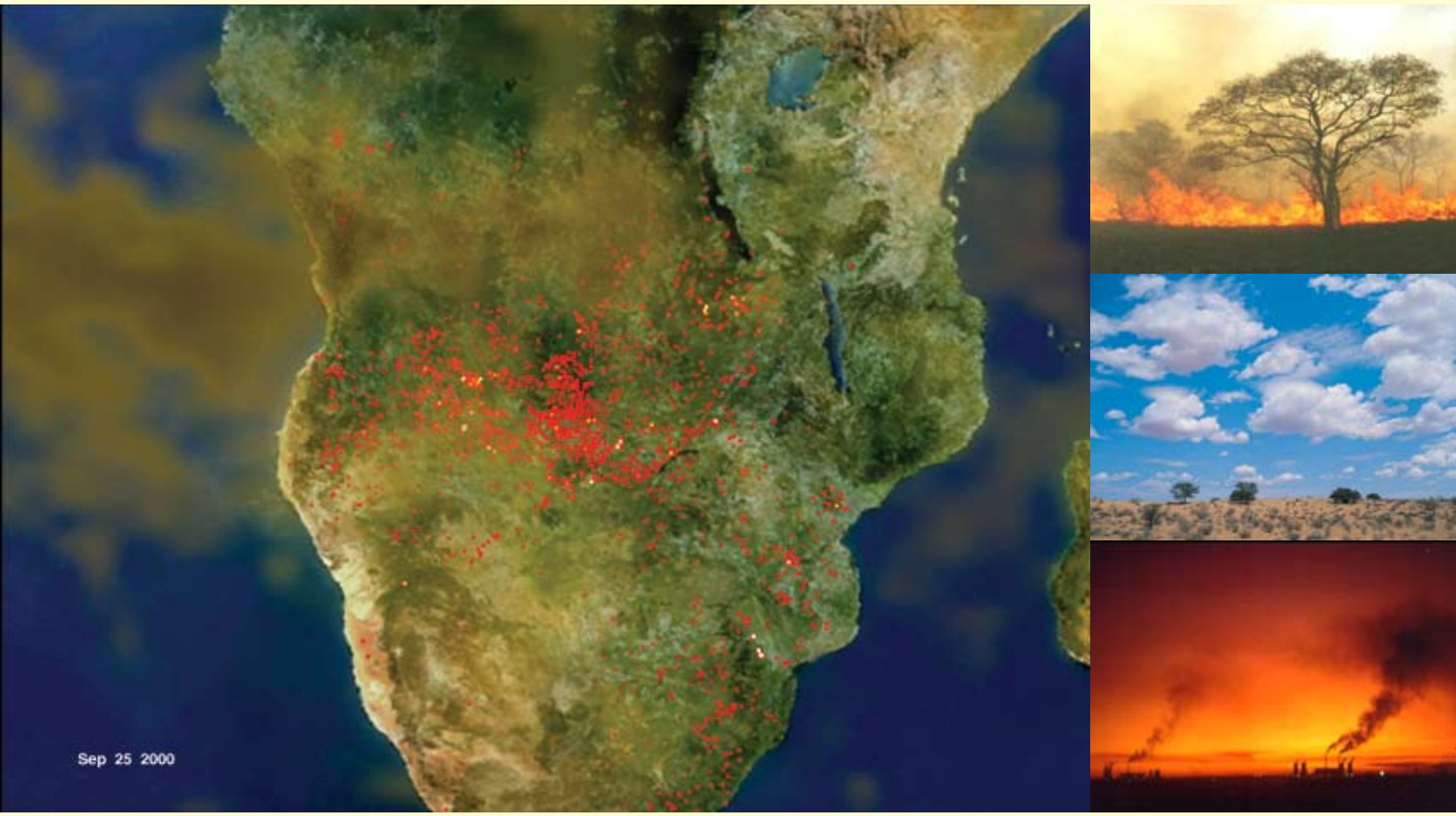
The Workshop for Enhancing Collaborative Research on the Environment in Sub-Saharan Africa

Arlington, Virginia USA
24-26 January 2005



WORKSHOP REPORT

David C. Hartnett[1] and Fredrick H. M. Semazzi[2]

[1]Division of Biology,
Kansas State University,
Manhattan, KS 66506

[2]Department of Marine, Earth
and Atmospheric Sciences
North Carolina State University
Raleigh, NC 27695

