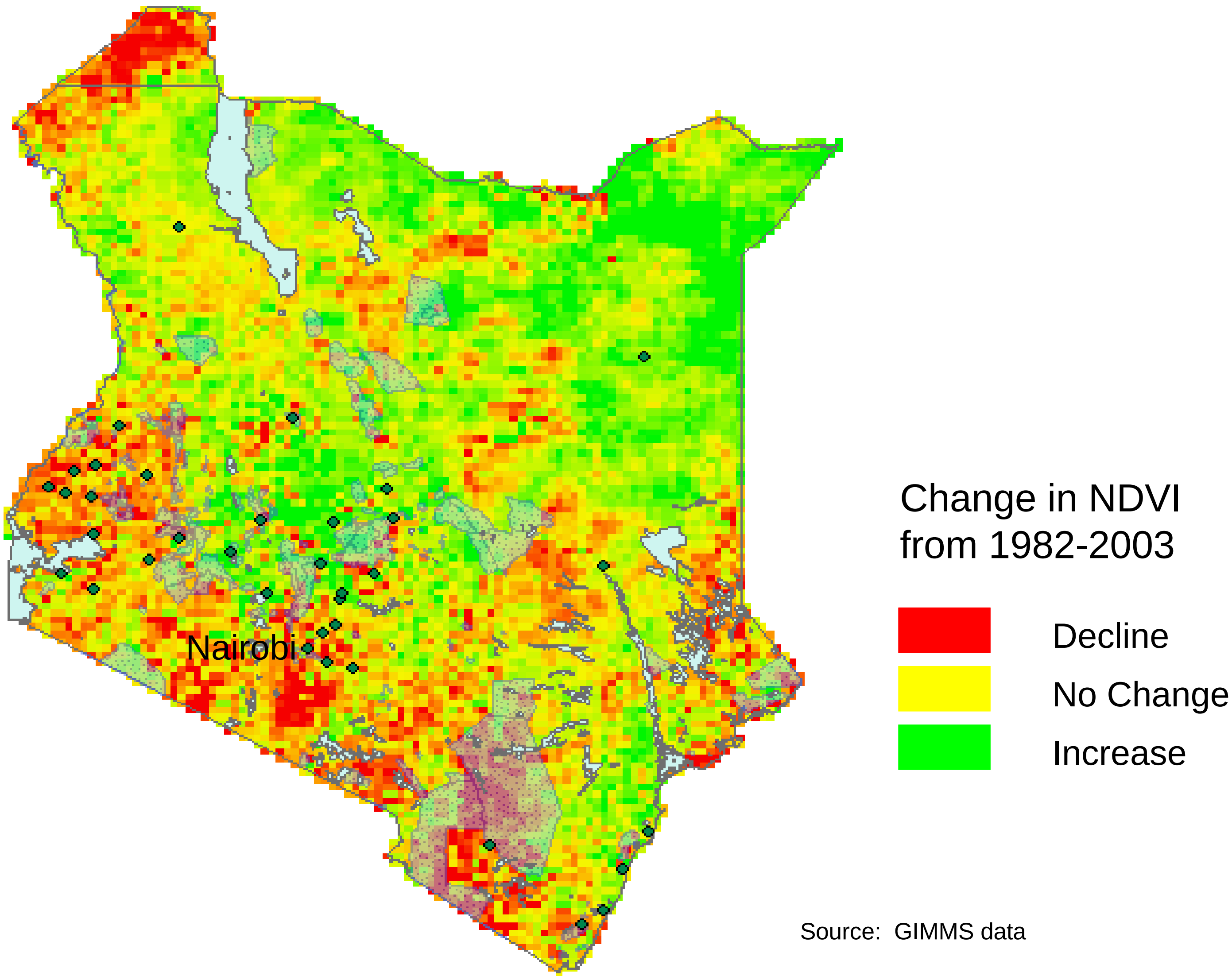
Ecosystem is shaped by humans, anthropogenic.



Forest: dark green
***Woodland/shrubland*: light green**
***Grassland*: orange**
Agriculture: yellow
Barren: grey
Water: blue
Urban: red.

Source: GLC2000

Savanna vegetation changing following pastoralist sedentarization (intense management, smaller grazing orbits, fencing, fire, etc.), and more agriculture.



Source: GIMMS data

Land use models

Processes

Population Demographics

Crop Production Model

Climate based

Conflicts

Resources

Modeling Approaches

Urban expansion

→MCE

Agricultural expansion

→ Neural Net based

Deforestation

→Cellular Automaton

→Rule based

Model Integration

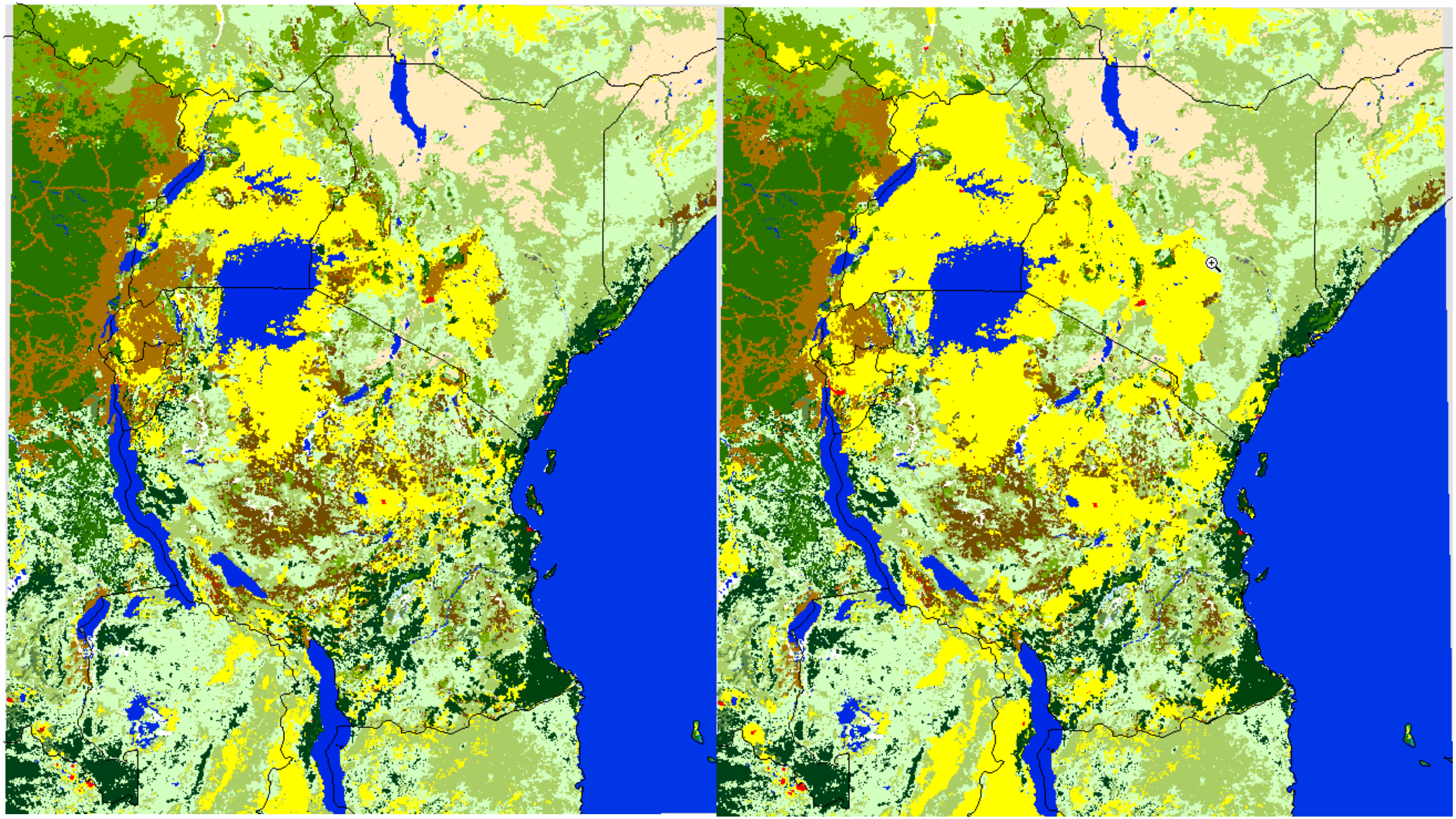
Integrate in a Geographic Information System

5 year time steps

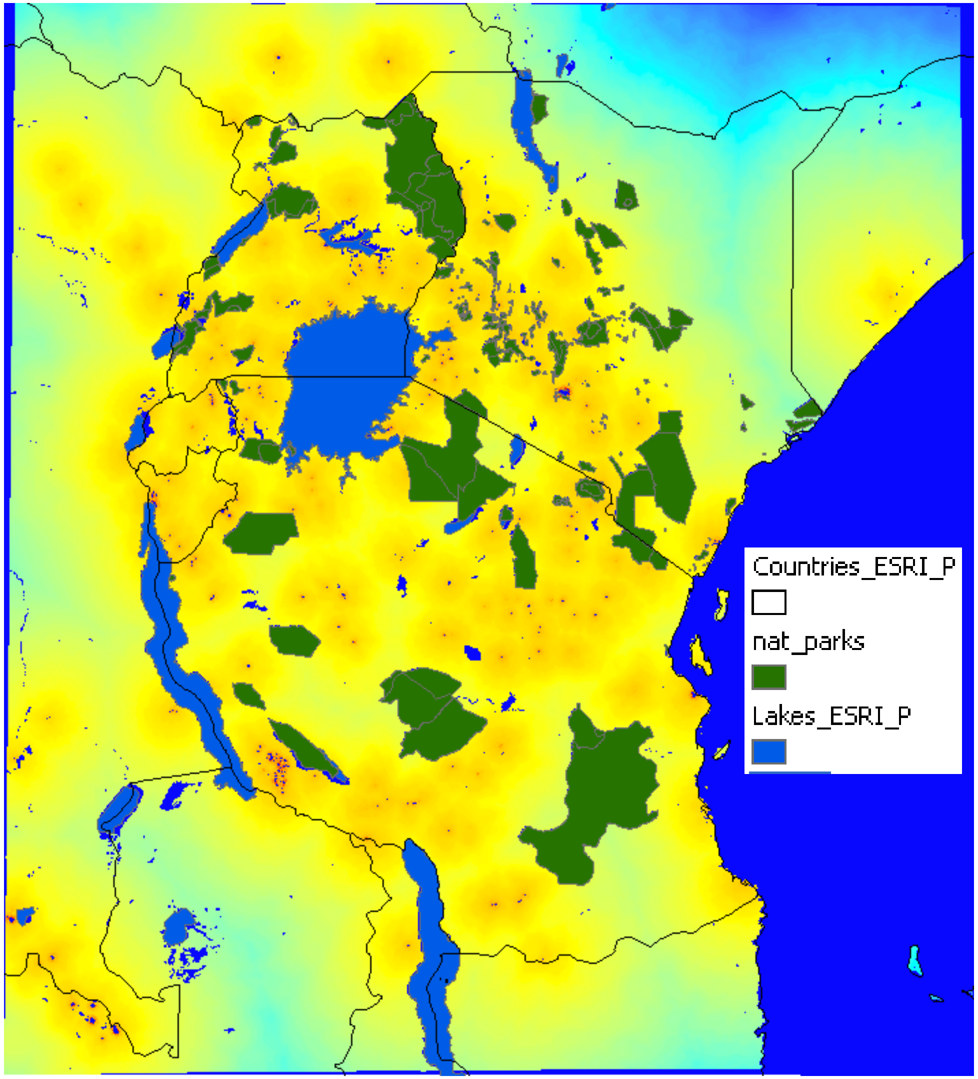
Looping

Feed to a land surface model

Agricultural Forecast:
2005 (left)   2030 (right)



