Final Report for Period: 09/2001 - 08/2002 **Submitted on:** 11/27/2002
Principal Investigator: Campbell, David J. **Award ID:** 0119821
Organization: Michigan State University
Title:
BE/CNH: Climate and Land Use Change Processes in East Africa

Project Participants

Senior Personnel

Name: Campbell, David
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Pijanowski, Bryan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Winkler, Julie
Worked for more than 160 Hours: No
Contribution to Project:

Name: Olson, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Andresen, Jeffrey
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

NOAA Great Lakes Environmental Research Lab
Brent Lofgren led the regional climate modeling proof of concept activity

International Livestock Research Institute
ILRI shared in the costs of hosting the workshop; ILRI research scientists participated in the workshop and are senior scientists on the proposals written post-workshop

Other Collaborators or Contacts

We held a Workshop in Nairobi Kenya at which the project was discussed.

Attendees (including PIs) at the Workshop are listed in the following Table:

APPENDIX 1 - LIST OF PARTICIPANTS

Andresen, Jeff USA
Department of Geography
Climatologist
Michigan State University
314 Natural Science
East Lansing, MI48824

Atieno, Fred Kenya
International Livestock Research
Institute(ILRI)
P.O. Box 30709
Nairobi, Kenya

Butt, Bilal Kenyan
Department of Geography
RA For Climate Change
Michigan State University
314 Natural Science
East Lansing, MI48824, USA

Campbell, David USA
College of Social Science
Associate Dean
Michigan State University
Professor of Geography
203 Berkey Hall
East Lansing, MI48824, USA

Doherty, Ruth USA
Environmental and Societal Impacts Group
Visiting Scientist
NCAR 3450 Mitchell Lane PO Box 3000
Boulder, CO 80301, USA

Kasoma, Dr. P. Uganda
Makerere University
Director, MUIENR
Institute of Environment and Natural Resources
P.O. Box 7298
Kampala, Uganda

Kihumba, Francis Kenya
National Environment Secretariat
Deputy Director,
Bruce House 10th Floor
P.O. Box 67839
Nairobi, Kenya

Kshatriya, Mrigesh Kenya
International Livestock Research Institute(ILRI)

Ecosystem Modeller
P.O. Box 30709
Nairobi, Kenya

Kuska, Russ Kenya
International Livestock Research Institute(ILRI)
Director of GIS Lab
P.O. Box 30709
Nairobi, Kenya

Lofgren, Brent USA
NOAA/Great Lakes Environmental Research Laboratory
Physical Scientist
2205 Commonwealth Blvd
Ann Arbor, MI48105-2945 USA

Magezi, Stephen A.K. Uganda
Uganda Meteorology Department
Assistant Commissioner for Meteorology
Yusufu Lule Road at Post Office Building
P.O. Box 7025 Kampala
Uganda

Maitima, Joseph Kenya
International Livestock Research Institute(ILRI)
Regional Coodinator,
Ecological, LUCID Project
P.O. Box 30709, Nairobi, Kenya

Manyika, Kanizio F.K. Tanzania
Division of Environment 255 0741-426060
Vice President's Office
P.O. Box 5380
Dar es Salaam, Tanzania

Mbekenga, Desderius Tanzania
Environment Protection and Management Services
Assistant Managing Director of EPMS
P.O. Box7775
Dar es Salaam Tanzania

Mwangi, Albert M. Kenya
UNDP/GOK Environment and Natural Resources Programme
National Programme Manager
National Environment Secretariat
Bruce House 10th Floor
P.O. Box 67839 Nairobi Kenya

Nganga, John Kenya
Department of Meteorology
University of Nairobi, Chiromo campus
P.O. Box 30197
Nairobi, Kenya

Odada, Eric Kenya
Pan African START Secretariat (PASS)
Programme Director
University of Nairobi, Chiromo campus
Pan African START Secretariat
Department of Geology
Riverside Drive PO Box 30197
Nairobi, Kenya

Ojoo-Massawa, Emily Kenya
National Environment Secretariat
National Coordinator,
Bruce House 10th Floor
Climate Change Enabling Activities
P.O. Box 67839
Nairobi, Kenya

Olson, Jennifer Kenya
International Livestock Research Institute(ILRI)
Regional Coordinator,
Land Use & Socioecon.
P.O. Box 30709
LUCID Project
Nairobi, Kenya

Palutikof, Jean UK
Climatic Research Unit
Director, Internal Affairs
University of East Anglia
NorwichNR4 7TJ UK

Pijanowski, Bryan USA
Department of Zoology
Assistant Professor
Michigan State University
203 Natural Science
East Lansing, MI48824 USA

Reid, Robin Kenya
International Livestock Research Institute(ILRI)
Coordinator, People Livestock and Environment Programme   P.O. Box 30709
Nairobi, Kenya

Robinson, Tim Kenya t.robinson@cgiar.org
International Livestock Research Institute(ILRI)
Biological, Climate and Disease Modelling
P.O. Box 30709
Nairobi, Kenya00100

Shein, Karsten USA
Department of Geography
Ph.D. Candidate
Michigan State University
314 Natural Science
East Lansing, MI48824 USA

Taylor, David Kenya
International Livestock Research Institute(ILRI)
Deputy Director, Research
P.O. Box 30709
Nairobi, Kenya 00100

Thornton, Phillip Kenya
nternational Livestock Research Institute(ILRI)
Coordinator, SAIA Programme
P.O. Box 30709
Nairobi, Kenya 00100

Yanda, Pius Z. Tanzania
Institute of Resource Assessment
Research Professor
University of Dar es Salaam
P.O. Box 35097
Dar es Salaam Tanzania

Collaborating Scientists, Unable to Attend Workshop

Lusch, David USA
Center for Remote Sensing
Senior Research Specialist
Michigan State University
1405 S. Harrison Road
308 Manly Miles
East Lansing, MI48824USA

Mugisha, Sam Uganda
Makerere University Institute of Enviornment and Natural Resources
Lecturer/Researcher
P.O. Box 7298
Kampala, Uganda

Muyungi, Richard Tanzania
Director Department of Environment
Vice President's Office
P.O. Box 5380
Dar es Salaam Tanzania

Salehi, Habib USA
Department of Statistics
Chairperson, Stats & Pro
Professor, Stats and Math
Michigan State University
East Lansing, MI48824

Semazzi, Fred USA
Department of Marine, Earth, and Atmospheric Sciences
Professor
North Carolina State University
Box 8208 120 Research III
Raleigh, NC27695-2808

Wangui, Edna Kenya
International Livestock Research Institute(ILRI)
Ph.D. Candidate
P.O. Box 30709 Nairobi, Kenya

Winkler, Julie USA
Department of Geography
Professor of Geography
Michigan State University
314 Natural Science
East lansing MI 48824

Activities and Findings

Research and Education Activities:

I. WORKSHOP IN NAIROBI, KENYA TO DISCUSS LAND-CLIMATE INTERACTIONS

II. PROOF OF CONCEPT ACTIVITIES
A. REGIONAL CLIMATE MODEL DEVELOPMENT
B. LAND USE CHANGE ANALYSIS
C. CREATION OF DATABASES

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:

The graduate students who worked on this project developed greater appreciation of the issues involved in their research areas. These included database compilation, coordination, and management for Geography RA Bilal Butt, and parametirization of the regional climate model for Computer Science RA Nitin Jaiswal.

Outreach Activities:

The participation of policy-makers from Kenya, Uganda, and Tanzania in the Workshop provided an opportunity for the scientific issues to be contextualized in the realities of the policy priorities of the countries of east Africa. This provided the policy-makers with a greater appreciation of the capabilities of scientists to address research questions with an explicit policy relevance.

PIs have made a number of public presentations that have been informed by the outcomes of the workshop and the proof of concept activities.

Journal Publications

Books or Other One-time Publications

Web/Internet Site

Other Specific Products

Contributions

Categories for which nothing is reported:

Any Journal

Any Book

Any Web/Internet Site

Any Product

Any Contribution

CLIMATE AND LAND USE CHANGE PROCESSES
IN EAST AFRICA:
SCIENTIFIC ASSESSMENT AND POLICY IMPLICATIONS

A COLLABORATION BETWEEN SCIENTISTS AND POLICY-MAKERS IN THE USA, EAST AFRICA AND UK

FINAL REPORT
NSF Biocomplexity Program
BE/CNH 0119821

David Campbell, Principal Investigator
Department of Geography and African Studies Center, Michigan State University

Jeffrey Andresen
Department of Geography, Michigan State University

Jennifer Olson
Department of Geography, Michigan State University

Julie Winkler
Department of Geography, Michigan State University

Bryan Pijanowski
Department of Zoology, Michigan State University

Table of Contents

I. INTRODUCTION

This is the Final Report for the Planning Grant from the NSF Biocomplexity Program, Proposal Number 0119821, Proposal Title BE/CNH: "Climate and Land Use Change Processes in East Africa." The PI and Co=PIs for this proposal from Michigan State University are: PI - David Campbell, CO-PI(s) - Jeffrey Andresen, Jennifer Olson, Julie Winkler, and Bryan Pijanowski.