Table of Contents

I. **Executive Summary** 3

II. **Workshop Objectives and Rationale** 5

III. **Workshop Program** 7

IV. **Results** 9
- A. *Current status of U.S.-SSA collaboration* 9
- B. *Unique scientific opportunities in the SSA region* 13
- C. *Key Issues and Challenges* 15
  - 1. Science themes and research needs 15
    - a. Ecology – ecosystem functioning, biodiversity, and land use 16
    - b. Water - aquatic systems, hydrology, and water resources 17
    - c. Climate – climate change, atmosphere-biosphere interactions 18
    - d. Social Sciences – socio- bio- physical linkages 19
  - 2. Operational issues 20
    - a. Strengthening Collaboration 20
    - b. IT/Communication/Data Issues 21
    - c. Networks 22
    - d. Equipment and Infrastructure 23
    - e. Training Activities and Programs 23
- D. *Recommendations* 24
  - 1. Science: research priorities and key questions and issues 24
  - 2. Training activities 25
  - 3. Enhancing multidisciplinary approaches: integration of biological, physical and social sciences 25
  - 4. Operational issues 26
    - a. IT and Data 26
    - b. Infrastructure 26
    - c. Strengthening U.S.-SSA collaboration and Networking 27
    - d. African Support and Capacity building 28

V. **Appendices** 29
- A. *List of participants* 29
- B. *Sample invitation letter* 35
- C. *Framework for working group discussions* 37
- D. *List of acronyms* 38
- E. *List of references* 39
- F. *Poster titles & abstracts* 40

The workshop for Enhancing Collaborative Research on the Environment in Sub-Saharan Africa was funded by the Office of International Science and Engineering of the National Science Foundation. The workshop was coordinated by David C. Hartnett and Fredrick H. M. Semazzi. The workshop was funded by National Science Foundation Grant OISE-0444295 and the cognizant NSF program official for this grant is Elizabeth Lyons.

I. Executive Summary

The US National Science Foundation (NSF) supports extensive cutting-edge science in sub-Saharan Africa (SSA). To reach the full potential and impact of this investment, greater scholarly collaboration between US and SSA scientists and among disciplines, and stronger partnerships among institutions, organizations, and programs funding SSA projects are needed. To address this issue, the Workshop for Enhancing Collaborative Research on the Environment in Sub-Saharan Africa (SSA) was held January 24-26, 2005. The workshop objectives were to: 1) explore strategies for strengthening scholarly collaboration in science and engineering between the US and SSA and strengthening NSF's portfolio of sponsored research in the region, 2) articulate and promote the realms of scientific investigation that are best and uniquely suited to the SSA environment, 3) identify and recommend mechanisms to enhance and sustain communication, connectivity, and networking of people and programs, 4) promote multi-disciplinary collaboration and synthesis of results across hierarchical levels, and the capacity building necessary to address important regional and global environmental issues, 5) explore strategies to foster greater interests and expand opportunities for US students and young scientists working in SSA, and 6) build partnerships between the NSF scientific community, other funding groups, and other organizations and agencies that can support the African side of collaborative science.

Key Issues and Challenges:

The workshop evaluated NSF-sponsored environmental research in the SSA region. Although this research is contributing much toward conceptual advances in several scientific fields and is providing opportunities for students and young investigators, the potential scientific contributions and broader impacts of SSA research are not being fully realized. One key issue limiting strong scholarly collaboration is inadequate support for African research collaborators and institutions. As a US domestic agency, NSF support is limited to US scientists and institutions, thus other mechanisms, such as partnerships between NSF and other funding agencies or organizations are needed to address this issue. Other factors hindering scientific progress and strong collaboration include: 1) a lack of connection and coordination among projects and programs or a comprehensive approach to addressing scientific questions, 2) lack of adequate infrastructure in SSA, including IT capacity, 3) a lack of sensitivity among the US scientific community to local values and needs of host countries and institutions and African goals for research that will directly address societal needs and provide policy-relevant information to their wider community, and 4) inadequate multi-disciplinary networking and integration of the social, biological, and physical sciences to address important issues Other factors such as institutional disincentives, bureaucratic hurdles, and cultural differences have also hindered progress. There is a need to develop a comprehensive approach to address regional and global environmental issues by enhancing cooperation and collaboration across disciplines, regions, and hierarchical levels.