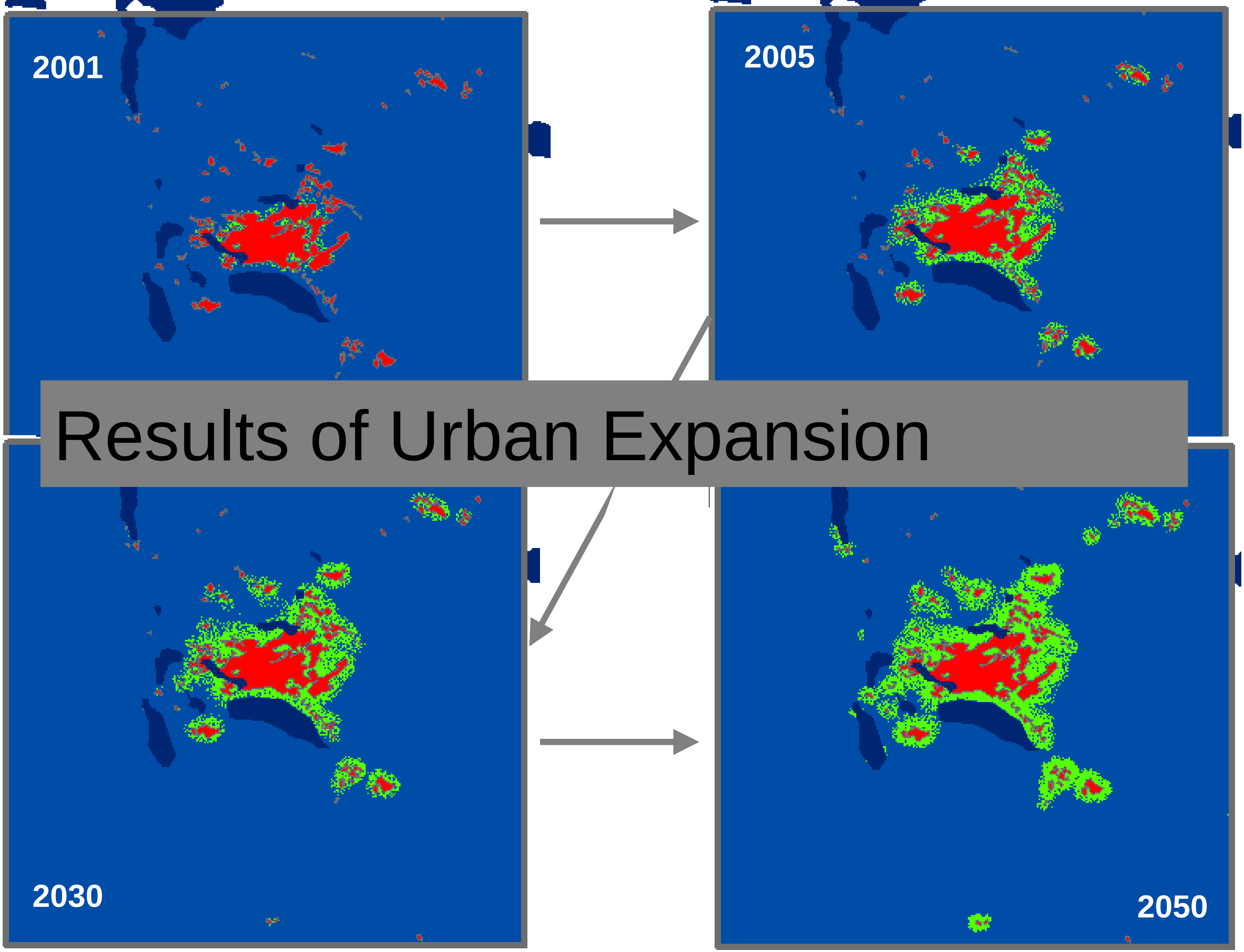
East African Urbanization



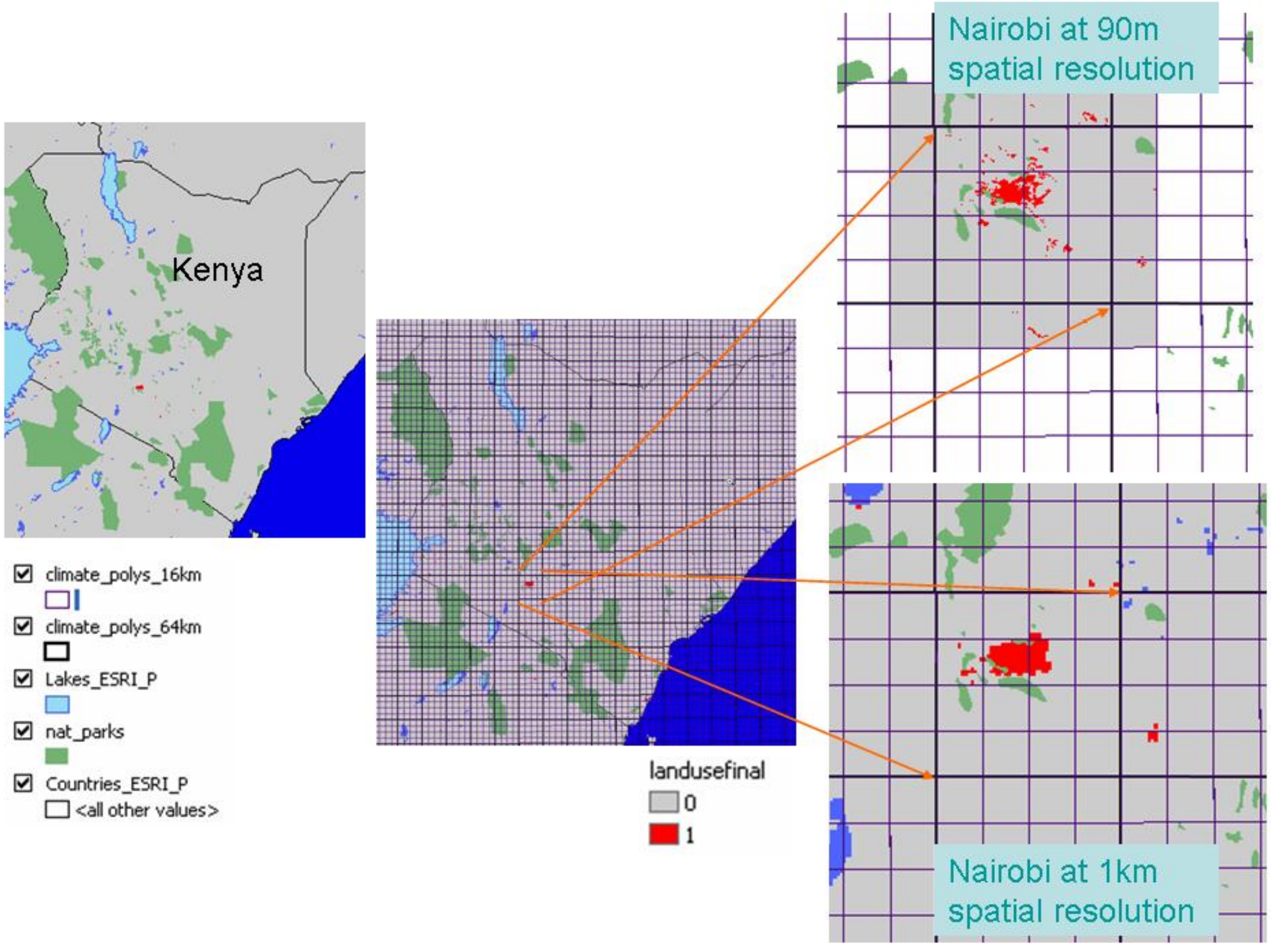
- MCE map
- Red/orange = greatest likelihood of urbanization
- Problems with Ethiopia and Mozambique

  not enough information in drivers

Results of Urban Expansion



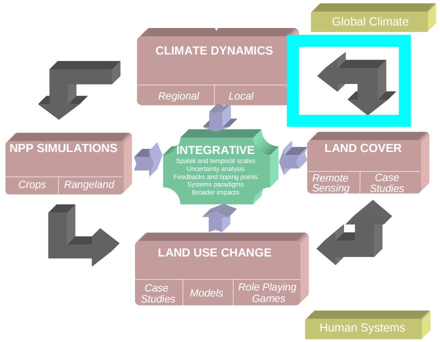
Scaling Issues



- Different Patterns
- Different information passed on to climate model

Scaling Issues

- Study the interaction of different fractional covers of urban at varying spatial resolutions of the LULCC change map with disparate spatial resolution climate grid → which scale will be best suited to couple both models?
- How will shape and patterns within the landscape influence this coupling?
- Merge Urbanization with Agricultural expansion maps



Linking Land Cover and Regional Climate

Challenge: Creating the best representation of the land surface variables to link to the regional climate.

Jianjun Ge, David Lusch, Joseph Maitima, Jennifer Olson, Jiaguo Qi, Nathan Torbick, Jing Wang, Lijian Yang

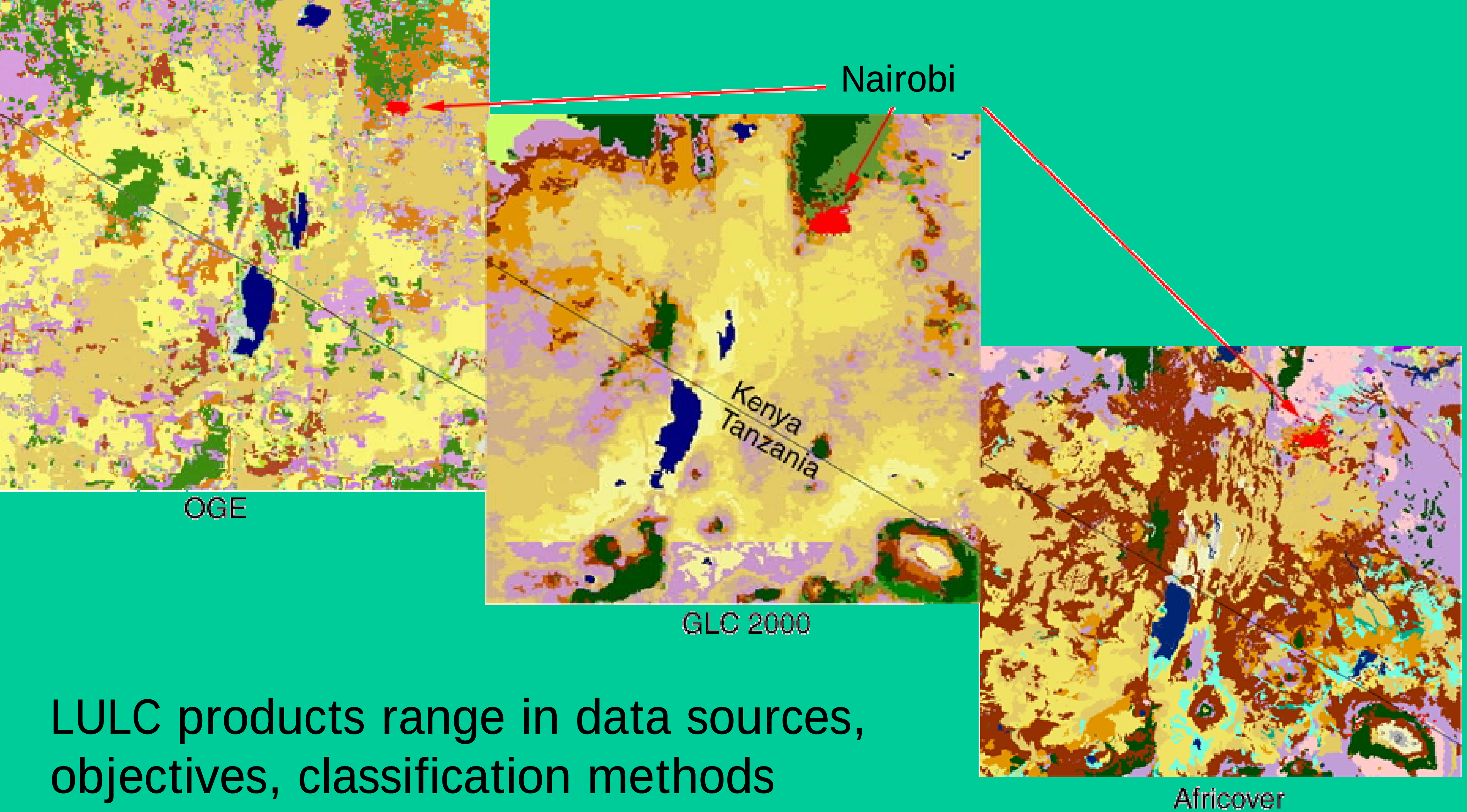
LC Objectives

To assess land use/cover change impact on regional climate

- To better characterize LC as input to regional climate model (RAMS)
- To quantify the LC requirements for regional climate modeling. Specifically to assess the effect of land cover classification accuracy on regional climate simulation. This links the human land use to the regional climate
- To assess the degree of LCC impact on regional climate
  - Categorical changes
  - Continuous changes

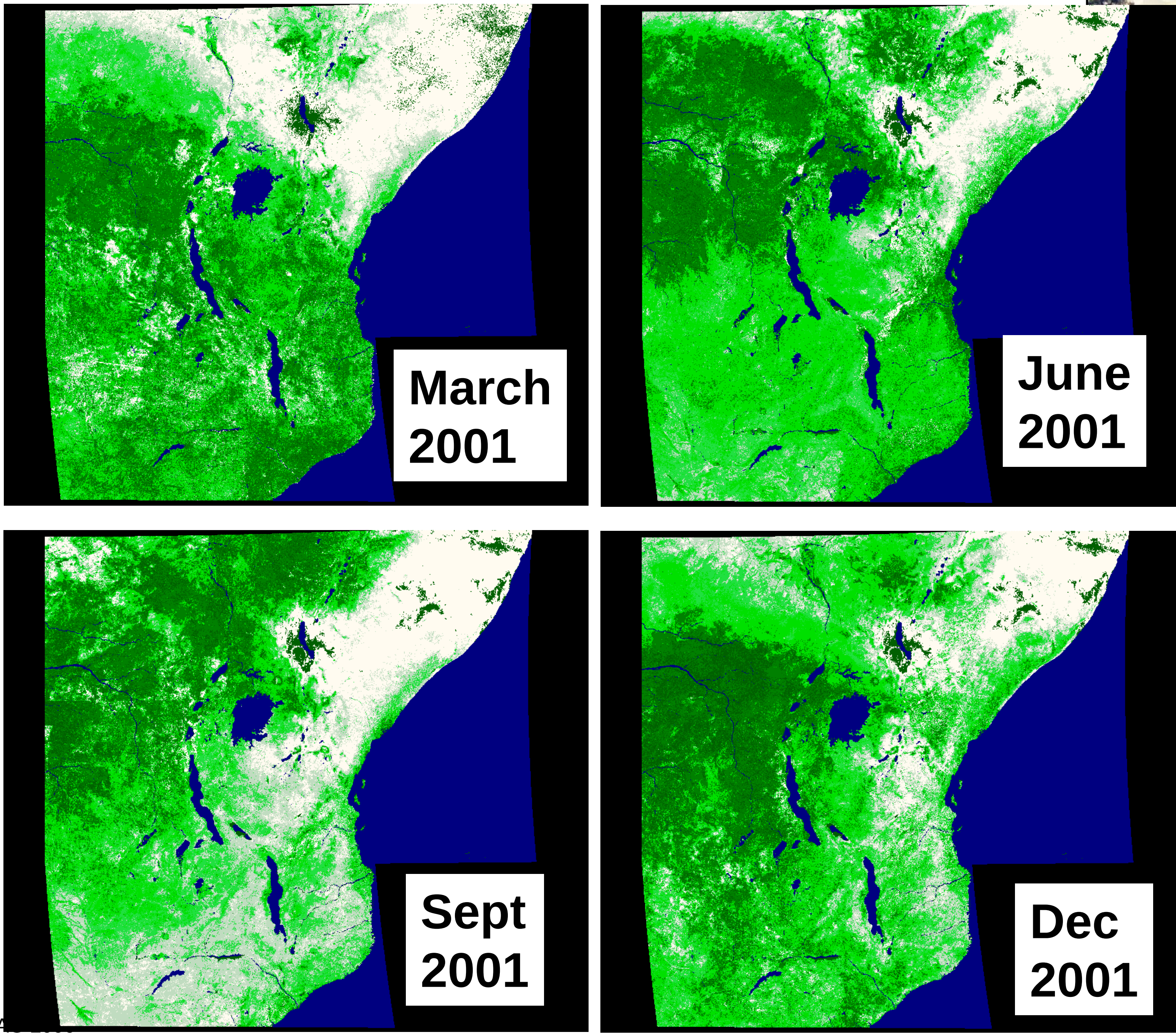
Data

- LU/C
  – GLC2000, Africover, IGBP, MODIS
- Biophysical Variables
  – LAI, EVI, DEM, Albedo, LST, and Precip. etc.
- Scales
  – Continental – Case Study/Field-Observations