Three principal activities were undertaken under the Planning Grant: (1) A Workshop involving collaborators from East Africa, US, and UK; (2) a series of Proof of Concept activities; and (3) the compilation of databases required for the modeling components of this project. The results of these activities are summarized in this Report.

In addition, linkages were established with other projects and institutions conducting related research both in and outside of the East Africa region in order to develop collaborative ties and/or gather data and information. These included the Land Use Change, Impacts and Dynamics (LUCID) project, START, the Miombo Project (Paul Desanker) and LUCC/IGBP. Further, the project team developed a project website, together with a CD-ROM, with much relevant project materials and background literature. A regular communication system based on email was developed for the preparation of the planning meeting and for subsequent project activities including proposal writing.

II. WORKSHOP REPORT HELD IN NAIROBI, KENYA, FEBRUARY 6-8, 2002

A. Workshop Venue

A workshop was held at the International Livestock Research Institute (ILRI) in Nairobi, Kenya from February 6 to 8, 2002. Mr. F. Kihumba representing Mr. Oloo K'Omudho, the Director of the National Environmental Secretariat, Ministry of Environment and Natural Resources, Government of Kenya, opened the workshop. David Campbell, representing Michigan State University, and David Taylor representing ILRI, welcomed the participants. Participants included scientists from Kenya, Tanzanian and Ugandan academic and research institutions, and government representatives from national environmental or climate governmental agencies. Also attending were scientists from Michigan State University, the University of Colorado, the National Oceanic and Atmospheric Administration, and the University of East Anglia (see Appendix 1 for the list of participants)

The objective of the workshop was to facilitate exchanges between scientists and policy makers in Africa, the US and the UK in the design of a research proposal, and to establish modalities for collaborative preparation and implementation of the research project.

B. Science Benefits to USA and East Africa

The participants concluded that understanding the implications for East Africa of short- and medium-term climatic variability and of projected climate change is vital for providing information on the potential impacts of climate change on agricultural systems and livelihoods, on ecosystems and other natural resources such as water, and carbon sequestration. The participants also expressed a strong interest in developing a better understanding of the impacts of land use change, such as deforestation, on the regional climate. Such information is essential to meeting commitments under international conventions and for formulating policies and programs that address: poverty alleviation; promotion of integrated land management and sustainable livelihoods; mitigation and adaptation strategies to global climate change; and identification of carbon stocks and the potential for carbon trading.

It became clear during the meeting that threatened agricultural production, both commercial and more subsistence oriented, is of paramount concern to national policy-makers. Of additional significance with the emergence of international interest in carbon trading is the necessity for baseline data on sequestered carbon, and on the impact of land use change on carbon sequestration.

To achieve these goals, procedures need to be enacted to systematically gather existing data, and engage in individual capacity and institution building to maintain data collection and analysis. These would facilitate addressing of key policy issues in the region including agricultural research and production, industrial production, health issues, and environmental concerns such as hydrology, land degradation, biodiversity conservation, and wetlands development.

To this end the group proposed a participatory project that would engage a range of stakeholders in East Africa, including producers, processors, consumers and policy-makers, and that would provide scientific analyses, with a strong applied focus, for effective and accessible information.

The participants recognized that the research would add to their scientific understanding of a number of issues beyond East Africa including: improved understanding of the sensitivity of climate to land use change; the development of a regional climate model in a new area with diverse topography and complex climate; and methodological improvements in model integration (e.g., statistical downscaling with crop/climate with LUCC, regional climate with LUCC)

A fundamental goal of the proposed collaborative project is to increase individual and institutional capacity to conduct policy-relevant land/ climate scientific research and to apply the understandings from the research to formulate and implement effective policies and programs. It was agreed that capacity building of scientists, policy makers and students from East Africa and the US is integral to all project activities. Collaboration between scientists, policy makers, and stakeholders enables sharing of knowledge, experience, and skills among project participants.

C. Proof of Concept Activities

There was a discussion of the results of the proof of concept activities related to regional climate modeling, crop-climate modeling, land use/land cover modeling, role playing simulations, and the importance of the interactions and feedbacks between the concepts and models of these activities. A summary of the results of the proof of concept research is provided following this workshop section.

D. Working Groups

Break out groups discussed issues related to climate modeling, land use/cover change analysis, and studies of the societal impact of climate change. Participants assessed the viability of various approaches and the data and information needed to conduct the activities.

1. Climate Modeling

The working group on climate modeling highlighted the need to collect and collate historical data, and metadata as a basis for spatial and temporal analysis of past and current climatic trends. Information on changes in frequency and intensity of El Nino events, for example, would be vital.

Such analyses together with reviews of the scientific literature would be the basis for understanding contemporary climate variability and parameterizing a downscaled GCM.

The group also addressed the issue of uncertainty arising from emission scenarios, land use change dynamics, and extrapolation across scales. These and the inclusion of better information on land characteristics in the region such as land use, topography, and lakes are important for the climate modeling activities and interpretation.

Future work would include the continued elaboration of a regional climate model; developing future scenarios based on downscaled GCMs, including attention to uncertainty; exploration of teleconnections involved in patterns of climate change; and multiple iterations of a regional scale model including feedback with the land use change models.

*2. **Impacts Assessment***

The goal of this activity is to define the key potential impacts of a medium and long-term change in climate on the region's agricultural systems and rural livelihoods. The effects of climate change on key economic sectors of the region, such as hydroelectricity, were also discussed as being very important, as were characteristics of the region's principal agricultural systems. An important objective is to quantify their performance under current and perturbed climate scenarios.

The project will define the economic, social, and biophysical components of these systems and define the key components and linkages that are vulnerable to climatic change. These will facilitate crop and range/ climate modeling, assessment of coping strategies re drought, and household behavior to risk analyses. This will permit assessment of the risk involved in agricultural production systems currently, and under scenarios of perturbed climate projected by the climate modeling activities. Such risk analysis will allow for implications to be drawn for future land use practices based upon experience of past events such as droughts, and assessment of contemporary drivers of land use dynamics.

*3. **Land Use and Land Cover***

The most important information for land use/ cover change model building and interpretation is the identification of the driving forces underlying the contemporary patterns of land use/cover. An historical dimension extending to the colonial period would be ideal for this, but the spatial modeling would focus on the period since 1970s. The post-1970 period illustrates the impact of political independence on land use, and the availability of satellite imagery since the early 1970s facilitates modeling using GIS and related spatial approaches. All three countries have existing land use/ cover change information, mostly at the local scale, but Tanzania especially has good lower resolution coverage.

Key questions for effective modeling and interpretation relate to data reliability and its availability over time and space; ability to identify key driving forces, their spatial influence and their intensity over time – some are seen as continuous, such as population growth, others as more intermittent, such as government policy, and others as uncertain but recurrent, such as droughts. To be included in the scenarios of future land cover change are the effects of climate change on crop and rangeland productivity and extent, information obtained from other component activities.

E. Plenary Discussion

1. *Integration of Climate, Crop-Climate, and Land Use Models*

The initial step is to project likely future climate scenarios on the basis of statistical downscaling of global climate models to East Africa. This will provide projections of climatic changes, e.g. temperatures, climatic variability and frequency of extreme events, including flood and drought.

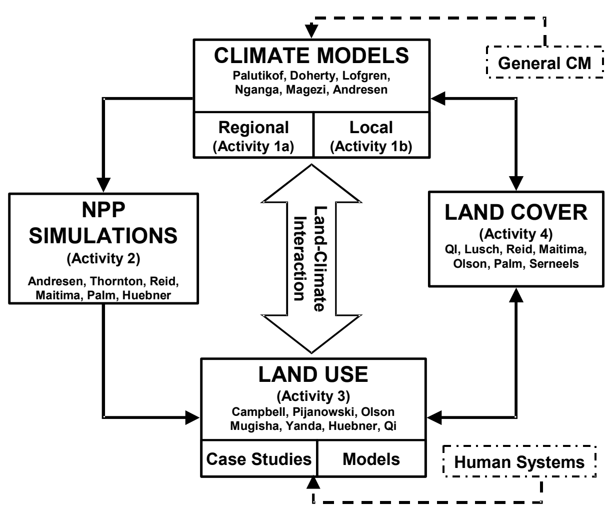
These projected scenarios will provide input to series of deterministic simulation models for crops, rangelands and natural ecosystems, and will be assessed through field studies, and field workshops in several areas of East Africa. This will facilitate assessment of crop production and livestock productivity, and land use/land cover under projected climatic changes, and implications for mitigation and adaptation strategies.