A key challenge is balancing the basic scientific goals of NSF-sponsored research with the need for sensitivity among the US scientific community to values and needs of African host countries and institutions for research that will directly address societal needs and provide policy-relevant information to their wider community. The majority of SSA peoples are engaged in land-based livelihoods, and human welfare and community sustainability in the region are tightly and directly linked to the integrity and conservation of natural ecosystems. Thus, much of the ecological research within SSA is driven principally by societal needs for sustainable, science-based resource management.

An important result of the workshop was the identification of several unique scientific opportunities that SSA provides for advancing basic scientific understanding and for addressing important global issues. In the global context, SSA represents a unique geographic region, comprising a great diversity of ecosystems and people, and unique human-land-water-atmospheric interfaces and interactions for study. With respect to biological, atmospheric, and earth sciences it presents several unique opportunities and resources for advancing knowledge and addressing important regional and global environmental problems. With respect to the social sciences, it is a unique region with strong linkages among ecology, sociology, and economics, and where accelerated economic transition is driving rapid environmental change. It is a globally significant region that host's world-class research sites and institutions. There is great potential for interdisciplinary studies and for bringing together US and African scientific expertise and knowledge in strong intellectual collaboration. If realized, expanded scientific US-SSA collaboration in the region has enormous potential for addressing some of the worlds most complex and important environmental problems.

Recommendations:

A summary of general recommendations of the workshop is provided below. Further details and specific recommendations are included below in the full report.

Increased Funding for Research in SSA - The workshop identified 5 important scientific issues and themes of high global scientific importance and also relevant to the environment and societal needs of SSA. These include: 1) *climate,* including atmospheric processes, climate change, climate modeling, and atmosphere-biosphere interactions, 2) *biodiversity dynamics*, including inventory of biota, loss of biodiversity, invasion of exotic species, population ecology and management of keystone species, and links between biodiversity and ecosystem function, 3) a*nimal and human disease,* 4) *land-use and land cover change,* including ecosystem responses to anthropogenic environmental change, urbanization, effects of change on human

livelihoods, and environmental change in savannas and forests, 5) *water issues and water resources,* including study of river basins and wetlands, water and human health, and trans-boundary issues. Water distribution, quantity and quality are also areas with high potential for integration of hydrological engineering. It is recommended that NSF increase support in these areas where research investment in the SSA region is most likely to have the greatest impact and yield significant new scientific understanding of key environmental processes and problems.

Enhanced Support for Multi-disciplinary Research Integrating Biological, Physical, and Social Sciences - There is a critical need for increased support for multi-disciplinary SSA research that effectively integrates the social sciences with the biological and physical sciences to solve important environmental problems. Continued and expanded support is recommended for NSF programs such as Biocomplexity and Coupled Natural-Human Systems to advance our understanding of the linkages between biodiversity, ecosystem function and sustainability, and human societies. These programs are crucial in providing a mechanistic understanding of ecological patterns and processes, and their implications for global change, biodiversity dynamics, and society, and for the development of sustainable land-based human livelihoods. Development of new interdisciplinary networks and increased funding for multi-disciplinary modeling is also recommended.

Enhanced Training and Student Opportunities - The provision of greater funding opportunities for students, post-doctoral researchers and other young scientists to conduct research in SSA was recommended as a key to fostering sustainable, long-term collaborations and scientific progress. Expansion of distance learning programs available to both US and SSA students was also recommended as an effective approach to help build a true international community of scholars focused on SSA

Improved Communication, Coordination, and Networking - Specific operational strategies were recommended for strengthening collaboration between US and SSA and enhancing the communication and networking of researchers within and between regions. There is also need for creating more opportunities for graduate students in the US and Africa to building professional relationships among themselves. These include establishment and maintenance of a web-based directory/database of SSA scientific personnel, institutions, and programs involved in environmental research and training in SSA and the development of research networks around important research themes.

Enhanced IT – The need was identified for enhanced investment in data rescue/digitization programs, promotion of a culture of free sharing of data through policies and incentives, development of long-term observations, clearinghouse databases for archiving data for supporting interdisciplinary collaborative research, and expansion of digital libraries. Improved IT infrastructure and greater use of IT is required to support interdisciplinary collaboration in the key areas of training, literature & data management, computing, and distance learning. Future efforts should focus on enabling network infrastructure, ready access to new technologies, well-trained local support and ongoing educational opportunities for local scientists and engineers. In addition to training scientists, enhanced training programs for technical and support staff are recommended as crucial for the success and advancement of science and engineering in the SSA region.