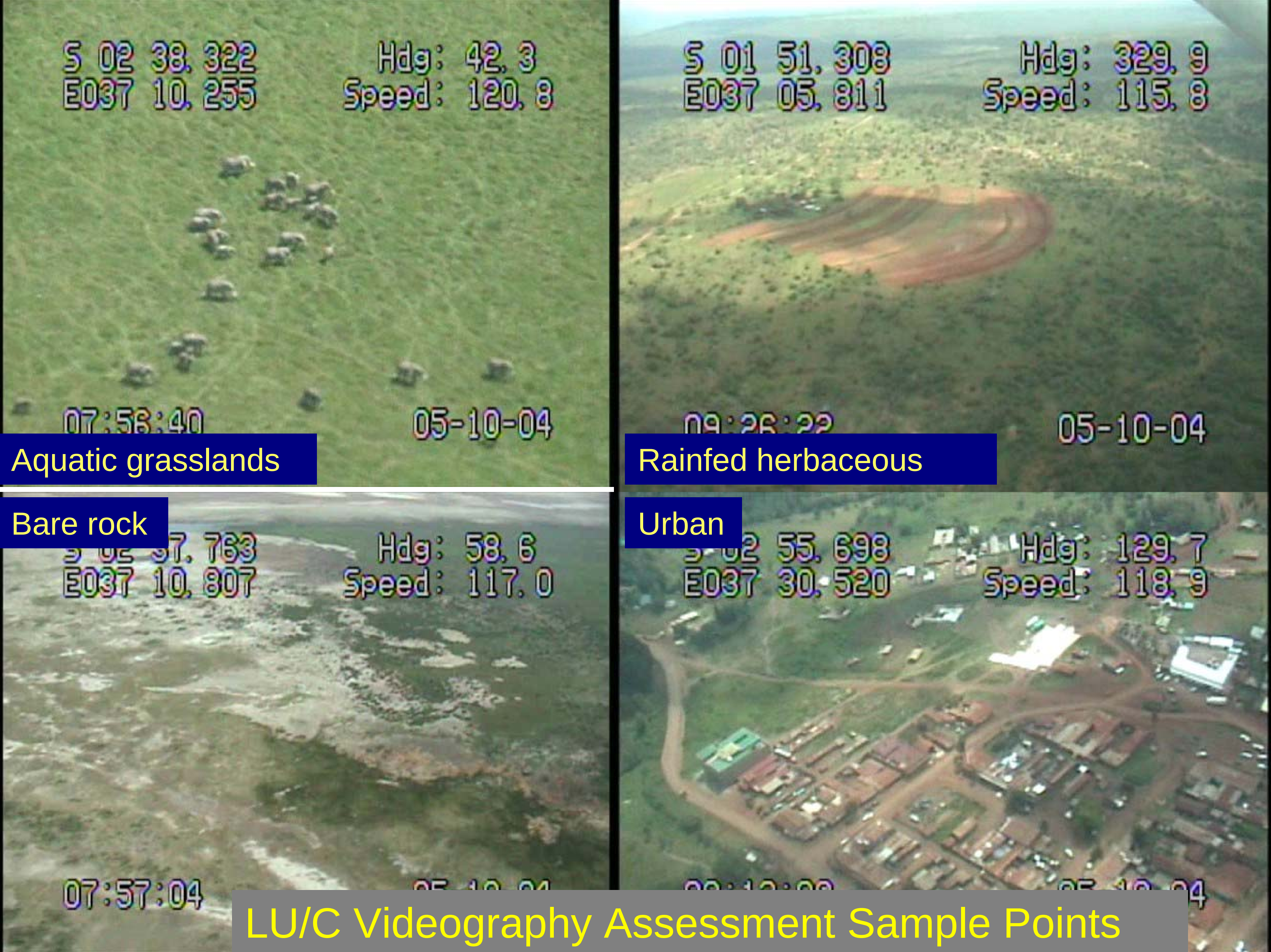


LULC products range in data sources, objectives, classification methods

LAI from MODIS



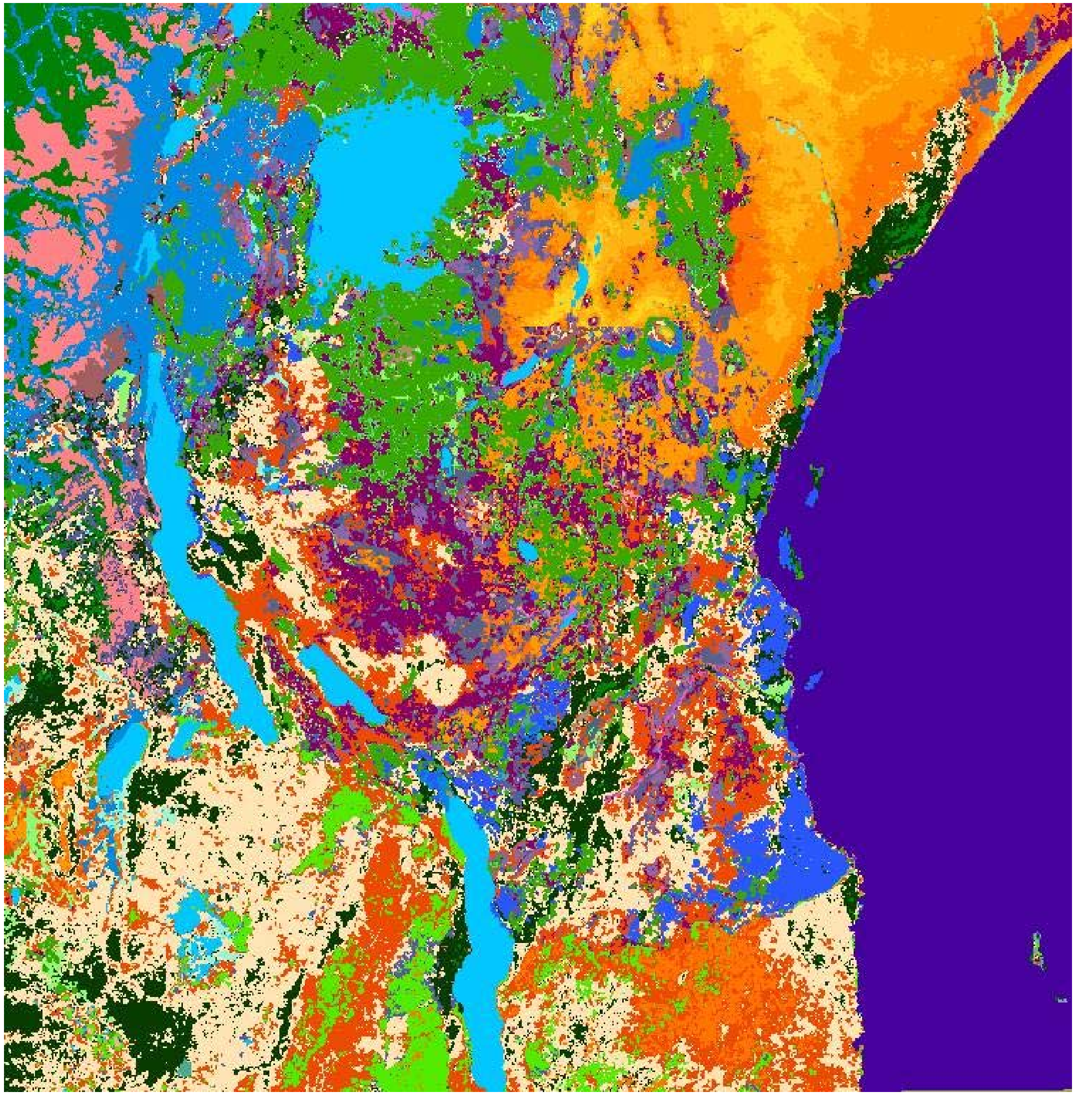
LU/C Videography Assessment Sample Points



Assessments and Developing LULC Scheme

- Multiple LULC assessments and evaluations
  - Strengths and weaknesses
  - Videography over selected ecological gradients
  - Q-statistic (uses LAI as ‘evaluator’)
- Develop LULC Schemes for models
  - Create hybrid CLIP-cover
    - LU from Africover, LC from GLC2000
    - Crosswalk to LEAF2, biophysical variables

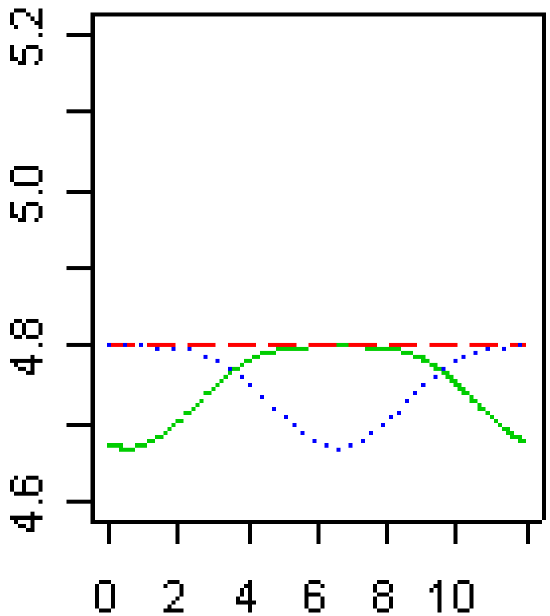
Clip-cover, hybrid land classification



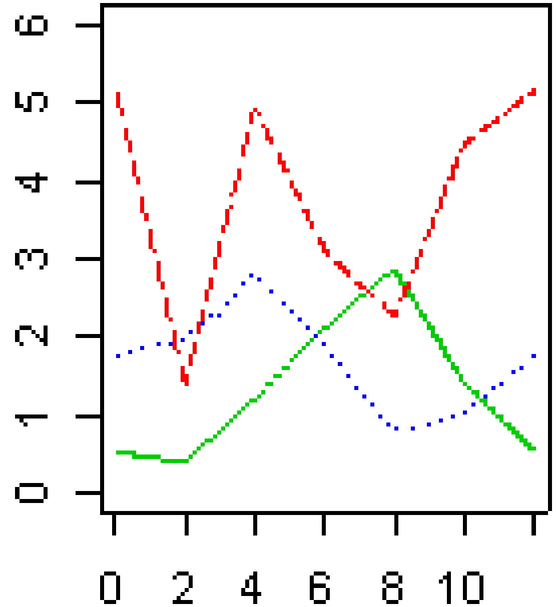
Phenology (seasonal LAI)