The outcomes of the modeling exercises, and detailed information from the field studies on the ecological gradients of Mounts Kenya and Kilimanjaro, and SE Uganda will be applied to parameterize and run two GIS and neural net-based models, the Land Transformation Model and a multi-agent based environmental model coded in the SWARM agent based modeling package. These models will then project the findings from the case study scale to the regional scale in order to provide input on land cover to the regional climate modeling activity.

The final modeling component is to specify a regional climate model that includes topography, particularly the mountains, the African Great Lakes, and projected characteristics of land cover. These will provide input to a regional climate model in terms of land-atmosphere boundary conditions. The team will run a regional climate model to investigate longer term feedbacks to crop-climate models and to land use/land cover trends. The output of the regional climate model will then be used to generate iterations through impacts on production systems and land use/land cover, and feedback to the regional climate model.

A conceptual framework for how models and activities coupling climate and land systems was developed by the workshop team and is presented in Figure 1. This framework helps frame the key integrating questions coupling human and natural systems.

Figure 1. Climate-land conceptual framework.



2. *Assessing the implications of model outputs for livelihoods and natural systems*

The modeling exercises provide a perspective for stakeholders and policy makers on the significance of projected changes for livelihoods, natural resources management, and carbon sequestration.

Plenary discussion of these activities recognized that the future scenarios projected by the land use/ land cover models would be valuable to evaluating policy options and emphasized the importance of interpretation of model outputs in terms of the realities of driving forces and of regional political and economic trends. For the outcomes to be of relevance to East Africa, a combination was proposed of model outputs, role-playing simulations, and grounded interpretation of results.

The results of the short- and long-term climate-land use modeling exercises will be interpreted with reference to the long-term case studies, and through a series of community-based “feedback seminars” with local stakeholders and through workshops with policy-makers. This would allow assessment of possible livelihood changes, their implications for land use and land cover, and the consequences for poverty reduction, sustainable resource management and biodiversity conservation.

The projections of decadal regional scale climate change for land use and land cover will permit assessment of the implications for biophysical systems including land degradation, biodiversity conservation and carbon sequestration. These are also important to policy as the countries of the region assess their commitments to international conventions, and their involvement in the programmatic and research activities of the Operational Programs of the Global Environment Facility (GEF).

3. ***Stakeholder involvement and evaluation of alternative adaptation and mitigation strategies and policy for East Africa.***

It was agreed that effective assessment of adaptation and mitigation strategies and the appropriate enabling policy framework should be made in collaboration with institutions in East Africa. These would include those representing government, NGOs, stakeholders such as farmers, herders, labor organizations, and the business and scientific communities. Workshops and seminars with stakeholders were identified as the most appropriate means of communicating the results of the project, evaluating their implications, and discussing policy options.

F. Formulation of a Research Proposal

1. ***Research design***

The Research Design will integrate case study analysis and state of the art modeling to assess the impact of climate change scenarios for East Africa upon livelihood systems, carbon sequestration, and conservation natural resources. The implications will be assessed in terms of policy to facilitate effective participatory mitigation and adaptation, and to evaluate the potential for carbon sequestration.

The design includes three major activities – 1. Climate, crop, and land use modeling; 2. Assessing the implications of model outputs for livelihoods and natural systems; and 3. Evaluation of alternative adaptation and mitigation strategies and policy for East Africa.

2. ***Key hypotheses and research questions***

Primary research questions that will be addressed through the research include:

- What is the impact of climate and climatic variability on land use/ land cover, ecosystems, and human welfare?
- What are the socio-economic and biological drivers of land use change, which in turn lead to land, cover change in the region?
- Is large-scale climate change likely to influence regional land use/land cover change, and if so, to what extent will the changes affect major land uses such as pastoral or food crop production systems? What are the implications for carbon sequestration?

- At what spatial and temporal scales do climate change and land use/land cover change interact? How are these scales relevant to policy?
- What adaptation and mitigation strategies might be anticipated on the part of farmers and herders, and what impact might these have upon human welfare, poverty alleviation, land use and sustainability of natural resources?
- How can land use practices be modified to reduce the potential impacts of climate change?
- What policy implications may be drawn from these analyses?
- What conceptual frameworks and methodologies contribute to effective integrated assessment?

Although the research will focus on a specific region, by addressing the above themes it will contribute to a broader understanding of interactions between physical and human processes, and will be useful for examining other regions.

*3. **Deliverables***

Anticipated output of this project, based upon projections of climate change and land use/cover changes, include:

- Data bases, model outputs and projections, maps of projected scenarios, related to climatic variability and trends, crop and livestock production, land use and land cover,
- Analyses and syntheses that draw implications of projected scenarios for poverty alleviation, improved human welfare, sustainability of livelihoods, carbon sequestration, and natural resources management;
- Policy-relevant assessment of the likely impacts of climate change on commercial agriculture, and on farming and on pastoral livelihoods and natural ecosystems;
- Capacity building through i) "field seminars" with stakeholders; ii) short courses with policy-makers to evaluate policy and program interventions to address varied impacts of climate change and land use change; iii) formal training of young scientists and informal exchanges between mid-career scientists from Kenya and the US;
- Workshops that will explore the implications of findings for policy and programs related to poverty alleviation, natural resources management, biodiversity conservation, agricultural research, and land use planning.

Development of conceptual, analytical and methodological approaches that will enhance similar integrated assessment in other regions of Africa and in the US.

APPENDIX 1 - LIST OF PARTICIPANTS

Name	Country	***(1) Mailing Address***
Andresen, Jeff Climatologist Associate Professor	USA	Department of Geography Michigan State University 314 Natural Science East Lansing, MI48824USA
Atieno, Fred GIS Tech	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya00100
Butt, Bilal RA For Climate Change Project	USA	Department of Geography Michigan State University 314 Natural Science East Lansing, MI48824, USA
Campbell, David Associate Dean Professor of Geography	USA	College of Social Science Michigan State University 203 Berkey Hall East Lansing, MI48824, USA
Doherty, Ruth Visiting Scientist	USA	Environmental and Societal Impacts Group NCAR 3450 Mitchell Lane PO Box 3000 Boulder, CO80301, USA
Kasoma, Dr. P. Director, MUIENR	Uganda	Makerere University Institute of Environment and Natural Resources P.O. Box 7298 Kampala, Uganda
Kihumba, Francis Deputy Director, Environment	Kenya	National Environment Secretariat Bruce House 10th Floor P.O. Box 67839 Nairobi, Kenya
Kshatriya, Mrigesh Ecosystem Modeller	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya

Kuska, Russ Director of GIS Lab	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya
Lofgren, Brent Physical Scientist	USA	NOAA/Great Lakes Environmental Research Laboratory 2205 Commonwealth Blvd Ann Arbor, MI48105-2945 USA
Magezi, Stephen A.K. Assistant Commissioner	Uganda	Uganda Meteorology Department Yusufu Lule Road at Post Office Building

for Meteorology		P.O. Box 7025 Kampala Uganda
Maitima, Joseph Regional Coodinator, Ecological, LUCID Project Lucy Kirori Administrative Assistant	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi Kenya00100
Manyika, Kanizio F.K.	Tanzania	Division of Environment Vice President's Office P.O. Box 5380 Dar es Salaam, Tanzania
Mbekenga, Desderius Assistant Managing Director of EPMS	Tanzania	Environment Protection and Management Services P.O. Box7775 Dar es Salaam Tanzania
Mwangi, Albert M. National Programme Manager	Kenya	UNDP/GOK Environment and Natural Resources Programme National Environment Secretariat Bruce House 10th Floor P.O. Box 67839 Nairobi Kenya

Nganga, John Professor	Kenya	Department of Meteorology University of Nairobi, Chiromo campus P.O. Box 30197 Nairobi, Kenya
Odada, Eric Programme Director Pan African START Secretariat	Kenya	Pan African START Secretariat (PASS) University of Nairobi, Chiromo campus Department of Geology Riverside Drive PO Box 30197 Nairobi, Kenya
Ojoo-Massawa, Emily National Coordinator, Climate Change Enabling Activities	Kenya	National Environment Secretariat Bruce House 10th Floor P.O. Box 67839 Nairobi, Kenya
Olson, Jennifer Regional Coordinator, Land Use & Socioecon. LUCID Project	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya00100
Palutikof, Jean Director, Internal Affairs	UK	Climatic Research Unit University of East Anglia NorwichNR4 7TJ UK
Pijanowski, Bryan Assistant Professor	USA	Department of Zoology Michigan State University 203 Natural Science East Lansing, MI48824 USA