Funding Partnerships – Given the constraints of the National Science Foundation and other US funding agencies, it was recognized that the formation of formal funding partnerships between NSF and other international agencies and organizations, SSA partner governments, and NGOs is needed to provide adequate and balanced support for strong US-SSA scientific and training collaboration. It is strongly recommended that the NSF seek formal partnership with other organizations and foundations that have strong and complementary commitments to science and development in SSA. Enhanced coordination between NSF and other organizations supporting environmental research as a foundation for sustainable development would be a critical component of a broad strategy to implement National Science Board recommendations to enhance collaborative science and engineering in developing countries. A formal partnership between NSF and USAID would be logical and synergistic, as USAID aims to improve human wellbeing and environmental sustainability, and NSF can most effectively provide the needed sound scientific basis for sustainable development in SSA. It is also recommended that NSF, as well as US institutions, should formally engage with regional networks such as the Southern African Development Community (SADC) and the New Programme for African Development (NEPAD) as an effective means to enhance coordination and foster greater support for US-SSA research collaboration and networking, and for building capacity within the region.

Changes in NSF Proposal Criteria – Specific changes in NSF proposal evaluation policies were recommended to further foster stronger and more balanced intellectual collaboration and to insure that US scientists fully engage their African colleagues in all phases of the research planning and implementation, and that US scientists demonstrate broader impacts of proposals relevant to SSA. In addition to scientific merit, additional recommended proposal criteria include a) demonstrating relevance and benefits to the host country, including increasing accessibility of results to host countries via appropriate plans for dissemination of results, b) potential for developing sustainable collaborative training and research partnerships and/or capacity building opportunities beyond the period of support, c) appropriate consideration and compliance with laws, regulations, customs and values of the host country and institution, and d) how African collaborators will be fully engaged as partners and sufficient support for their participation.

II. Workshop Objectives and Rationale

The US National Science Foundation (NSF) supports extensive cutting-edge science in sub-Saharan Africa (SSA). The majority of this research is in the general area of the environment. It extends across a range of disciplines and is pushing the frontiers of knowledge on several fronts. NSF support in SSA is addressing important global environmental issues, advancing concepts and theory in the biological and physical sciences, while at the same time providing important scientific foundations for social-economic development in the SSA region. The potential scientific and broad impact of NSF's investment in Africa could be maximized further by greater scholarly collaboration between US and SSA scientists and stronger partnerships among institutions, organizations, and NSF programs funding SSA projects. The full potential of NSF-sponsored research in SSA can be realized through building a stronger international community of scholars and partnerships among agencies and organizations to address important global and regional issues.

The National Science Board (NSB) recommended that the NSF strengthen international cooperation in science and engineering with developing countries. However, a key constraint of the NSF, as a US domestic federal agency, is that it is unable to fund non-US institutions or non-US scientists. Thus, it is clear that the NSF cannot accomplish this objective alone, and the NSB recommended that the NSF develop partnerships with other funding groups that can provide complementary support by funding foreign collaborators and institutions. To address this issue, and to explore ways to strengthen NSF's portfolio of awards in SSA, the Workshop for Enhancing Collaborative Research on the Environment in Sub-Saharan Africa was held January 24-26, 2005 in Arlington, VA. The workshop was supported by the National Science Foundation. The participants for this workshop included 29 scientists from 10 Sub-Sahara African countries, 51 NSF-funded scientists (Principal Investigators) representing several disciplines and many universities and research institutions from throughout the US, 14 US graduate students and post-doctoral researchers, and 20 representatives from US and international agencies and organizations. Principal Investigator (PI) meetings have been conducted by several NSF programs as an effective tool to enhance interaction and collaboration. This meeting was the first to have a regional focus and the first that was broadly multidisciplinary, involving NSF-supported scientists with awards from several NSF directorates and representing several disciplines (e.g. ecology, atmospheric sciences, anthropology, sociology, and engineering). This report is produced for the National Science Foundation, other agencies and organizations, and the community of US and African scientists and scholars working in SSA.

The specific objectives of the workshop were to:

1. Explore strategies for strengthening scholarly collaboration in science and engineering between the US and SSA and strengthening NSF's portfolio of sponsored research in the region.