Deciduous shrubland and sparse trees

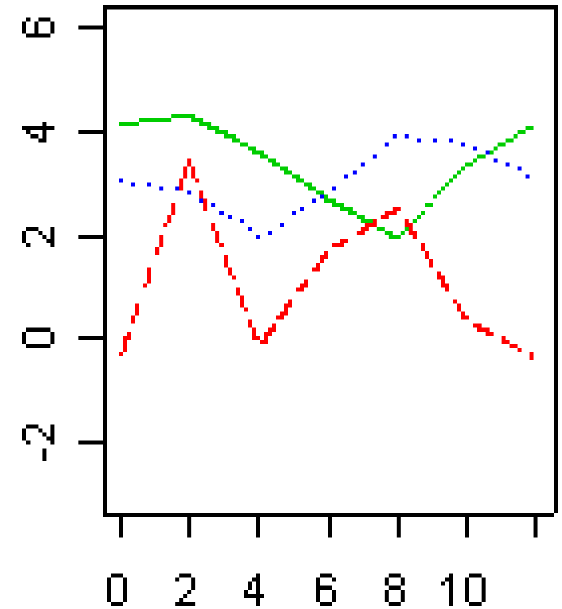
RAMS default

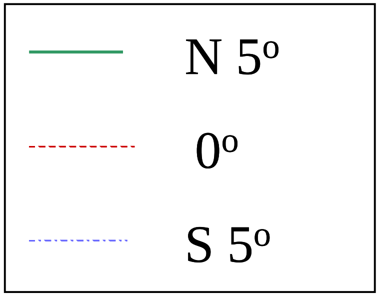


Improved spline curve of MODIS data



Difference

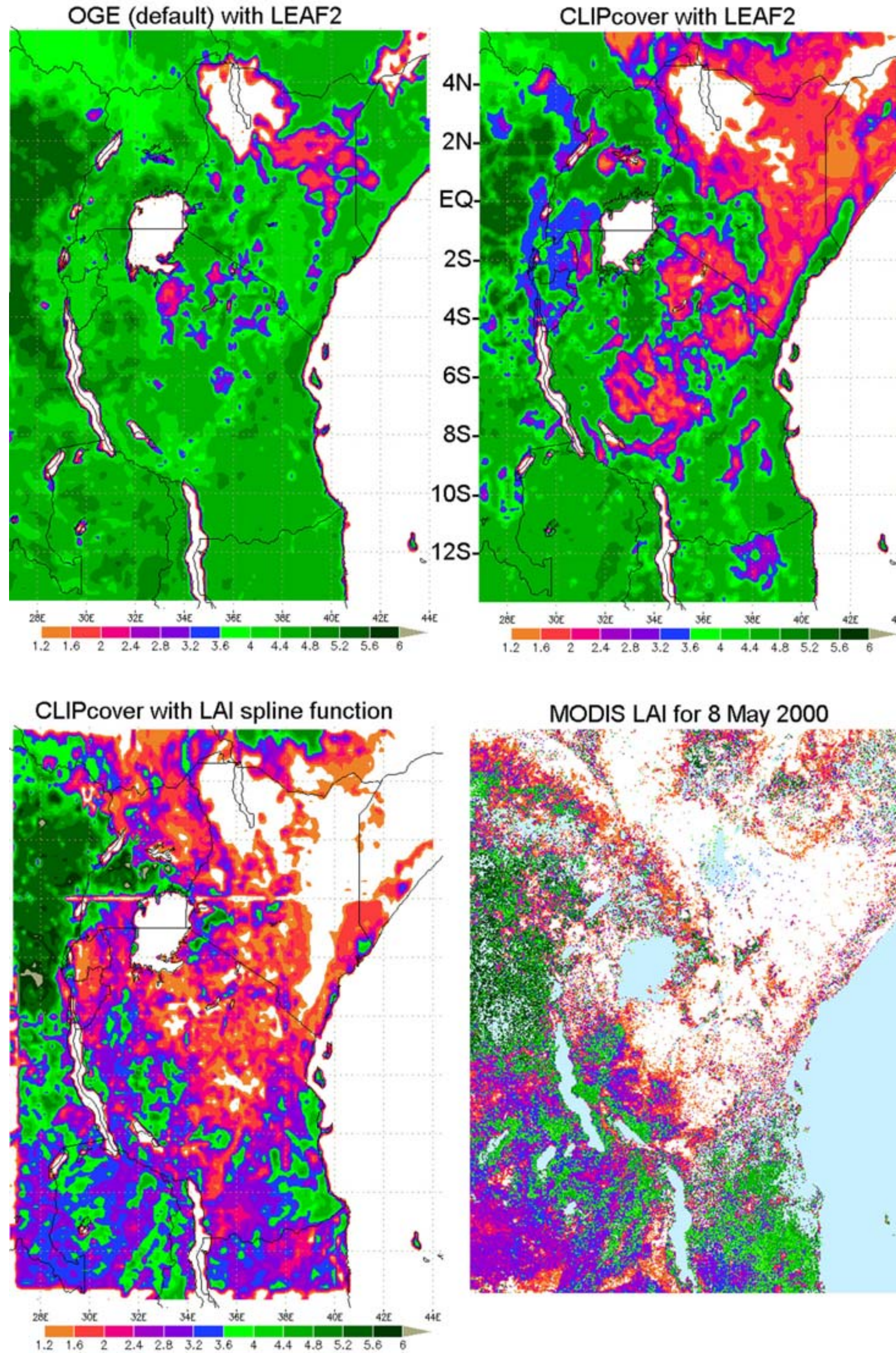




Result: Improved representation of land surface in RAMS

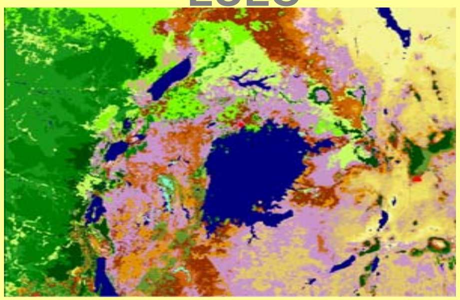
LAI shown in:

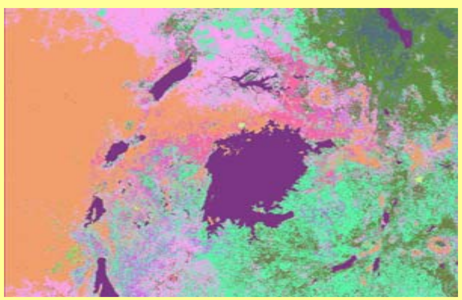
1. RAMS default land cover, and default cover parameters.
2. CLIP-cover, with default land cover parameters.
3. CLIP-cover with new spline functions
4. MODIS observed LAI for that period.

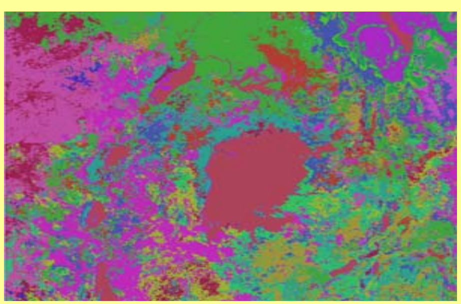


Methods for Biophysical Parameters

LULC







RAMS MODEL

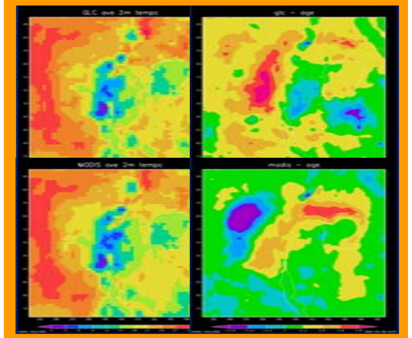
Biophysical Parameters

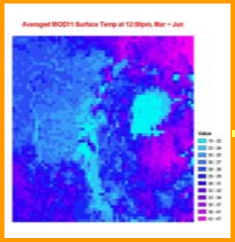
Land – Atmosphere Feedback

Crosswalk to Predetermined Defaults

- Albedo
- Leaf Area Index
- Range of Leaf Area Index
- Vegetation Fraction
- Range of Vegetation Fraction

Simulations





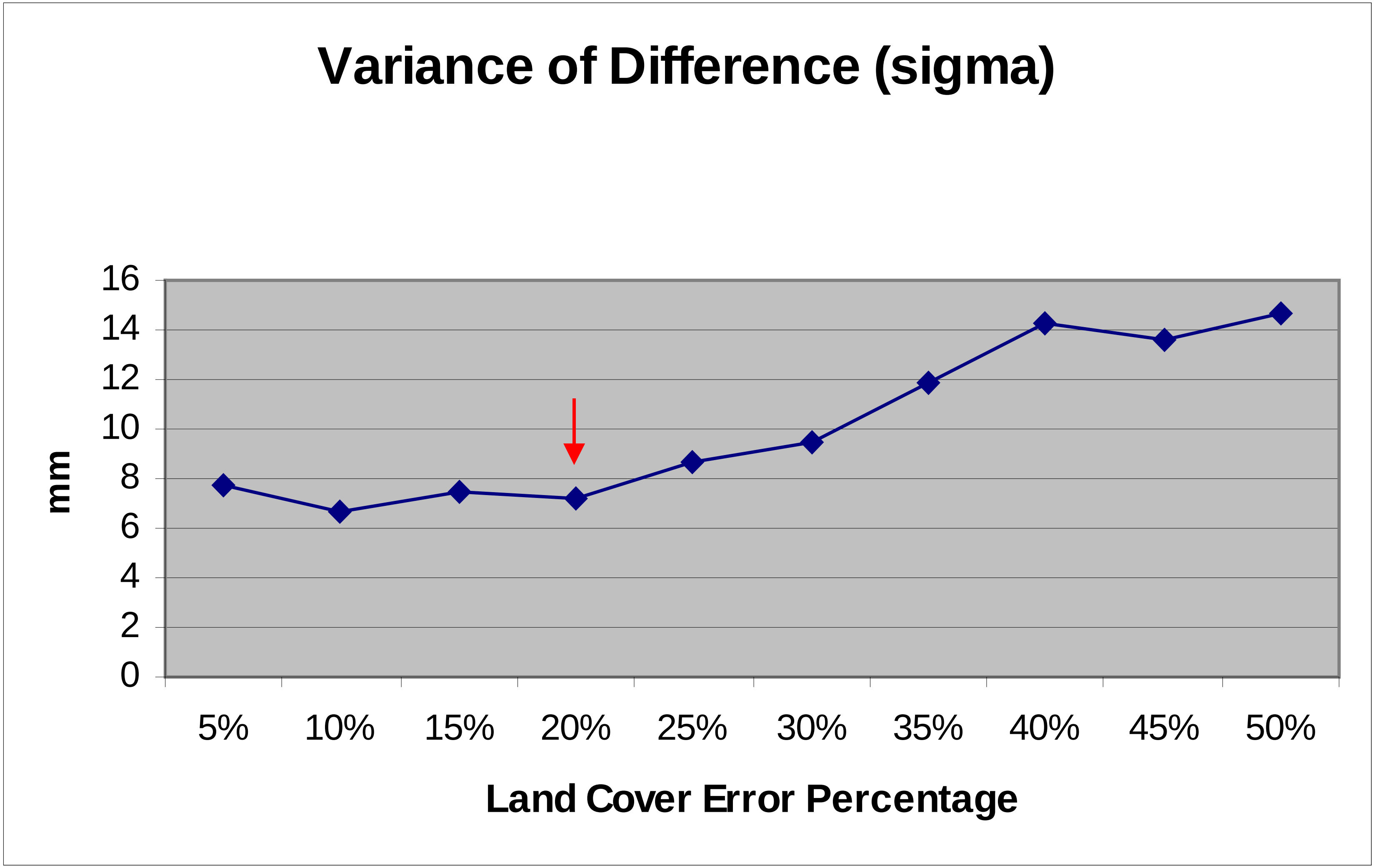
RS

Testing the effect of land cover classification accuracy on climate simulations

Experimental Design

- Classification error was added to original GLC2000 dataset at random locations and by random predominant (five) classes, which was increased from 0% to 50% at 5% interval
- RAMS was run 11 times with different amount of errors in land cover. These runs are called R00, R05, R10, …., R50.

Result: 20% difference in LC appears to trigger significant changes in RAMS.



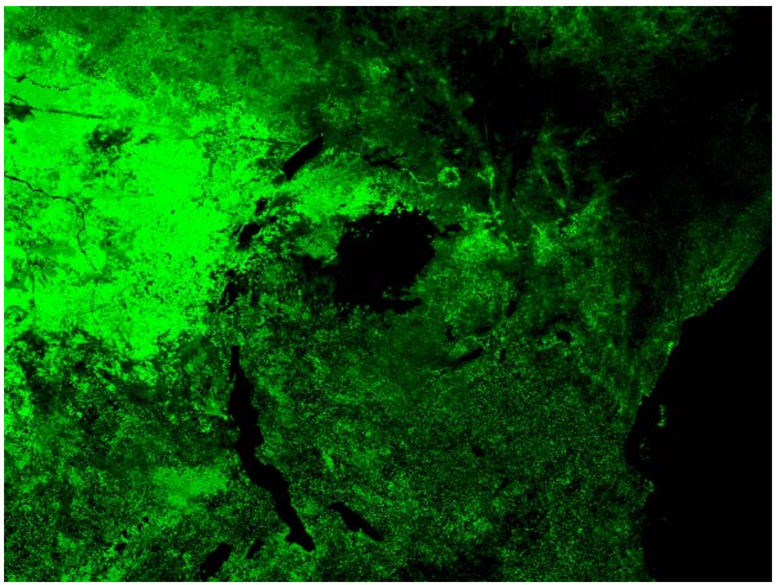
Testing the effect of reducing the “amount” of vegetation on the regional climate

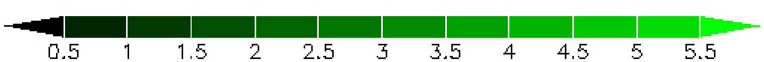
Leaf Area Index

- LAI in RAMS was improved by incorporating monthly 1km MODIS LAI image data.
- LAI values were reduced in RAMS to 50% at 5% rate. 11 runs were conducted.
- Kain-Fritsch without interior nudging was used to evaluate results.