Reid, Robin Coordinator, People Livestock and Environment Programme	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya00100
Robinson, Tim Biological, Climate and Disease Modelling	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya00100
Shein, Karsten Ph.D. Candidate	USA	Department of Geography Michigan State University 314 Natural Science East Lansing, MI48824 USA
Taylor, David Deputy Director, Research	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya00100
Thornton, Phillip Coordinator, SAIA Programme Systems Analyst	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya00100
Yanda, Pius Z. Research Professor	Tanzania	Institute of Resource Assessment University of Dar es Salaam P.O. Box 35097 Dar es Salaam Tanzania

Unable to Attend Workshop

Name	Country	Mailing Address
Lusch, David Senior Research Specialist	USA	Center for Remote Sensing Michigan State University 1405 S. Harrison Road 308 Manly Miles East Lansing, MI48824USA
Mugisha, Sam Lecturer/Researcher	Uganda	Makerere University Institute of Environment and Natural Resources P.O. Box 7298 Kampala, Uganda
Muyungi, Richard Director Department of Environment	Tanzania	Director Department of Environment Vice President's Office P.O. Box 5380 Dar es Salaam Tanzania
Salehi, Habib Chairperson, Stats & Pro Professor, Stats and Math	USA	Department of Statistics 425 Wells Hall Michigan State University East Lansing, MI48824 USA
Semazzi, Fred Professor	USA	Department of Marine, Earth, and Atmospheric Sciences North Carolina State University Box 8208 120 Research III Raleigh, NC27695-2808 USA
Wangui, Edna Ph.D. Candidate	Kenya	International Livestock Research Institute(ILRI) P.O. Box 30709 Nairobi, Kenya Old Naivasha Rd
Winkler, Julie Professor of Geography	USA	Department of Geography Michigan State University 314 Natural Science

III. PROOF OF CONCEPT ACTIVITIES

A. Regional Climate Model Development

As a proof of concept demonstrating the effects of radical changes in land use over large areas, some scenarios were run using a regional climate model over a domain encompassing all of Kenya, Uganda, Tanzania, Rwanda, and Burundi, along with parts of surrounding countries and the Indian Ocean. The two cases run were the vegetated case, with a realistic current distribution of vegetation, and the unvegetated case, with all land prescribed as unvegetated desert. A third case, the reduced vegetation case is currently being executed. Vegetation is represented in the model by a set of parameters including surface albedo, roughness length, leaf area index, and rooting depth that are typical of the specified type of vegetation. Each case was executed using lateral boundary conditions taken from the NCEP/NCAR Reanalysis Dataset for the year 1993.

The radical removal of vegetation represented by the difference between the vegetated and unvegetated cases results in drastic differences in surface fluxes of heat and moisture. The evaporation (latent heat flux) from the land surface that is present in the vegetated case, as one would expect, becomes almost absent in the unvegetated case. This difference is offset by a decrease in net solar absorption and an increase in the sensible heat flux from the surface in the unvegetated case. In general, precipitation is reduced in the unvegetated case. A full analysis of the winds has not been completed, but one interesting result is that during December, part of the rainy season, onshore winds from the Indian Ocean in the vegetated case seem to originate from an area of atmospheric downwelling just off the coast and within the regional model domain, while in the unvegetated case, they are more connected with easterly winds originating outside of the model domain.

One of the downfalls of this model is that it has a strong tendency to simulate too great an amount of clouds at low levels. Despite the lack of a moisture supply from the surface, this excessive cloudiness phenomenon appears to be more severe in the unvegetated case than in the vegetated case (also note that these clouds tend to result in very little precipitation). This leads me to speculate that spatial homogeneity of land use is a major factor that leads to a very permanent and strong temperature inversion, which becomes associated with a persistent stratus cloud deck. Experiments are planned regarding the sensitivity of this quantity of cloud cover to the degree of spatial homogeneity of the land use.

Master's student Nitin Jaiswal was hired through funding from the NSF grant as a 1/4-time research assistant for two semesters. This was supplemented by a summer fellowship for Jaiswal, funded by the Great Lakes Environmental Research Laboratory, during which time part of his duties were further work on executing the model runs. The Great Lakes Environmental Research Laboratory provided funding for Brent Lofgren's time worked on this project.

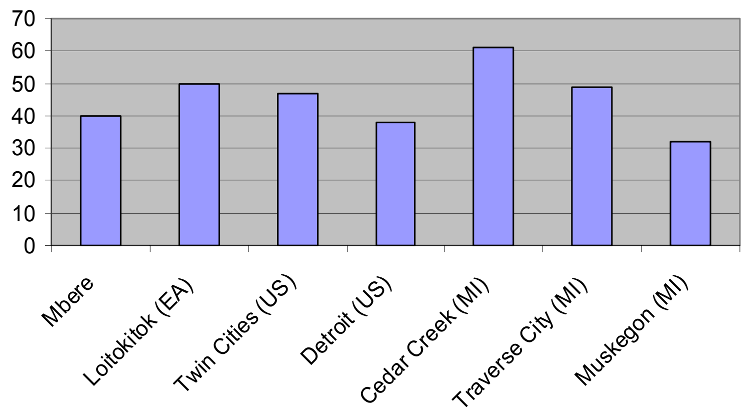
B. Land Use Change Analysis

1. The Land Transformation Model

MSU's Land Transformation Model (LTM) is a spatial allocation tool that can be used to assess variables associated with of historical land use change (Pijanowski et al., 2001a; 2001b; 2002a). The models uses neural nets which train on data processed by a GIS to numerically solve spatial interactions between surrogates (e.g., distance from the nearest road, size of a parcel) of land use change drivers. The model has several strengths. First, very few spatial drivers (e.g., 3-7) can be used to build an accurate model. Second, neural nets are able to generalize across datasets and across spatial regions (Pijanowski et al., 2001a) and thus can be a useful tool to scaling up from small training sets.

The LTM for East Africa will enable generalizations to be made about land use changes over wide areas via extrapolation from detailed case studies. Information on time series land use change from the four East African case study sites will be used in future to conduct ‘learning exercises” that will train the LTM and establish a set of initial parameters for the model. Once the initial LTM is established the team will introduce information from time series climate data to simulate the impact of climate change on land use. The introduction of climatic data represents an innovation in such modeling approaches.

Figure 2. Percent Accuracy of LTM Predicting Locations of Transitions



In the proof of concept activity the LTM was shown to perform very well on predicting locations of historical agricultural extensification in two key East African case study areas: Embu/Mbeere on the slopes of Mt. Kenya, and Loitokitok on the slopes of Mt. Kilimanjaro.

Spatial data layers of land use (1958, 1985), transportation, digital elevation, and the location of towns and rivers, from Olson (1998), were used to parameterize and test the LTM with data commonly available in East Africa. This 40 km region was modeled at a 30m-cell size. Training of the neural network followed the format of Pijanowski et al. (2002a). We used a back propagation, feed-forward neural network with one hidden layer to train on a portion of the cells parameterized with proximity (e.g., distance to road), density (e.g., the density of agricultural surrounding a cell), and location (e.g., elevation) spatial rules. Weights for node connections were then saved for a testing phase where all cells from the region were used to estimate the output (0=no transition; 1= transition into cropping). Probabilities were then used to identify the number of cells for transition; the same number of cells that were observed to transition was then selected to transition by the model. The observed versus modeled transition cells were compared across spatial scales.

Overall, the model performed well in Mbeere (Figure 2), especially considering that the agricultural system of that period was shifting cultivation, correctly predicting nearly 40% of the cells that transitioned. The locations of the under-predicted cells suggest that model performance would be improved with soil data. A similar procedure was employed to use the LTM to project the patterns observed in land use change analyses based on satellite imagery in the Loitokitok area on the slopes of Mt. Kilimanjaro (Figure 3). For this exercise, we projected agricultural expansion to the years 2005 and 2010 and then estimated case study area-wide albedo based on Claussen (1997). We estimate that albedo for the entire area is likely to decrease by 2% in the next 10 years. Albedo is one of the land surface inputs of the regional climate model.