2. Articulate and promote the realms of scientific investigation that are best and uniquely suited to the SSA environment

3. Identify and recommend mechanisms to enhance and sustain communication, connectivity, and networking of people and programs

4. Promote multi-disciplinary collaboration and synthesis of results across hierarchical levels, and the capacity building necessary to address important regional and global environmental issues

5. Explore strategies to foster greater interests and expand opportunities for US students and young scientists working in SSA.

6. Build partnerships between the NSF scientific community, other funding groups, and other organizations and agencies that can support the African side of collaborative science.

NSF supports a diverse and extensive array of research in the countries of SSA. Some of the most competitive programs at NSF are funding leading investigators and high quality research throughout SSA, and are providing great research opportunities for students and young investigators. NSF support for research in SSA has been increasing in recent years in terms of the number of awards, number of countries included, and total funding. The volume of NSF support in the SSA region exceeded $23 million during the past 5 years. The majority of this investment is in the area of environmental research and it extends across a wide range of science disciplines, with the potential to make very significant contributions to social-economic development in the region and yield solutions to both regional and global environmental problems. The potential broad impact of much of this work is currently limited, however, due to limited or no interaction and collaboration at the level of the individual research projects, and at the level of the NSF programs funding SSA projects. Recognizing that major discovery often occurs at the interface of individual disciplinary endeavors, there is strong and urgent need to build an international SSA community of scientific scholars in the general area of the environment to realize the full potential and impact of NSF support.The workshop focused on environmental science in SSA for a number of reasons:

1) Environmental research focusing on SSA aligns with the National Science Board (NSB) recommendations that NSF strengthen cooperation in science and engineering with developing countries, and with the research priorities of many African nations where environmental research is increasingly needed for sustainable, science-based resource management. It also aligns with scientific interest in environmental research and education and current NSF support in that more than 75% of NSF's research support in Africa is al-

located to environmental research, including a diverse array of programs in Biology, Geosciences, Engineering, SBE, MPS, OISE and others.

2) In many academic disciplines, but particularly the sciences, intellectual relations and academic cooperation between the US and Africa lags behind that of other regions. This limited scholarly collaboration is due to social, economic, and political constraints and challenges, including intellectual, institutional, and ideological diversity of scholarly cultures and capacities (Zeleza, 2002). A focus on SSA will help enhance US-Africa intellectual collaboration in the sciences.

3) In a global context, SSA represents a unique geographic region, comprising a great diversity of ecosystems and people, and unique land-water-atmospheric-human interfaces and interactions for study. It is a globally significant region with respect to biodiversity, geosciences, and atmospheric sciences, and hosts world class research sites and institutions (e.g. Serengeti, Lake Malawi, Gobabeb, Cape Floral Kingdom, Okavango Delta, Kruger National Park, Inhaca, Marion Island, Maputaland and others). The SSA region provides unique opportunities for advancing general understanding of environmental processes and patterns, the development of new theories and models, and our development of a predictive understanding of ecosystem responses to global change.

4) There are numerous research areas and regional and global environmental issues of mutual interest and importance to both SSA and the US, and a significant knowledge base is already being built by researchers in the region. Enhanced collaboration between US and SSA scientists can yield not only advances in our scientific understanding of the environment, but our capacity to address key environmental issues in developing regions around the world. The combination of these factors and enhanced collaboration between US and SSA scientists can yield major advances in our scientific understanding of the environment and our capacity to address key environmental issues.

5) Scientific research in SSA can contribute significantly to our fundamental understanding of ecological processes and the global environment. Due to the congruency of many ecosystem types in North America and SSA and the similarity in the array of environmental processes and patterns characteristic of systems in these two regions, enhanced cross-continent research can yield significant advances in our understanding of the degree of generality or system-specificity of ecological principles and environmental effects (ecological rules and contingencies sensu Lawton, 1999). For example, comparative studies of congruent SSA and North American grassland ecosystems are providing crucial understanding of the generality of ecological principles and ecological rules and contingencies that govern terrestrial ecosystems and the services they provide. Studies of atmosphere-biosphere interactions and other processes in SSA can add significantly to our understanding of global processes. Holistic and multi-disciplinary study of SSA environments can also provide greater scientific understanding of complex coupled human-natural systems. Where collaborative, cross-continent comparative studies have previously been undertaken in an integrative approach, they have enhanced our general understanding of ecosystem ecology and environmental management.