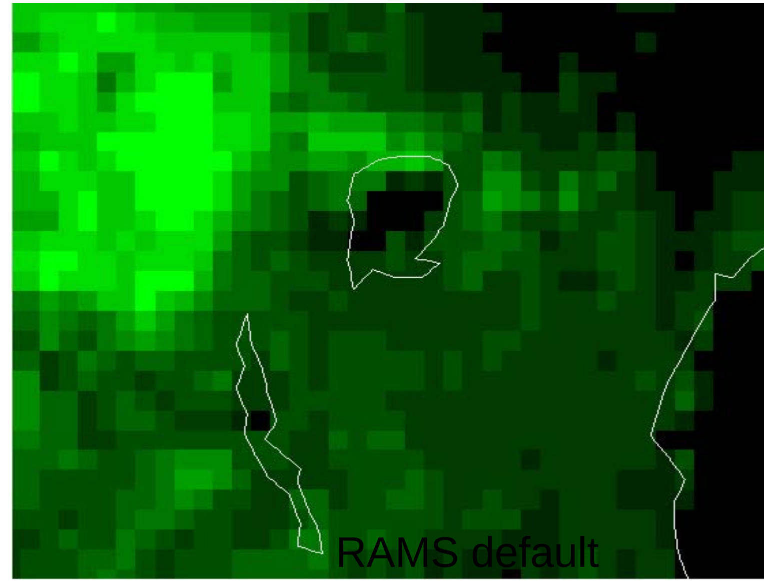
March 15th 2000

MODIS

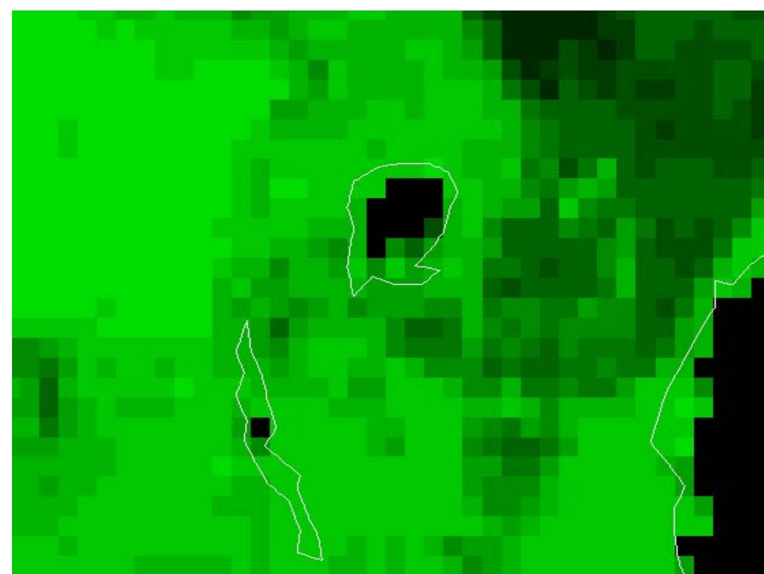




RAMS new



RAMS default



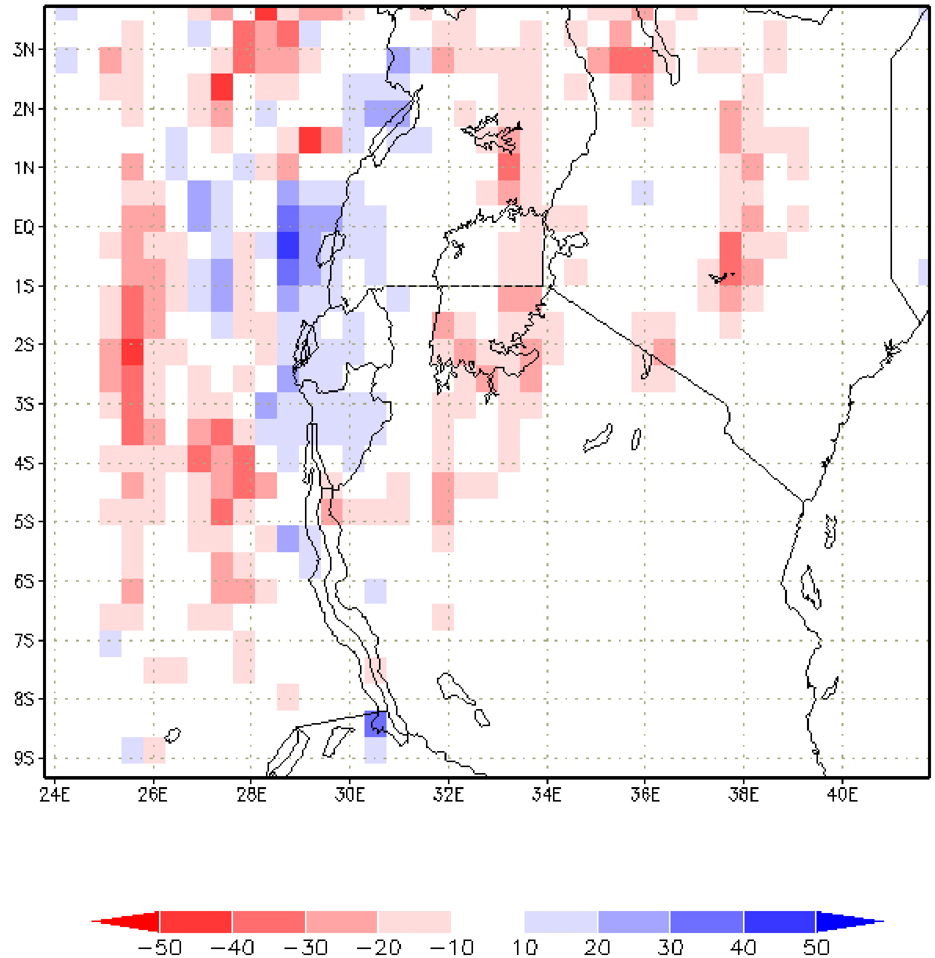
Result: Reductions of vegetation density can be associated with significant changes in precipitation.

Change in precipitation with a 50% reduction in LAI.

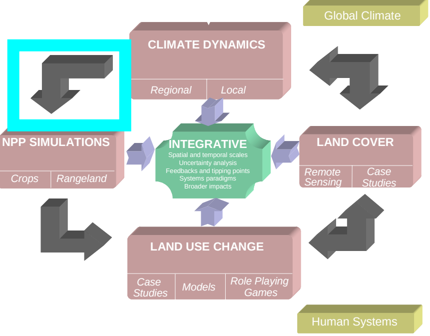
March-May, 2003

Max difference: 46.7102

Variance: 10.1359



mm



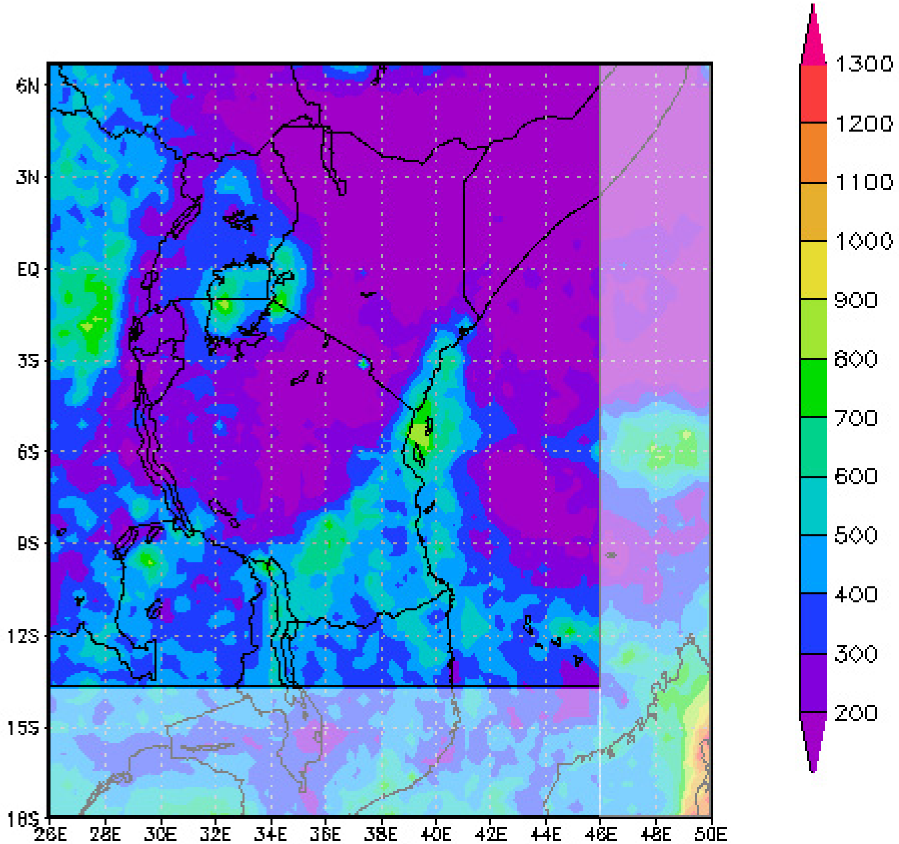
Linking climate change and vegetation

Challenge: Identify historic trends, and develop future scenarios, of the regional climate.

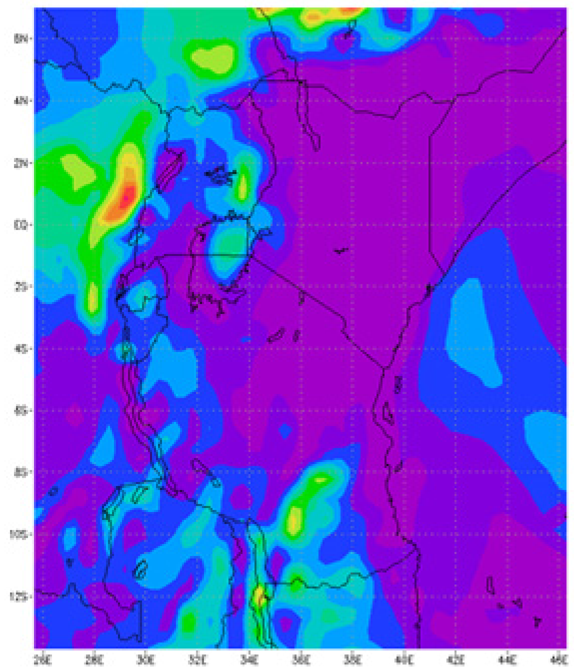
Jeff Andresen, Declan Conway, Clair Hanson, Sarah Hession, Marianne Huebner, Brent Lofgren, Nathan Moore, Jean Palutikof.

Using Satellite-Derived TRMMS data to validate RAMS

TRMM 3B42(V6) 00Z01Feb2000-00Z30Jun2000
Accumulated Rainfall [mm]



Modeled Precip, Feb-June 2000
using RAMS (mm)



Using Weather Station Data to Calibrate RAMS

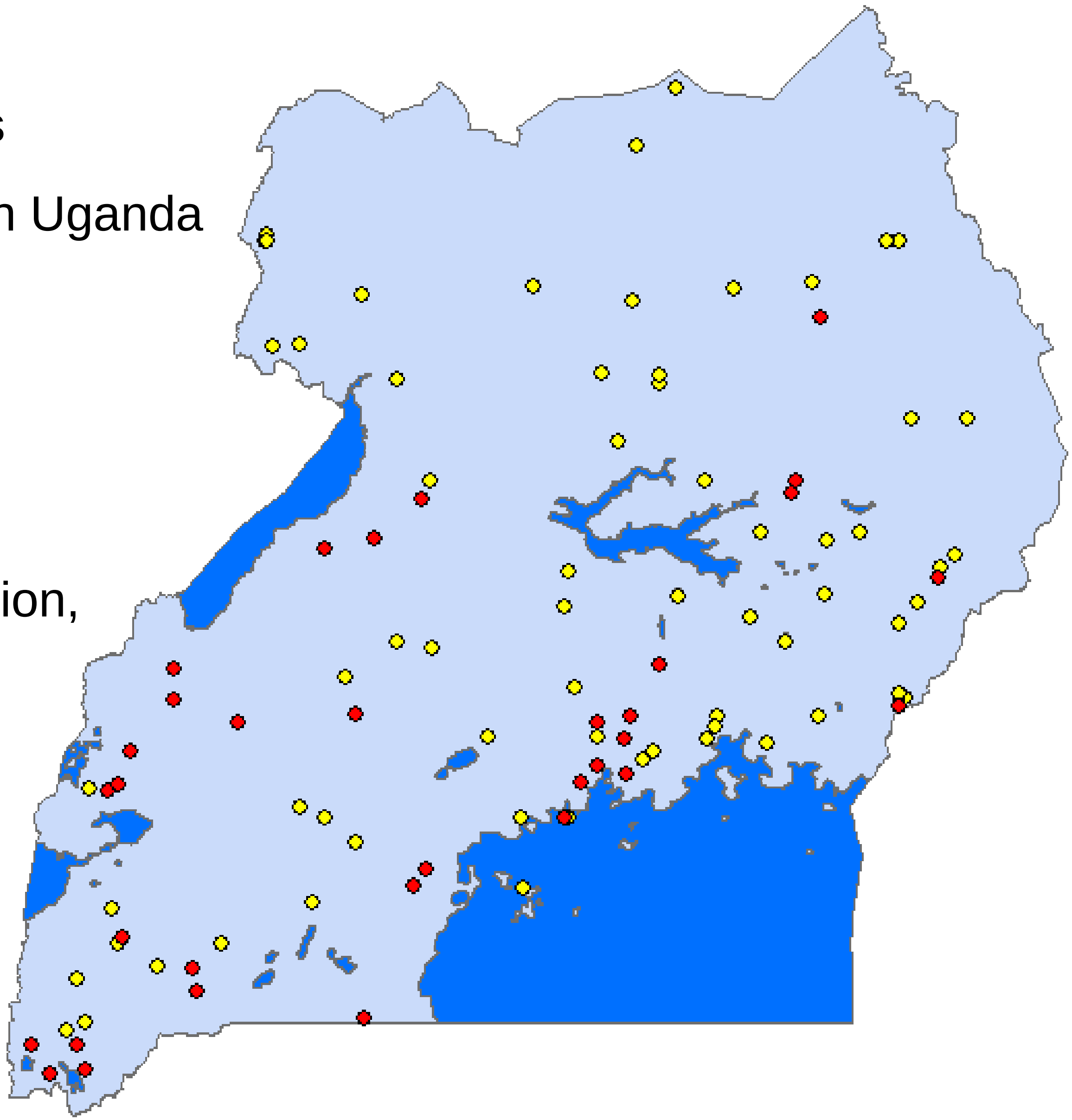
Precipitation stations

102 station located in Uganda

Spatial and temporal inconsistency.

Baseline year 1987.