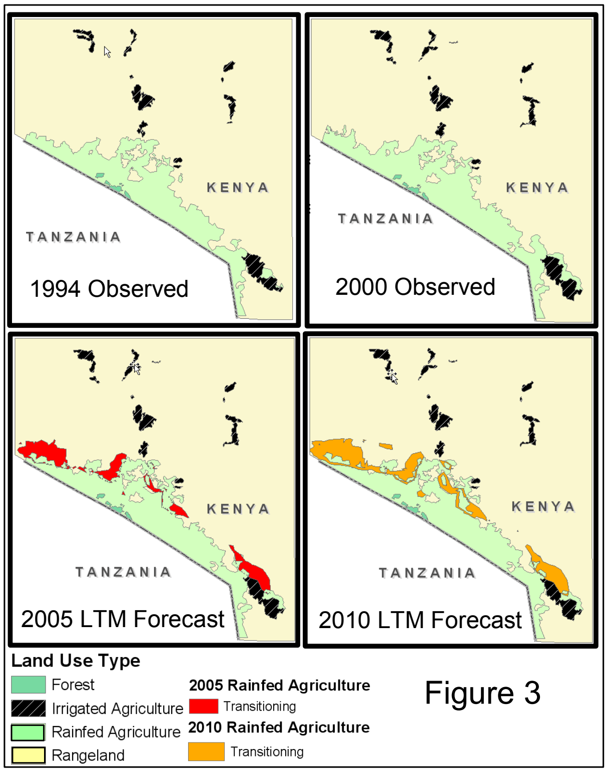


Figure 3

2. *Multi-Agent Based Economic Landscape (MABEL) Model*

MABEL is a SWARM based model that simulates individual, group and institutional behavior as agents. Agents are able to respond to exogenous factors, such as climate, economics, population provided with a set of information inputs about their land holdings (soils, crop production potential, economic condition of the farm, age of agent). Simple decision rules (e.g., economic utility functions) guide their choices for outcomes. Inputs and decisions can be modeled on very small time steps (e.g., daily) and at small spatial scales and extents. This model is similar to the form of agent models developed by Schneider *et al.* (2000).

The NSF Biocomplexity Planning Grant supported development work to examine how role-playing simulation (see below) can be used to parameterize agent behavior. MABEL differs from the LTM in that the agent-based model better explains the relationship between human behavior and outcomes (e.g., changes in land use). The LTM, on the other hand, requires few inputs to run and frequently predicts changes in land use with relative accuracy given that the drivers of land use change are not greatly altered over time.

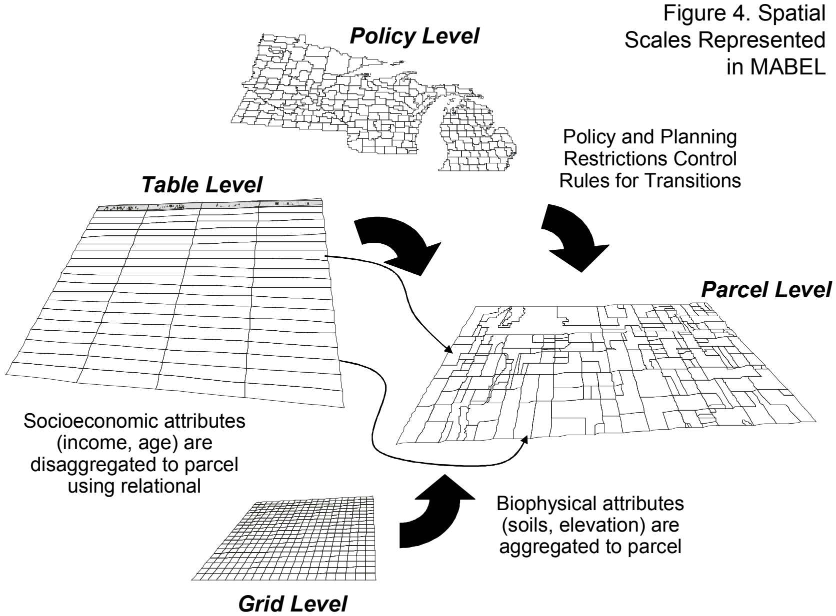


Figure 4. Spatial Scales Represented in MABEL

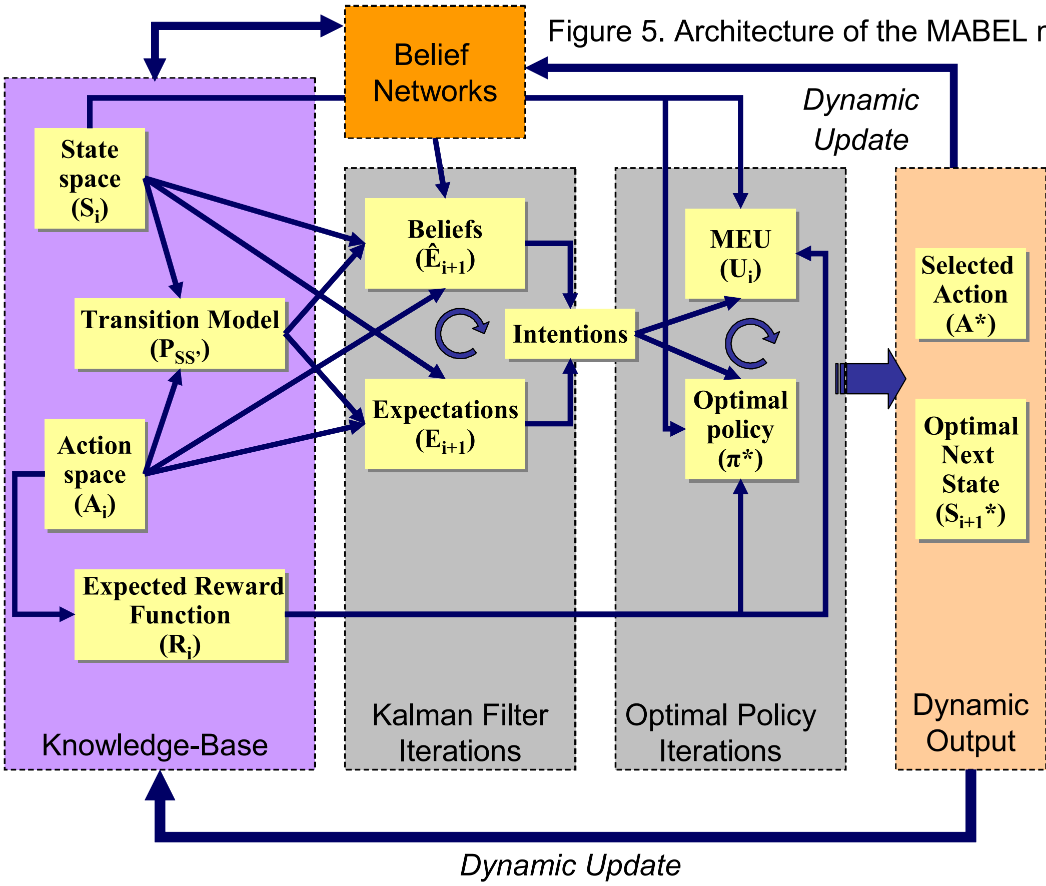
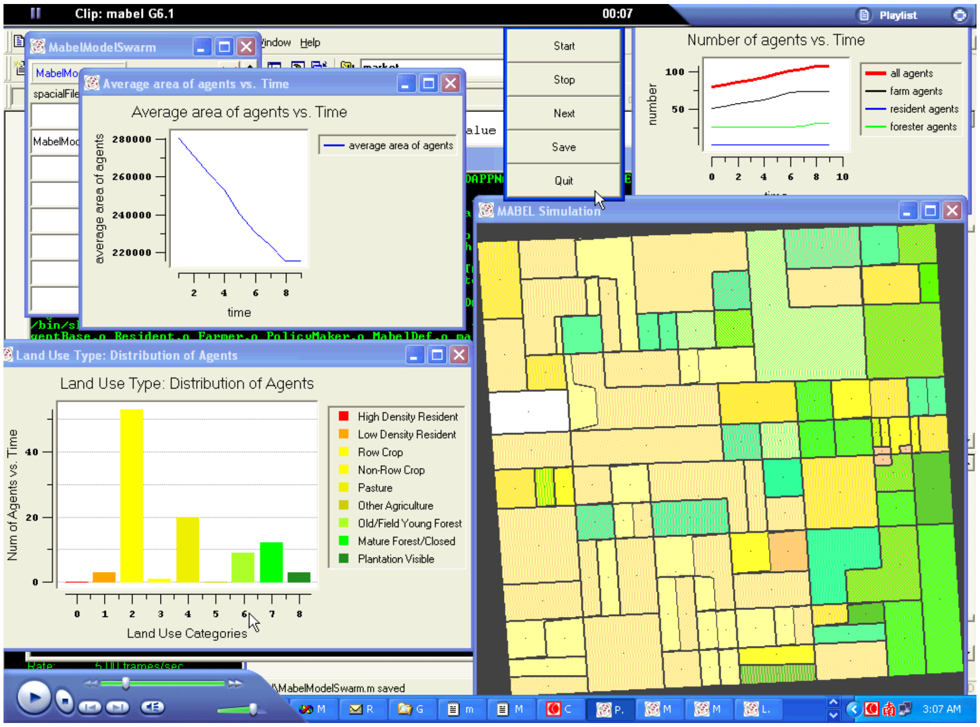


Figure 5. Architecture of the MABEL model

MABEL (Alexandridis et al, 2002) currently has three types of base agents: sellers, buyers and land use planners. Four different spatial scales (Figure 4) are currently represented in MABEL: cell (for biophysical attributes), parcel (ownership agent attributes), local government (aggregated census data), and manager levels (policy agent attributes). A knowledge base (Figure 5) stores information for each base agent's current and historical (last 10 time steps) state space, transition model, action space (possible choices for agents) and expected reward values. These are combined to formulate each agent's beliefs and expectations for actions in the next time step. Beliefs and expectations are combined using the statistical Kalman filter approach to formulate the agent's intentions. Intentions are then compared against other actions in order to determine the maximum expected utility (MEU) from an action. Once an action is chosen, it is then presented to a belief network for updating of the knowledge base. Buying and selling is determined by each individual's economic utility for all potential land use types (urban, agriculture, forest or wetland). The interface to the model allows users to follow agent's actions, attributes at each time step (e.g., land value) as well as averages for all instances of each base agent. Values from each simulation are then saved and are analyzed in relationship to patterns of parcelization and land use changes (see Figure 6 for a screen grab of the SWARM interface to MABEL used in the simulation of land use change in Mecosta, County, Michigan). Data used to initialize the model for the US version is obtained from the 5% Public Use Micro Sample (PUMS) census long-form database.