6) The SSA region consists of mostly developing countries where rapid economic transition is driving rapid environmental change. Alterations of key ecosystem drivers (e.g. natural disturbance regimes in forests and savannas, hydrological regimes in rivers and wetlands, keystone species, atmospheric processes), and social, economic and political changes (e.g. rapid urbanization, trans-boundary environmental transitions) are occurring within the region, posing numerous significant scientific challenges and potentially altering the role of SSA in the changing global environment. It is a region with strong linkages among ecology, sociology, and economics, and where basic human welfare is intimately related to the integrity of natural ecosystems and sustainable natural resource management. Current policy-making regarding environmental issues and conservation planning and implementation in Africa are often poorly informed by good science, and many globally important environmental issues are trans-boundary issues, requiring strong scientific collaboration and coordination both among countries and among regions.

There have been no previous mechanisms or efforts to link and coordinate multi-disciplinary research among African countries or between Africa and the US. There have been a few recent programmatic efforts to foster greater cooperative research in some areas. For example, the Environmental Long-Term Observatories Network of Southern Africa (ELTOSA) is a network of country environmental observatories and long-term ecological research networks encompassing the natural environments and their socio-economic context in southern Africa (Biggs et al. 1999, Henschel et al. 2003). ELTOSA was recently initiated to promote the understanding of long-term environmental processes and episodic changes in SSA at the local to global scale, to facilitate cooperation among scientists and resource managers, improve connectivity between country programs, and to assist with advising funding agencies in southern Africa. ELTOSA is beginning to form stronger linkages with the US and other regions through the International Long-term Ecological Research (ILTER) program. In addition, a few programs have addressed specific questions at the regional or continental scale (e.g. the SAFARI Campaign), but there have been no efforts to develop a comprehensive approach to address regional and global environmental issues by enhancing cooperation and intellectual collaboration across disciplines and hierarchical levels.

A general goal of this SSA workshop was to increase broader understanding, among researchers and across disciplines, of the SSA environment and its global significance. We are optimistic that the broader impacts of the meeting will include an enhanced partnership among researchers and educators to effectively integrate discovery, teaching, training and learning, to address regionally and globally important scientific questions and challenges pertaining to the environment in SSA.

III. Enhancing Collaborative Research on the Environment in Sub-Saharan Africa: Workshop Program

Monday, January 24, 2005

9:00 – 10:00 Opening Session – Welcome & Introductions
Dr. Kerri-Ann Jones (Director, OISE)
Dr. Arden Bement (Director, NSF)
Dr. Fredrick Semazzi (Co-Coordinator, PI)
Dr. Elizabeth Lyons (OISE/Africa)

10:00 – 10:30 Plenary Talk I - Dr. Robert Swap, University of Virginia,
"From SAFARI to SAVANA: An Example of International Interdisciplinary Research on the Regional Scale and Collaborative Consortia in Southern Africa"

10:30 – 12:30 Poster Session I

12:30 – 1:30 Lunch

1:30 – 2:00 Plenary Talk II - Dr. Ellinor Michel, Natural History Museum, London,

"The Nyanza Project: Interdisciplinary Research Training in Tropical Lakes Sciences - Paleoclimates, Geology, Limnology and Biology in Lake Tanganyika"

2:00 – 2:30 Plenary Talk III - Dr. Michael Adewumi, Pennsylvania State University

"The Alliance for Earth Sciences, Engineering, and Development in Africa (AESEDA): A U.S.-Africa Partnership"

2:30 – 3:00 Organizational meeting – set up working groups

3:00 – 5:00 Working Group Session I: Disciplinary Working Groups

Group A: Earth & Climate Scientists (GEO)
Moderator: Sharon Nicholson,
Rapporteur: Richard Anyah
Group B: Ecology & Ecosystems Scientists (BIO)
Moderator: Michael Coughenour,
Rapporteur: Stephen Mlingwa
Group C: Social Scientists – Anthropology, Archaeology, Geography (SBE)
Moderator: David Campbell,
Rapporteur: Emmanuel Wango

5:00 – 5:30 Wrap-up

5:30 Adjourn

Tuesday, January 25, 2005

8:00 – 10:30 Working Group Session II: Activity Type Groups

Group A: Student/Training Activities
Moderator: Dan Wubah,
Rapporteur: Paul Dirks
Group B: IT/Communications/Data Management
Moderator: Kristen Vanderbilt,
Rapporteur: Steve Huter
Group C: Infrastructure/Field Stations/ Equipment
Moderator: Nick Georgiadis,
Rapporteur: Estella Atekwana
Group D: Networks
Moderator: Steve Huter,
Rapporteur: Robin Reid