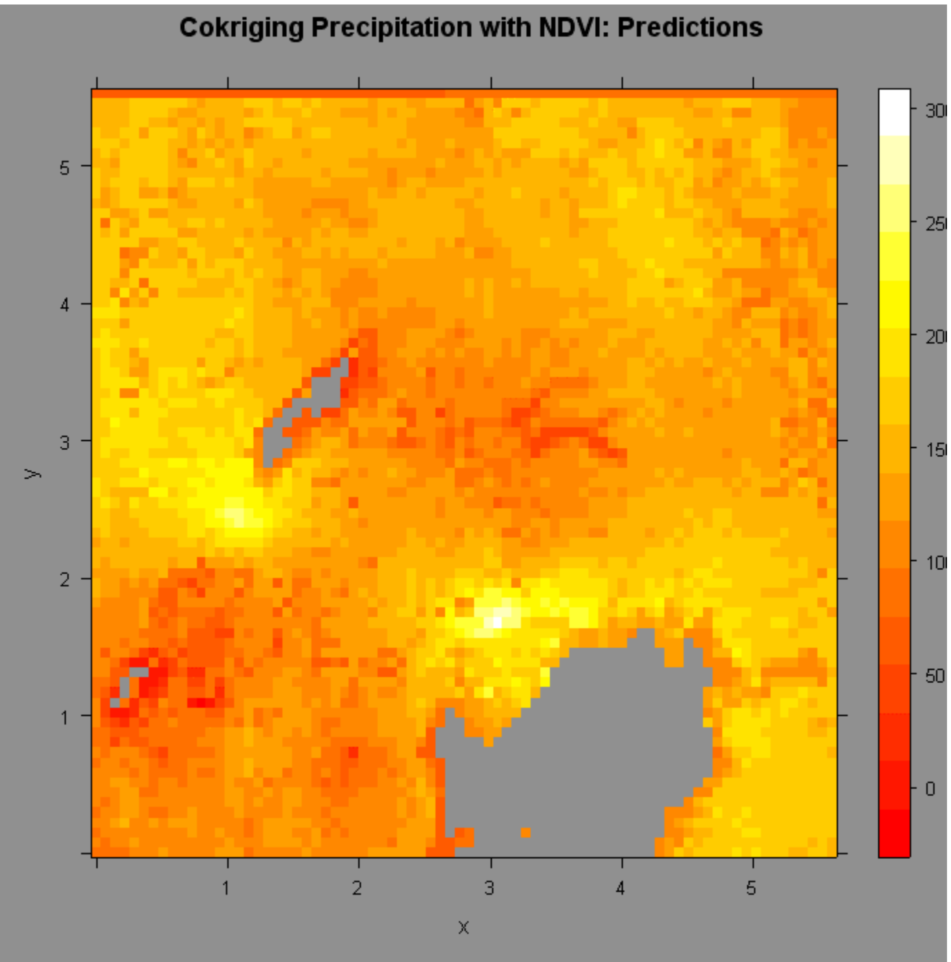
Analyzed with elevation, aspect.