We explored a variety of methods to parameterize a MABEL-like model for East Africa (see also section B.3 below). Case study areas currently have the requisite information required

Figure 6. Screen grab of the MABEL model interface.



for a MABEL-like model: parcel, land use/cover data and household survey information for several time periods. Parcel data and associated land use, household survey and biophysical attributes exist for all of the case study sites (see Figure 7 for parcel/land cover for Mbeere, Kenya). We recognize that there will be a variety of different types of agents that will interact in complex hierarchies.

In southern Kenya, for example, land use categories exist that both conflict and complement each other in terms of resource management, economic objectives, and environmental sustainability. These include herding, farming, and wildlife-based tourism. Different actors engage in these land uses, and decisions on resource allocation are contingent upon legal, political, and ethnic institutions and relationships. For example, an elected committee administers group ranches in this area with a chairman, secretary and treasurer. This committee manages broad policy issues. Individual members take decisions regarding size of herds, when and where to graze and water livestock, and on cropping strategies, and expected income from each crop. As land managers these individuals will respond differently to climate dynamics, to the relatively static biophysical environment (soils, topography, hydrography), and to cultural traditions, economic opportunities, policy initiatives, and relationships with land managers in other adjacent land use systems.

3. Role Playing Simulation

A third approach to modeling used was game or role-playing simulation. Such simulations are long established in the fields of military science and the social sciences. They are designed to allow actors representing key individuals, groups, and institutions to interact to address hypothetical scenarios. The outcomes yield specific results in terms of prospective effects of specified initial conditions and drivers of change. For example in resource conflict simulations, maps illustrate the outcomes of discussion and debate over economic, social, policy, and environmental concerns. Equally important are insights to the process of decision-making by individuals and groups, including alliance formation and application of power or force.

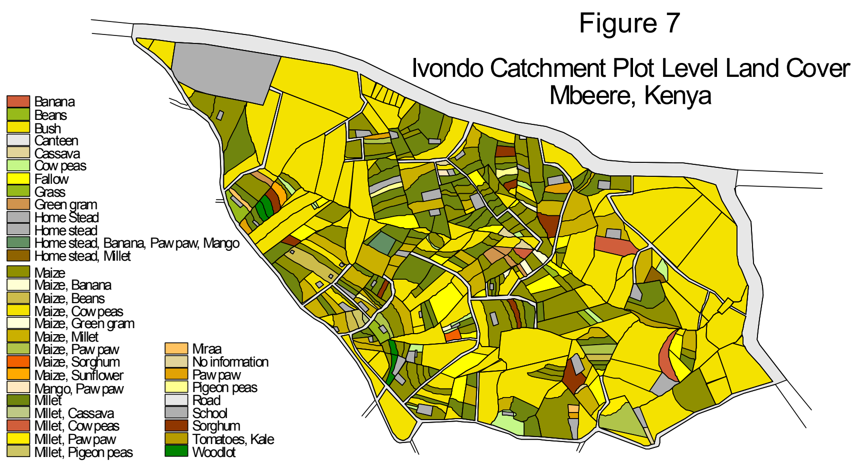


Figure 7
Ivondo Catchment Plot Level Land Cover
Mbeere, Kenya

The role-playing activity is based upon Campbell and Palutikof (1978). This version has been used in graduate and undergraduate instruction at the University of Nairobi, Michigan State University, and the University of Colorado. It has also been translated into French and widely distributed by ENDA, Dakar (Campbell and Palutikof 1980).

A key objective of the proof of Concept activity was to assess the degree to which the original 1978 role-playing exercise remained valid, and what changes were required to render it an effective contemporary simulation. The major change that was needed was to bring up to date the background data on demography, prices, herd sizes etc. Government data and recent scientific reports were employed to achieve this.

The simulation was run with MSU students from Kenya and Tanzania playing the roles of farmers and herders. During the role-play their decision-making processes were monitored, and at the conclusion they were debriefed to i. Assess the validity of the simulation in contemporary East Africa; ii. To identify the key drivers of land use change based on their experience in the game; and iii. To discuss and verify the negotiating processes that had been observed.

The simulation was judged to be highly representative of East African conditions. Further the key driving forces of change identified by the players confirmed those reported in our studies of land use change (Table 1) including the importance of:

- Land – its availability, distribution, and quality;
- Labor – availability for farming and herding, and remittances from migrants;
- Capital – the wealth of households, and their investments in landesque capital (soil conservation, soil fertility etc.) and in technology;
- Infrastructure – access to roads, ability to export produce to markets, boreholes, and irrigation works;
- The Policy Environment – laws on land allocation, economic policy (structural adjustment, exchange controls);
- The Biophysical Environment – climatic conditions, land capability, access to water, water quality.

Table 1. Examples of Drivers of Land-use Change in African Semi Arid Lands

ECONOMIC DRIVING FORCES

International

- Market Forces
- Trade Agreements
- Structural Adjustments

National

- *National Economic Policy* - agricultural pricing, transport, exchange rates
- *National Land-use Policy* – coherent land-use plan often lacking. Individual sectoral bureaucracies implement strategies in uncoordinated manner and with perhaps conflicting goals.
- *Land Tenure Policy* - Explicit and Perceptual
  Land Tenure Laws
  Customary Tenure: continuity and change
- *Dynamics of Primary Production* (dependent on soil and water resources)
- Modified Subsistence –Dynamics of Cropping and Livestock Systems
- *Economic Policy*
  - SAP and economic liberalization
  - Exports: meat, horticulture, coffee etc.
  - Imports – import substitution
- *Urbanization* - Urban demand for meat and vegetables encourages commercial production
- *Irrigation policy* - chemical pollution, salinization
- *Cash crops* - chemical pollution of water
- *Mineral production* - effluent, siltation

Local

- *Markets*
- *Herding* - diversifying to include agriculture, particularly at perennial water sites (fadama/bas fonds; swamp edges; streams; mountain slopes)
- *Rain fed agriculture* - immigration, intensification/ Extensification
- *Irrigated agriculture* - market demand, wholesalers
- *Economic differentiation* - options in land, labor and capital

INSTITUTIONAL/POLICY DRIVING FORCES

International

- International Conventions: Biodiversity, Climate Change, Desertification etc.
- Bilateral and multilateral governmental and commercial interests; NGOs Warfare

National

- Centralization versus decentralization
- Uncoordinated policy framework – lack of land-use planning
- Land tenure policy
- Political and economic power: Intersecting interests of government policy, commercial institutions, NGOs, and individuals
- SAPs and Economic liberalization

Local

- Land tenure - communal versus individual rights to land, trees and water
- Social differentiation in land rights - gender, young/old, tenants and squatters
- Informal land claims: Tenants/renters/squatters claim land rights
- Local NGOs

SOCIAL CULTURAL DRIVING FORCES

National

- Urbanization
- Immigration
- Leadership - governance issues

Local

- Population dynamics: growth, migration (gender and age specific), decline (AIDS) - intensification/extensification; maintenance of erosion control measures, cropping patterns, health and food security
- Diversification of herders into agriculture changes mobility and settlement patters. Altered land cover (natural vegetation decline, cropping increase).
- Cultural change - leadership issues debated (age, gender); ethic heterogeneity, religious diversity.
- Less trust in and recourse to traditional institutions. Disputes formerly settled by discussion; now more recourse to chiefs, police, courts and violence
- Redefinition of established cultural and economic categories - e.g. herders become herder-farmers; farmers become farmer-herders; economic and power relations between groups change.