10:30 – 12:30 Poster Session II

12:30 – 1:30 Lunch

1:30 – 3:00 Working Group Session III: Country/ Region Groups

Group A: South Africa, Botswana, Namibia
Moderator: Mary Scholes,
Rapporteur: Joh Henschel
Group B: Mozambique, Tanzania, Madagascar
Moderator: Salome Misana,
Rapporteur: Anne Yoder
Group C: Uganda, Kenya, Ethiopia, & western Africa
Moderator: Laban Ogallo

3:00 – 3:30 Break

3:30 – 5:30 Working Group Session IV: Key Issues/ Themes Group

Group A: Water
Moderator: Susan Ringrose,
Rapporteur: Tad Park
Group B: Land Use and Land Cover Change
Moderator: Niall Hanan,
Rapporteur: Jennifer Olson
Group C: Climate change & Atmosphere-Bio Interactions
Moderator: Greg Jenkins,
Rapporteur: Moses Tenywa
Group D: Biodiversity Conservation
Moderator: Wayne Getz,
Rapporteur: Wendy Turner

Wednesday, January 26, 2005

8:15 – 10:00 Working Group Reports, Session I: Disciplinary Groups

Group A: Earth & Climate Scientists (GEO)
Group B: Ecology & Ecosystems Scientists (BIO)
Group C: Social Scientists – Anthropology, Archaeology, Geography (SBE)

10:00 – 10:15 Tea/coffee break

10:15 – 11:45 Working Group Reports, Session III: Regional/Country Groups

Group A: South Africa, Botswana, Namibia
Group B: Mozambique, Tanzania, Madagascar
Group C: Uganda, Kenya, Ethiopia, & Western Africa

11:45 – 12:30 Lunch

12:30 – 2:15 Working Group Reports, Session IV: Key Issues/Themes Groups

Group A: Water
Group B: Land Use and Land Cover Change
Group C: Climate change
Group D: Biodiversity Conservation

2:15 – 2:30 Break

2:30 – 4:00 Working Group Reports, Session II: Activity Type Groups

Group A: Student/Training Activities
Group B: IT/Communications/Data Management
Group C: Infrastructure/Field Stations/ Equipment
Group D: Networks

4:00 – 5:30 Wrap-up – Themes & Recommendations

5:30 Adjourn

IV. Workshop Results

A.Current Status of U.S.-SSA Collaboration

Introduction

NSF currently supports environmental research across a wide range of science disciplines in Sub-Saharan Africa (SSA).

However, currently there is very limited interaction and collaboration at the level of the individual research projects, and at the level of the NSF programs funding SSA projects. There have been no significant efforts or mechanisms to link and coordinate multi-disciplinary research among African countries or between Africa and the U.S. There have been a few recent programmatic efforts to foster greater cooperative research in some areas (e.g. the Environmental Long-Term Observatories Network of Southern Africa [ELTOSA]). Currently, a strong knowledge base with respect to social scientific questions is lacking, and there is a need to develop conceptual guidelines and a common language among researchers in various disciplines for addressing scientific questions. Although researchers in some specific sub-disciplines are well networked, there remains very limited inter-disciplinary networking and collaborative research in SSA. Furthermore, current policy-making regarding various environmental issues and conservation planning and implementation in Africa are often poorly informed by good science, and there is a large disparity in levels of ecological research and networking among countries.

Intellectual relations and academic cooperation between the U.S. and Africa lags far behind that of other regions due to a number of social, economic, and political constraints and challenges including intellectual, institutional and ideological diversity of scholarly cultures and capacities. Currently, there are many factors hindering intellectual collaboration between U.S. and SSA researchers. A tradition of scientific imperialism in many developed countries (e.g. North American and European scientists simply using SSA as their laboratory) has limited progress in science and education in SSA. In general, intellectual exchange between the U.S. and Africa (both education and research) has been unbalanced. Factors such as financial constraints, African intellectual migrations (brain drain to the U.S.), institutional disincentives, bureaucratic hurdles, and cultural differences have all resulted in limited progress, although recent trends in transnational education, globalization of American scholarly societies, and expansion of on-line education may contribute to improved collaboration in education. Improved collaboration in science and engineering is urgently needed.