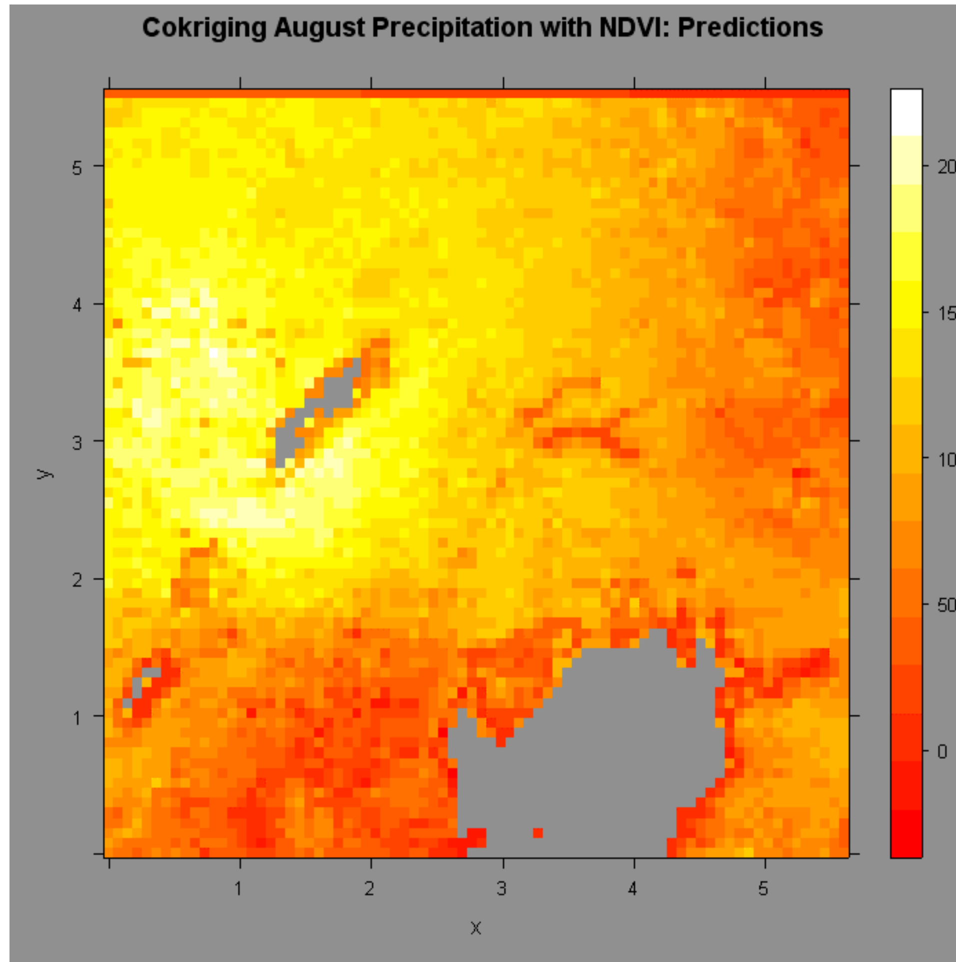


Co-Kriging Results - Precipitation

April 1987

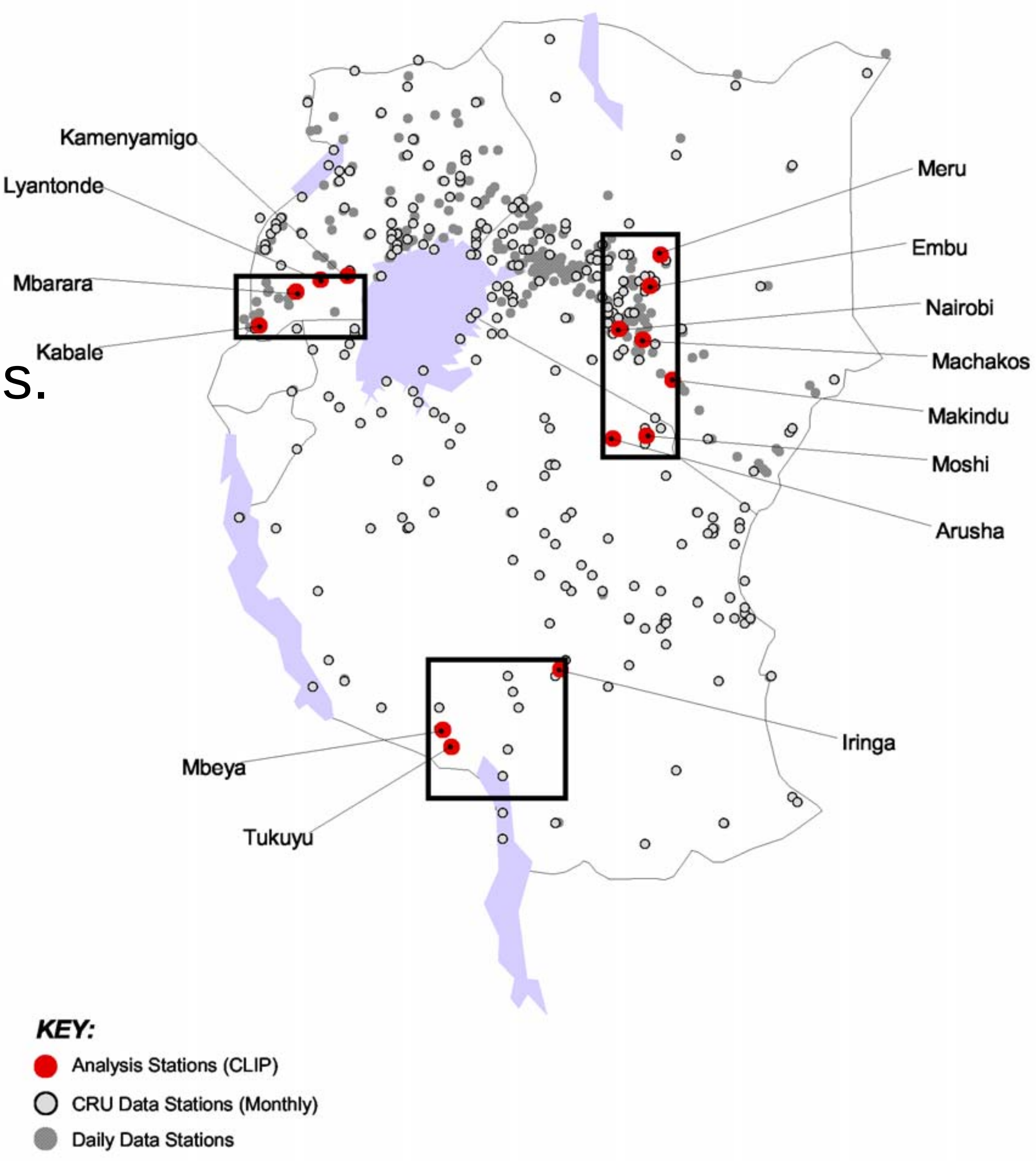
August 1987





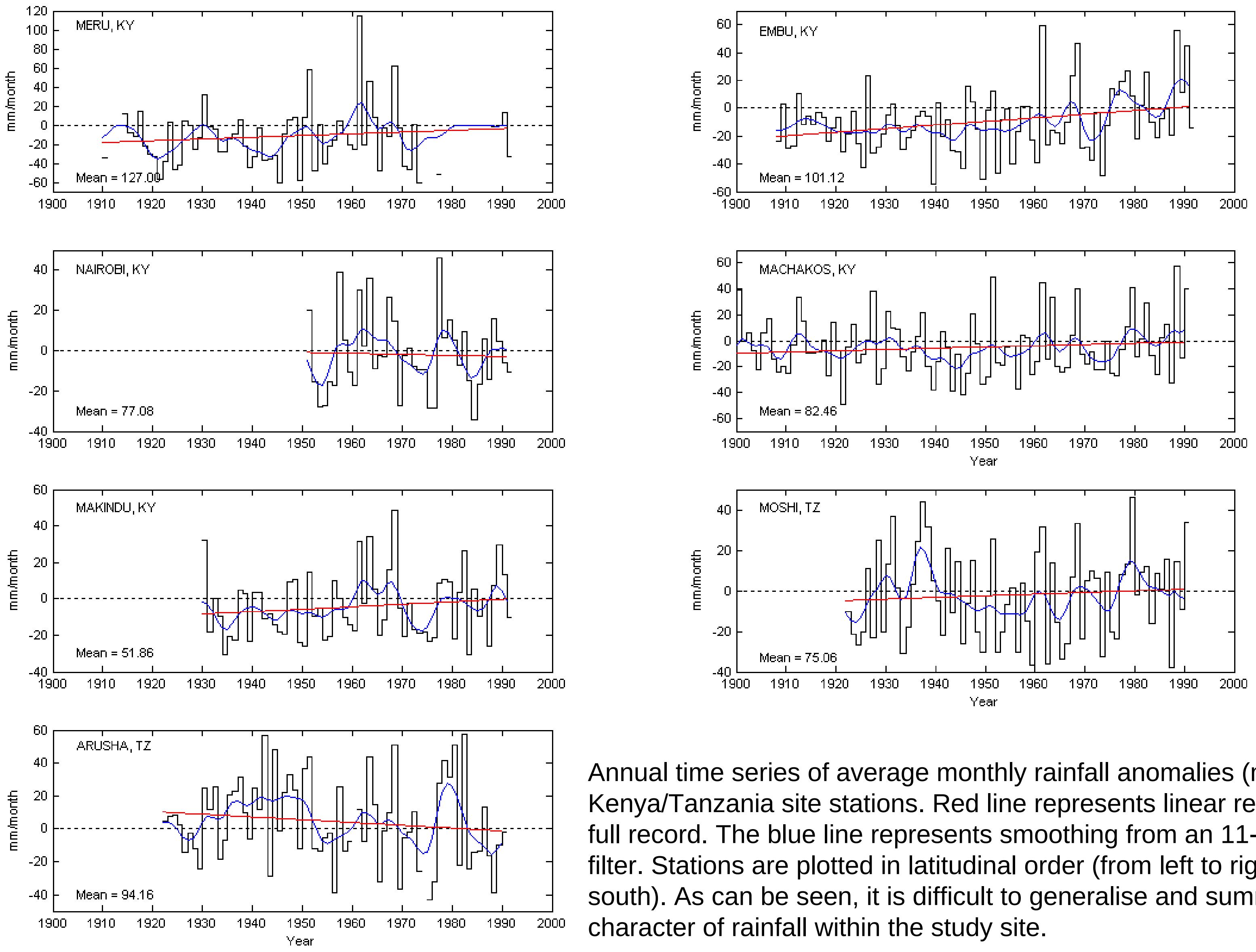
Analyzing historical climate trends

1. Conduct trends analysis of weather station precipitation data in case study sites.



Precipitation shows mixed results

Kenya Site - Annual Rainfall Anomalies w.r.t 1961-90

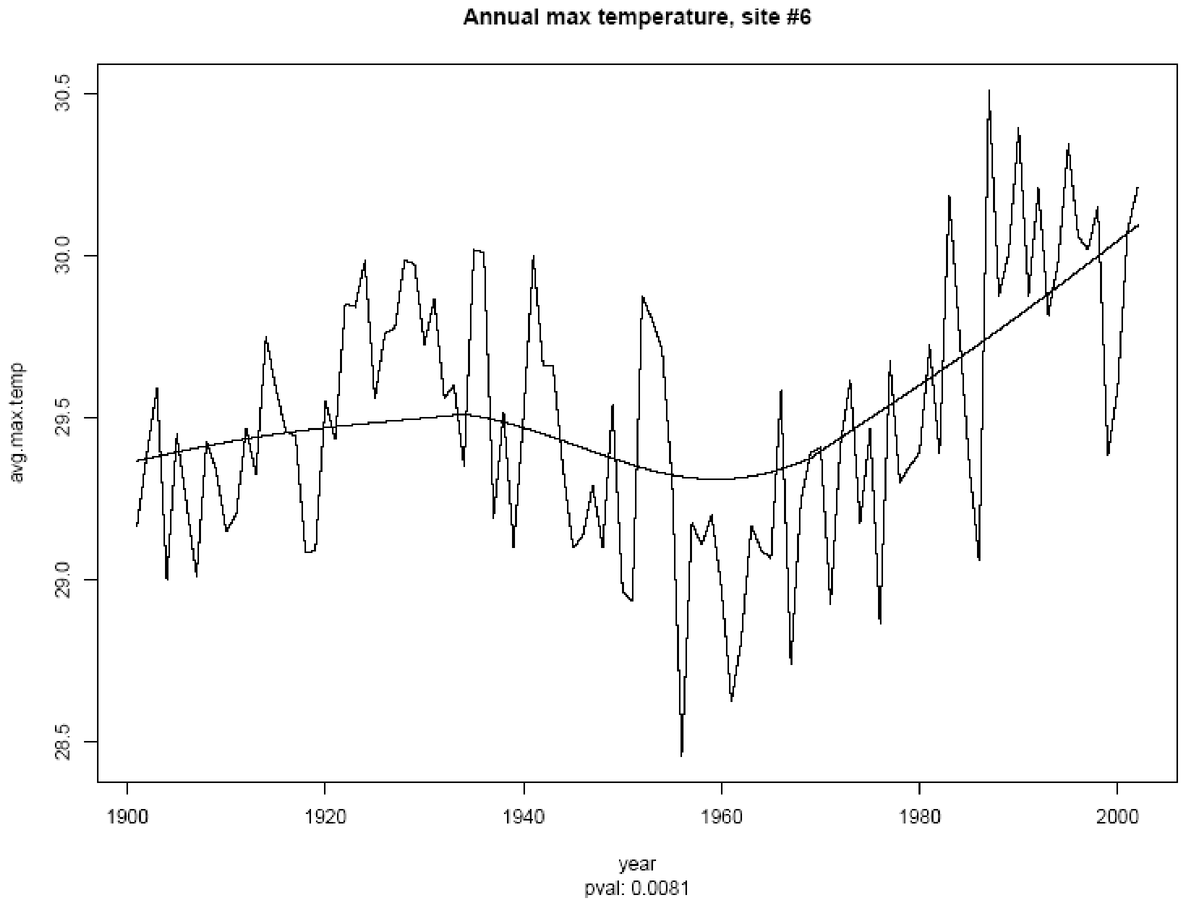


Annual time series of average monthly rainfall anomalies (mm) for the Kenya/Tanzania site stations. Red line represents linear regression over the full record. The blue line represents smoothing from an 11-point Gaussian filter. Stations are plotted in latitudinal order (from left to right, north to south). As can be seen, it is difficult to generalise and summarise the character of rainfall within the study site.

Historical temperature trends analysis:

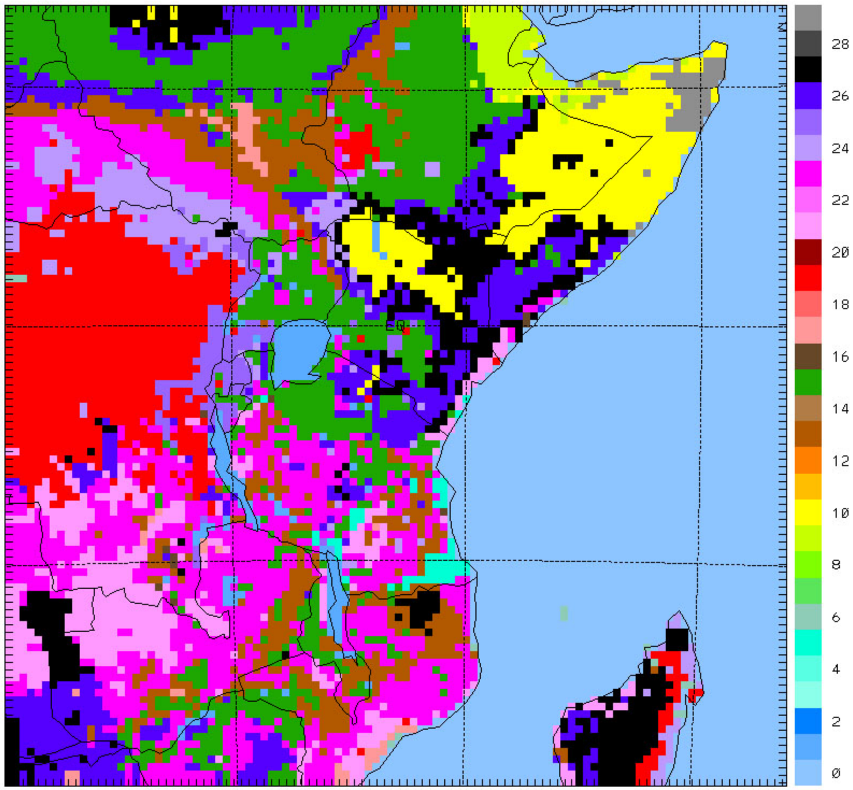
2. Statistically analyze new CRU gridded climate data (1901-2002).

Temperatures are generally increasing, especially since1950's.

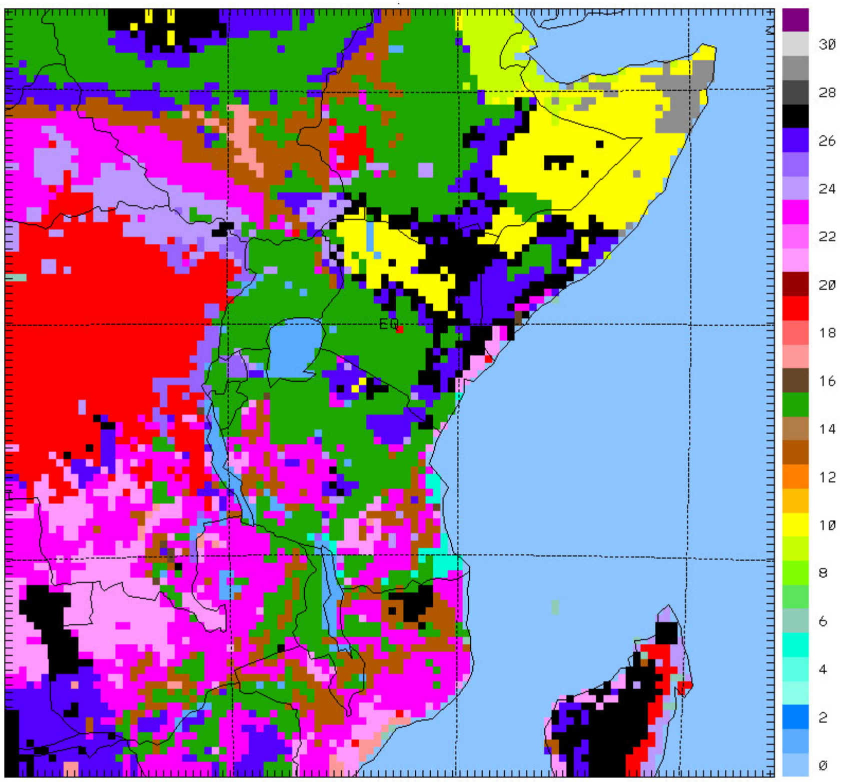


Climate simulation results: impacts of land cover change

Clip-cover 2000

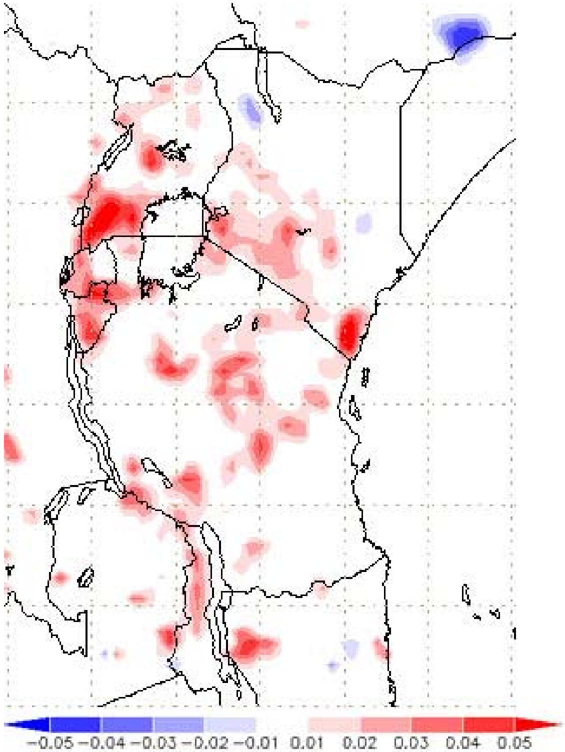


Clip-cover 2050

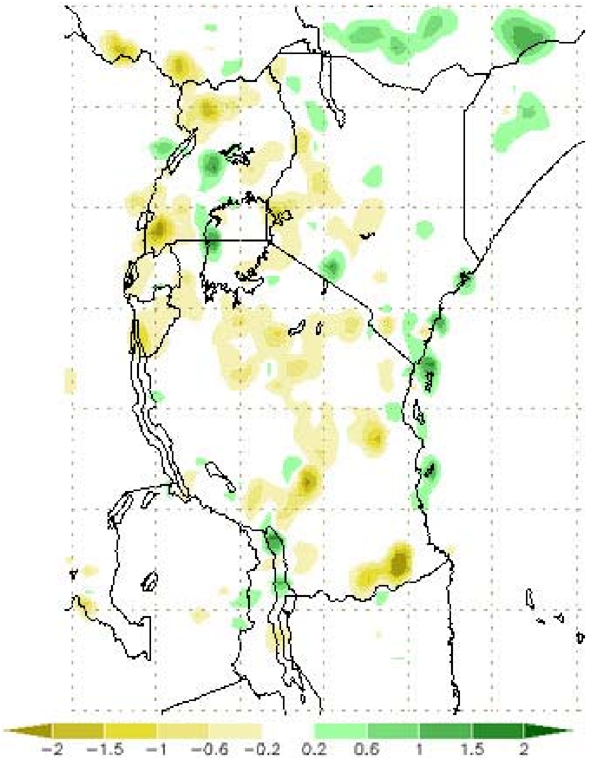


Comparing current and future surface characteristics due to land cover change (2050-2000)