ENVIRONMENTAL FACTORS

Rainfall

- Variability of Rainfall: long-term, inter-annual, seasonal, within growing season

Surface Water and Groundwater

- Swamp margins/ riparian zones/hillsides - occupied and crops vulnerable to damage by livestock and wildlife
- Water quality - chemical pollutions of water in irrigated areas - implications for the health of people, livestock and wildlife
- Water quantity - irrigation water in reduced supply
- Access to water more difficult for domestic use, agriculture, livestock and wildlife
- Change in hydrological cycle

Land Cover And Soils

- Vegetation - change in species composition; availability of fodder, medicinal plants, shade etc.

Soils:

Fertility decline- Evidence of land being taken out of production; enforced fallow Management - stall fed cattle - application of manure; chemical fertilizer

Soil Erosion - increased runoff, siltation, wind erosion, dust

- Woodland - change in species mix, change in spatial pattern - biodiversity of flora; potential for trees to replace grasses under less extensive grazing
- Habitat Depletion and Fragmentation - biodiversity of fauna

Source, After Campbell, 1999

Much discussion has taken place among the team regarding the modes of linking the findings of the different approached to land use modeling both to each other, and through scaling-up to the regional level to define the scenarios of future land cover that will be parameterized as inputs to the Regional Climate Model.

*4. **Linking MABEL-like models and Role Playing Simulation***

Post gaming simulation activities allowed us to explore how Microsoft's Bayesian Belief Networks (MS BBNx) could be used to document a role playing simulation participant's beliefs about relationships between climate, culture, education, policy and land use preferences. An example BBNx diagram composed by a participant pair shows that climate, education, policy, economics and culture all influence whether a family will chose to be pastoralists or farmers. A follow-up activity to this post-gaming simulation was an exercise to quantify the component interactions and to run the simulation under warmer and drier conditions. The result (Figure 8) shows that, under these future climate conditions, the preference for pastoralism increases. As the Belief Networks are a significant component to the MABEL model, these exercises relate the outcomes of role playing simulation with a MABEL-like model.

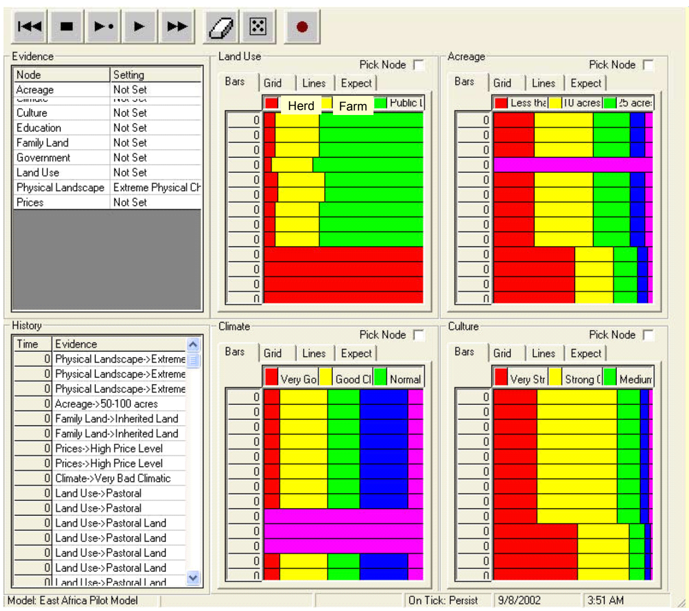


Figure 8. Simulation of land use change using belief networks constructed as a post-gaming exercise

C. Creation Of Databases

A large effort went towards GIS data base development for the East Africa region conducted jointly with the LUCID project. The data will provide topographic, land cover and other land surface information, and climate variables for linking to the RCM and the statistical downscaling model. Also collected from various institutions was a large variety of socioeconomic and biophysical data and information for land use/cover change analysis and prediction. The spatial data was transformed to a common projection and format.

*1. **Satellite Imagery and DEM's***

- East Africa GTOPO 1Km Resolution Digital Elevation Model
- Kenya 250M Digital Elevation Model
- USGS Land Use and BATS Land Cover Classifications for East Africa
- UNEP/Sioux Falls Satellite Imagery of Western, Central and Southern Kenya and Northern Tanzania from various dates – see attached path and row

Table 2. Available Satellite Imagery

Sensor	Path	Row	Date
ETM+	167	62	10/25/99
TM	167	62	3/28/95
TM	167	62	2/18/87
TM	167	62	5/16/84
ETM+	167	63	10/25/99
TM	167	63	2/1/83
ETM+	168	60	2/5/00
TM	168	60	3/19/95
TM	168	60	2/25/87
ETM+	168	62	2/21/00
TM	168	62	12/16/80
TM	168	62	2/16/89
TM	169	59	2/6/95
TM	169	60	2/6/95
TM	169	61	2/6/95
ETM+	169	60	2/12/00
ETM+	169	61	2/12/00
TM	170	59	4/20/95
TM	170	60	4/20/95
TM	170	61	4/20/95
TM	170	61	10/30/99

*2. **Spatial Databases***

- Various ILRI Kenya and East Africa regional databases Specifically
- Agro-climatic zones based on moisture and temperature
- Agro-ecological zones based on temperature and crop suitability
- Towns and urban centers
- '89 Census data for all administrative levels
- District level boundaries (1998)
- Land use derived from Landsat Images
- Cattle densities at third administrative level
- Protected areas
- A grid map of Kenya's topographic map sheets, including Survey Department index
- Digital Elevation model 250 m resolution
- '79 Census data for all administrative levels
- Lakes
- Provincial boundaries
- Tsetse distribution
- Major Towns
- Data from 6 rainfall stations (1991-1996)

- Forests
- River basins
- Data from 110 rainfall stations 1950’s Onwards (incomplete coverage)
- Distribution of lakes, reservoirs and water points
- Camel distribution
- Division level boundaries
- Location level boundaries
- Kenya's national boundary
- Annual rainfall
- Road Network for the Kenyan highlands
- Wheat production by province
- Maize production by province
- Sorghum production by province
- Millet production by province
- Rice production by province
- National Road Network (WFP)
- Wetlands
- Malaria Endemicity
- Agro-ecological zones based on length of growing period
- Major forest ranges
- Division level boundaries (2000)
- Percentage tree cover
- Contour Lines (100m)
- Villages
- Crop yields and livestock population
- Travel time to major urban centers
- National road network (Survey of Kenya)
- Rivers
- Climate grids (Ann. Precip. and PET)
- Sub location level boundaries
- Kenya Soils Properties Layer
- UNEP/GRID Gridded Population Density and Raw Population estimates based on district boundaries for 1960, 1970, 1980, 1990, 1995
- Various Data Layers from the Almanac Characterization Tools Set (ACT)
- Loitokitok/Amboseli GIS Layers
- Embu/ Mbeere GIS Layers
- Katuna/Mpalo GIS Layers
- Mt. Kenya Forest Land cover GIS From Kenya Wildlife Service (KWS)
- 1:50,000 Scale scanned topographic maps in digital form for the Amboseli/Loitokitok and Mt. Kenya study sites

3. ***Literature Collected***

- 1999 Concept Note on Environment and Development in Kenya –Ministry of Environmental Conservation, GoK
- 2001 Statistical Abstract
- 1999 Population and Housing census
- BATS Supporting Literature

- Numerous scientific journal articles relating to land use and land cover change and their drivers

IV. CONCLUSION

The activities described above have provided the research team to develop an internal coherence that has facilitated the preparation of a proposal to an intramural grant competition at MSU and to complete a full proposal to the November 2002 NSF Biocomplexity Program competition. The project team acknowledges with thanks the support of NSF in their research activity.

V. REFERENCES

Alexandridis, K.B., B.C. Pijanowski, and L. Zheng. in review. Simulating the Sequential Decision-Making Process of Agent-Based Actions in a Multi-Agent Based Economic Landscape (MABEL) Model. *Journal of Environment and Resource Economic*s.

Campbell, D.J. 1999. Response to Drought among Farmers and Herders in Southern Kajiado District, Kenya: A Comparison of 1972-1976 and 1994-1996. *Human Ecology* 27 (3):377-416.

Campbell, D.J., and J.P. Palutikof. 1978. Allocation of Land Resources in Semi-Arid Areas: A Simulation Based on the East African Experience. Nairobi: Institute for Development Studies, University of Nairobi.

__________________________. 1980. - "Gestion des ressources en zone semi-aride." African Environment Occasional Paper, 58, ENDA, Dakar, Senegal.

Clausen, M. 1997. Modeling biogeophysical feedback in the African and Indian monsoon region. Climate Dynamics 13: 247-257.