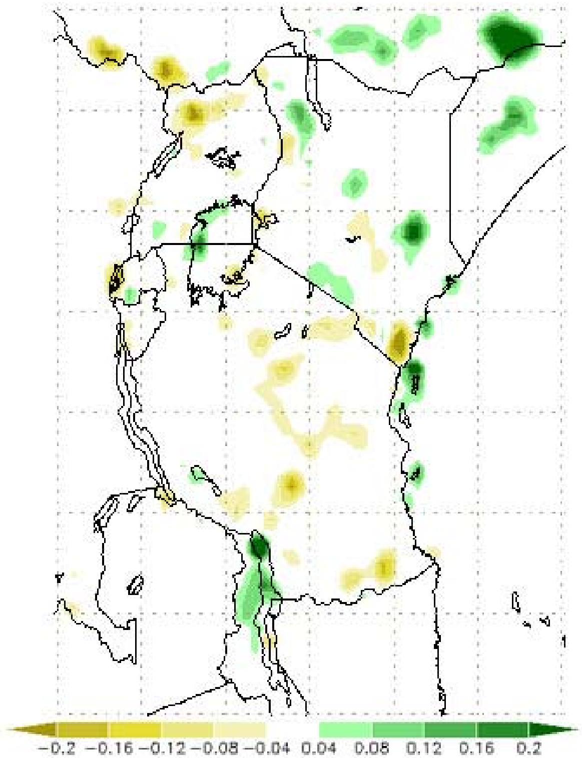
Albedo



LAI



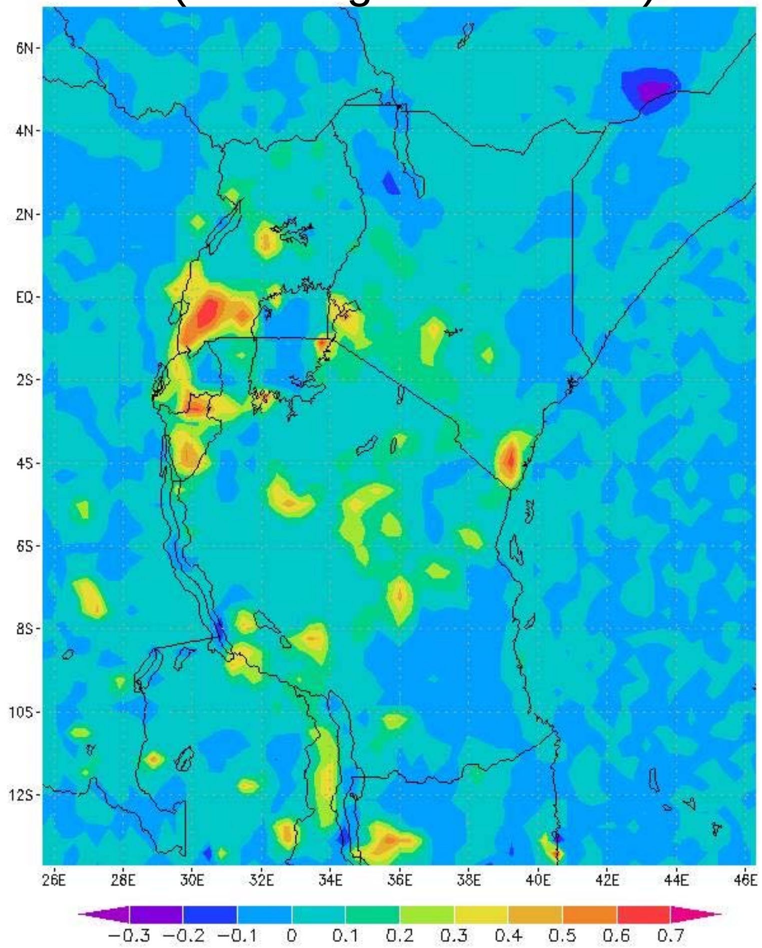
Fractional cover



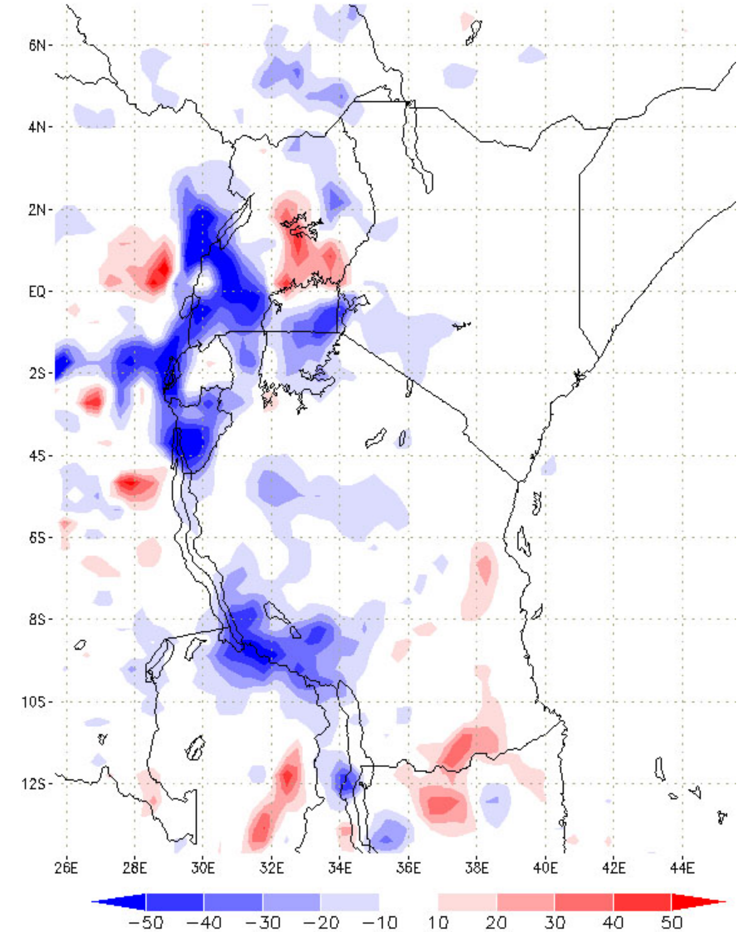
The large impact of forest reduction

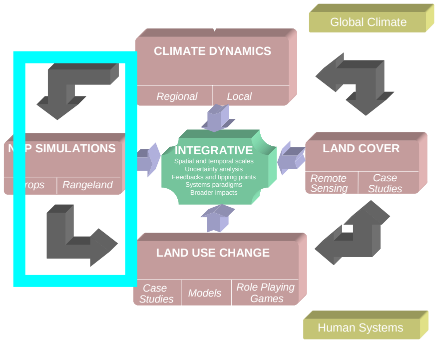
Hot spots show that mixed farming absorbs less energy, and has a lower latent heat flux than forest (convection is less likely).

Albedo
(% change 2050-2000)



Precipitation
(2050-2000 difference)





Linking climate change to vegetative productivity

Challenge: Spatial analysis of Net Primary Productivity (NPP) as it is altered by climate change

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Introduction to NPP

- Net Primary Productivity (NPP) is a key factor in Land Use and Land Cover Changes (LULCC)
- Maize yield represents NPP
- Future projections by Global Climate Models suggest:
  - Warmer climate
  - Uncertainty in rainfall
- Warmer climate will result in new pressure on soil, water, natural ecosystems, and livelihood of people leading to LULCC

Objective

To quantify the impact of climate on NPP in East Africa during two time periods

- Historical (1901-present), and
- Future (2007-2100)

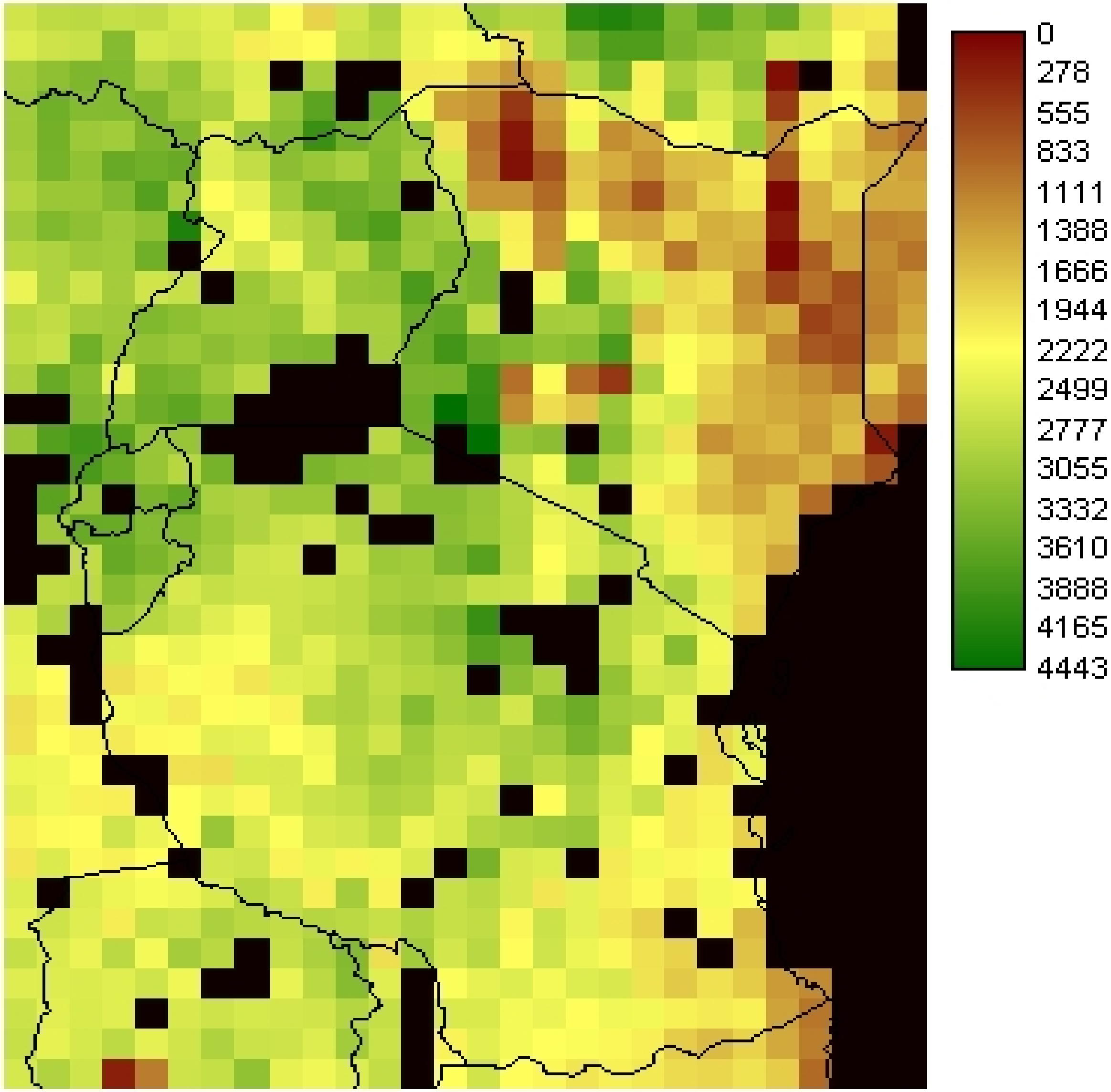
Methods

- Deterministic process based simulation models
- Gridded climatic data from Climate Research Unit (CRU's 2.01: 0.5° Lat / Long resolution)
- FAO (1974) soils data at 1:5M scale

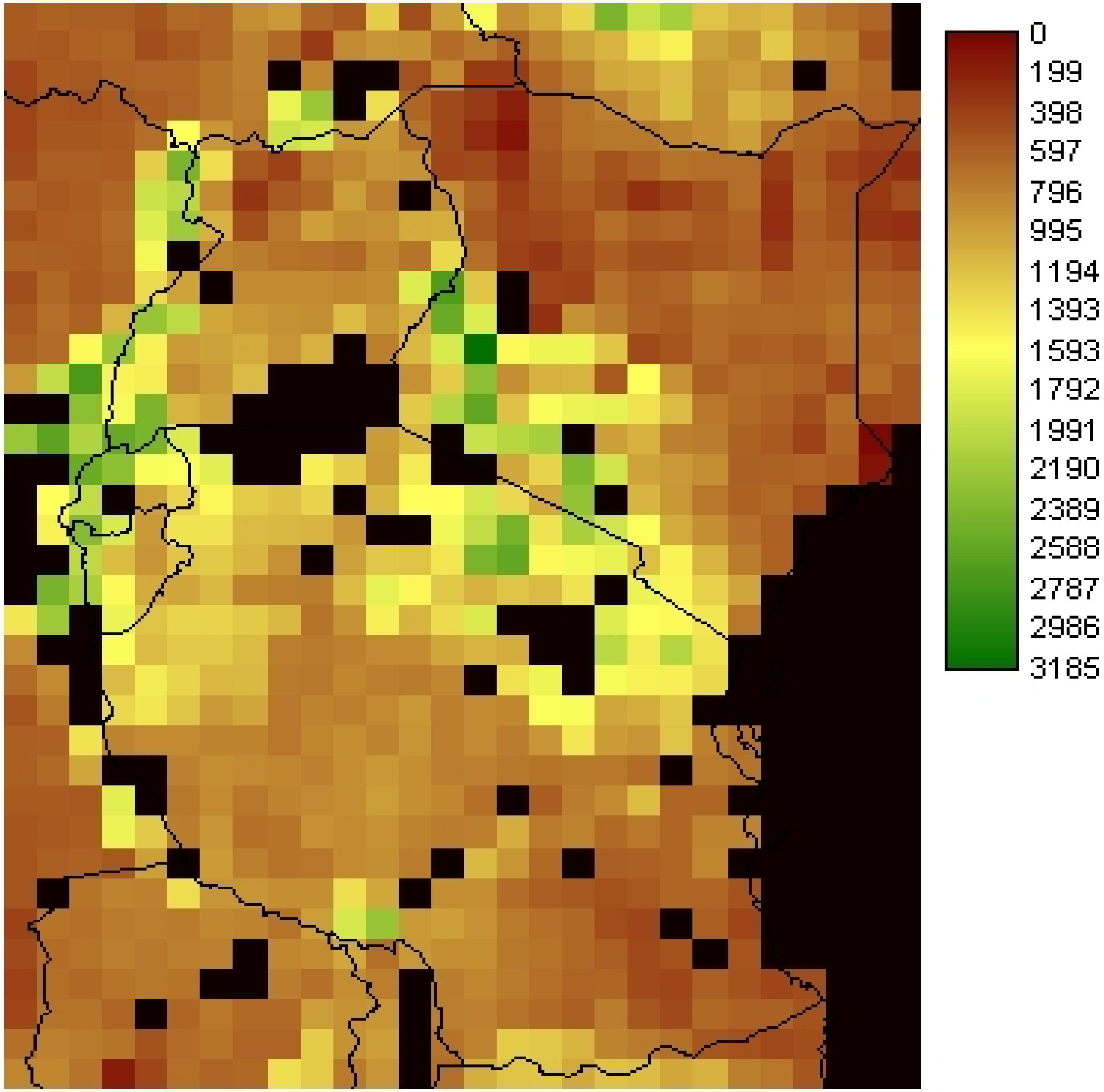
Results

- Simulated spatial pattern of maize yield during 1975-2002
  - Climatic potential
  - Model driver that influences yield most

Climatic potential of maize yield



Variations in soil type influence yield



NPP lessons

- Model simulations represent observed spatial pattern of maize yield
  - Higher yields in western Kenya, western strip of Uganda-Burundi-Rwanda, and in the hills of southern Tanzania
  - Lower yields in eastern Congo and northern Kenya and Uganda
- Variations in soil type (model driver) influence yield in East Africa unlike in the Great Plains of USA
- The cumulative probability of yield is an input to LULCC model

Feedback: People respond to altered vegetation

Increasing temperatures and potential evapotranspiration will place additional stress on crops, especially in drier areas. Lessons from recent and the current drought indicate that people will:

- Move to search for jobs and food in towns
- Seek to diversify their income sources
- Increase conflict over water, grazing
- Abandon cropping in some areas
- Develop irrigation where possible
- Livestock raising maintained.

Land use implications include altered farming systems, and perhaps a reduction in cultivated area.

Summary of preliminary results

- From Regional land-climate interaction: Decreasing vegetated cover from LUC is expected to lead to drier, warmer conditions
- From Global Climate Change, can expect increasing temperatures and an increase in potential evapotranspiration. This will lead to new pressure on the soil, water and vegetation. The results will reverberate through the human and biophysical systems.

Conclusion

- Challenges of working in an area with less available data requires careful adaptation of globally available datasets.
- Analytical approach integrating a variety of temporal and spatial scales.
- In East Africa, it appears that climate change combined with land use/cover change may alter the frequency and intensity of agricultural drought.


Thank you.