Olson, J.M. 1998. A Conceptual Framework of Land Use Change in the East African Highlands. Paper read at Earth's Changing Land: Joint Global Change and Terrestrial Ecosystems and Land Use and Land Cover Change Open Science Conference on Global Change, at Barcelona, Spain.

Pijanowski, B.C., B. Shellito, M. Bauer, and K. Sawaya. 2001a. Can an Artificial Neural Network Based Land Transformation Model Generalize Across Space and Time? Paper read at The Association of Photogrammetry and Remote Sensing, April 24-27, at St. Louis, MO.

Pijanowski, B., B. Shellito, and S. Pithadia.2001b. Architecture of the Land Transformation Model: Integrating GIS, Spatial Analysis Tools and Artificial Neural Network Software Using Object Oriented Approaches. The Coastal Geotools Conference, Charleston, South Carolina. January 6-9, 2001

Pijanowski, B.C., D.G. Brown, G. Manik, and B. Shellito. 2002a. Using Neural Nets and GIS to Forecast Land Use Changes: A Land Transformation Model. *Computers, Environment and Urban Systems* 26 (6): 553-575.

Pijanowski, B.C., B. Shellito, S. Pithadia, and K. Alexandridis. 2002b. Forecasting and Assessing Urban Sprawl Along in Coastal Watersheds along Eastern Lake Michigan. *Lakes and Reservoirs* in press.

FINDINGS

The Findings of the Project are discussed in detail in the Final Report of the project that is to be found elsewhere in this report.

I. WORKSHOP HELD IN NAIROBI, KENYA, FEBRUARY 6-8, 2002

A workshop was held at the International Livestock Research Institute (ILRI) in Nairobi, Kenya from February 6 to 8, 2002. The objective of the workshop was to facilitate exchanges between scientists and policy makers in Africa, the US and the UK in the design of a research proposal, and to establish modalities for collaborative preparation and implementation of the research project.

The key research foci identified by the participants were:

- What is the impact of climate and climatic variability on land use/ land cover, ecosystems, and human welfare?
- What are the socio-economic and biological drivers of land use change, which in turn lead to land, cover change in the region?
- Is large-scale climate change likely to influence regional land use/land cover change, and if so, to what extent will the changes affect major land uses such as pastoral or food crop production systems? What are the implications for carbon sequestration?
- At what spatial and temporal scales do climate change and land use/land cover change interact? How are these scales relevant to policy?
- What adaptation and mitigation strategies might be anticipated on the part of farmers and herders, and what impact might these have upon human welfare, poverty alleviation, land use and sustainability of natural resources?
- How can land use practices be modified to reduce the potential impacts of climate change?
- What policy implications may be drawn from these analyses?
- What conceptual frameworks and methodologies contribute to effective integrated assessment?

II PROOF OF CONCEPT ACTIVITIES

A. REGIONAL CLIMATE MODEL DEVELOPMENT

As a proof of concept demonstrating the effects of radical changes in land use over large areas, some scenarios were run using a regional climate model over a domain encompassing all of Kenya, Uganda, Tanzania, Rwanda, and Burundi, along with parts of surrounding countries and the Indian Ocean. The two cases run were the vegetated case, with a realistic current distribution of vegetation, and the unvegetated case, with all land prescribed as unvegetated desert. A third case, the reduced vegetation case, is currently being executed. Vegetation is represented in the model by a set of parameters including surface albedo, roughness length, leaf area index, and rooting depth that are typical of the specified type of vegetation. Each case was executed using lateral boundary conditions taken from the NCEP/NCAR Reanalysis Dataset for the year 1993.

The radical removal of vegetation represented by the difference between the vegetated and unvegetated cases results in drastic differences in surface fluxes of heat and moisture. The evaporation (latent heat flux) from the land surface that is present in the vegetated case, as one would expect, becomes almost absent in the unvegetated case. This difference is offset by a decrease in net solar absorption and an increase in the sensible heat flux from the surface in the unvegetated case. In general, precipitation is reduced in the unvegetated case. A full analysis of the winds has not been completed, but one interesting result is that during December, part of the rainy season, onshore winds from the Indian Ocean in the vegetated case seem to originate from an area of atmospheric downwelling just off the coast and within the regional model domain, while in the unvegetated case, they are more connected with easterly winds originating outside of the model domain.

Master's student Nitin Jaiswal was hired through funding from the NSF grant as a 1/4-time research assistant for two semesters. This was supplemented by a summer fellowship for Jaiswal, funded by the Great Lakes Environmental Research Laboratory, during which time part of his duties were further work on executing the model runs. The Great Lakes Environmental Research Laboratory provided funding for Brent Lofgren's time worked on this project.

B. LAND USE CHANGE ANALYSIS

B. 1. The Land Transformation Model. MSU's Land Transformation Model (LTM) is a spatial allocation tool that can be used to assess variables associated with of historical land use change (Pijanowski et al., 2001a; 2001b; 2002a). The models uses neural nets which train on data processed by a GIS to numerically solve spatial interactions between surrogates (e.g., distance from the nearest road, size of a parcel) of land use change drivers. The model has several strengths. First, very few spatial drivers (e.g., 3-7) can be used to build an accurate model. Second, neural nets are able to generalize across datasets and across spatial regions (Pijanowski et al., 2001a) and thus can be a useful tool to scaling up from small training sets.

In the proof of concept activity the LTM was shown to perform very well on predicting locations of historical agricultural extensification in two key East African case study areas: Embu/Mbeere on the slopes of Mt. Kenya, and Loitokitok on the slopes of Mt. Kilimanjaro.

B.2. Multi-Agent Based Economic Landscape (MABEL) Model.

MABEL is a SWARM based model that simulates individual, group and institutional behavior as agents. Agents are able to respond to exogenous factors, such as climate, economics, population provided with a set of information inputs about their land holdings (soils, crop production potential, economic condition of the farm, age of agent). Simple decision rules (e.g., economic utility functions) guide their choices for outcomes. Inputs and decisions can be modeled on very small time steps (e.g., daily) and at small spatial scales and extents. This model is similar to the form of agent models developed by Schneider *et al.* (2000).

The NSF Biocomplexity Planning Grant supported development work to examine how role-playing simulation (see below) can be used to parameterize agent behavior We explored a variety of methods to parameterize a MABEL-like model for East Africa. Case study areas currently have the requisite information required for a MABEL-like model: parcel, land use/cover data and household survey information for several time periods. Parcel data and associated land use, household survey and biophysical attributes exist for all of the case study sites for parcel/land cover for Mbeere, Kenya). We recognize that there will be a variety of different types of agents that will interact in complex hierarchies.

In southern Kenya, for example, land use categories exist that both conflict and complement each other in terms of resource management, economic objectives, and environmental sustainability. These include herding, farming, and wildlife-based tourism. Different actors engage in these land uses, and decisions on resource allocation are contingent upon legal, political, and ethnic institutions and relationships. For example, an elected committee administers group ranches in this area with a chairman, secretary and treasurer. This committee manages broad policy issues. Individual members take decisions regarding size of herds, when and where to graze and water livestock, and on cropping strategies, and expected income from each crop. As land managers these individuals will respond differently to climate dynamics, to the relatively static biophysical environment (soils, topography, hydrography), and to cultural traditions, economic opportunities, policy initiatives, and relationships with land managers in other adjacent land use systems.

B. 3. Role Playing Simulation.

A third approach to modeling used was game or role-playing simulation.

The simulation was judged to be highly representative of East African conditions. Further the key driving forces of change identified by the players confirmed those reported in our studies of land use change including the importance of:

- Land – its availability, distribution, and quality;
- Labor – availability for farming and herding, and remittances from migrants;
- Capital – the wealth of households, and their investments in landesque capital (soil conservation, soil fertility etc.) and in technology;
- Infrastructure – access to roads, ability to export produce to markets, boreholes, and irrigation works;
- The Policy Environment – laws on land allocation, economic policy (structural adjustment, exchange controls);
- The Biophysical Environment – climatic conditions, land capability, access to water, water quality.

Much discussion has taken place among the team regarding the modes of linking the findings of the different approached to land use modeling both to each other, and through scaling-up to the regional level to define the scenarios of future land cover that will be parameterized as inputs to the Regional Climate Model.

C. CREATION OF DATABASES

A large effort went towards GIS data base development for the East Africa region conducted jointly with the LUCID project. The data will provide topographic, land cover and other land surface information, and climate variables for linking to the RCM and the statistical downscaling model. Also collected from various institutions was a large variety of socioeconomic and biophysical data and information for land use/cover change analysis and prediction. The spatial data was transformed to a common projection and format.

C. 1. Satellite Imagery and DEM's

C. 2. Spatial Databases

C. 3, Literature Collected

This work was facilitated by the appointment of Bilal Butt as an RA for the project. Mr. Butt, a Kenyan, is a PhD student in the Departmentof Geography at Michigan State University.