One of the major obstacles to environmental research and training in SSA is lack of adequate infrastructure at the universities, including IT capacity, but the situation is beginning to change. Most of the research institutions lack basic computing infrastructure and capabilities that could expedite information and data retrieval/exchange. Most countries have very stringent data sharing policies that inhibit free flow of information/data among SSA scientists. In many SSA countries, ground based (in situ) observing systems have been diminishing with time since there is limited financial support for maintaining data networks. Though Internet access and available bandwidth are improving, obtaining or exchanging data over the Internet is still difficult in most countries in the region. Although there remains a clear technical divide between SSA and the U.S., this does not infer an intellectual divide.

There is a large disparity in levels of environmental research and networking among countries in Africa due to differing socio-political settings. This is largely linked to differences in levels of economic development and resultant levels of funding for ecological research from governments, corporations, and foundations. Similarly, there is a disparity of infrastructure and human capacity between more and lesser-developed countries. Universities in some countries are limited by poor facilities, and lack of funds for paying competitive faculty salaries. In other countries the situation is more favorable. There is talent and potential, and there are well-trained scientists in most countries. However, many ,if not most, countries do not have government funding agencies to support in-country environmental research. This limits the number of scientists, students, and projects involved in environmental research.

Despite these current limitations, there are many areas where significant scientific progress is being made in research, training, capacity building, and addressing key regional environmental issues in SSA. A few of the many examples include: 1) Many institutions, such as the Wildlife Institute (Tanzania) are doing active independent and collaborative research, and have good physical infrastructure (field stations) and good internet connectivity. 2) In countries such as Mozambique, environmental and ecological research are the leading disciplines. Research in these areas is well networked and integrated, and there is significant activity and progress in the area of land use and land cover change (LULCC) research. 3) Networks such as TANRIC (Tanzania) have been effective in compiling land use information and making good exploitation of remote sensing. 4) Some regional universities (e.g. University of Botswana, University of Dar es Salaam) are supporting greater research and training efforts, and the faculty are becoming engaged in the development of research agendas and programs. 5) In Madagascar and several other countries, there are many on-going NSF-funded projects and several well-established collaborations with U.S. institutions. 6) Several countries have initiated regional research projects to address trans-boundary environmental issues. 7) Several SSA countries are beginning to become better linked through regional networks such as ELTOSA. 8) The region hosts several world-class research sites and institutions that have established strong research and training programs (e.g. Serengeti, Lake Malawi, Gobabeb, Cape Floral Kingdom, Okavango Delta, Kruger National Park, Inhaca, Marion Island, Maputaland and others).

Below we summarize the status of research and training in several key areas relevant to the environment in the SSA region.

Current Status Based on Disciplines

Ecology

A long history of U.S ecologists working in Africa forms the basis for US-African linkages in ecological research. R. Estes initiated ungulate research in the Ngorongoro Crater, Tanzania in early 1960's with funding from the National Geographic Society. S. McNaughton and colleagues from Syracuse University carried out NSF-funded grazing ecosystem research projects in the Serengeti, Tanzania from 1974 to 2004. From 1980 to 1992, NSF funded a series of grants to J. Ellis, D. Swift, and M. Coughenour at Colorado State University in support of the South Turkana Ecosystem Project in northwest Kenya. This interdisciplinary project was one of the pioneering studies of coupled human-ecological systems. Craig Packer and colleagues at the University of Minnesota have carried out research on lions and other predators in the Serengeti and elsewhere since the 1970's. More recently, research in southern Africa by H. Shugart and colleagues at the University of Virginia has provided a basis for research on dry woodland dynamics in southern Africa. These are just a few examples of many individual or institutional U.S.-SSA linkages conducting ecological research.

International conservation organizations are important agents in ecological applications in East Africa and elsewhere. These organizations carry out environmental monitoring and fund a limited amount of ecological research. Much of the funding for ecological research in Africa is linked to conservation, and these organizations have supported much applied ecological research and are important networkers as they form critical linkages between ecologists and policy makers. Examples include NGOs such as African Wildlife Foundation, World Wildlife Fund, Conservation International, Wildlife Conservation Society, New York Zoological Society, and BirdLife International. Another example is the Global Environment Fund of UNDP, which supports national and international conservation and biodiversity initiatives.

There are many networks of ecologists in sub-Saharan Africa, both formal and informal. However, collaborations have usually been weak due to limited funding, a scientific culture of competition and suspicion rather than cooperation, and biopolitics of power and favorability among various sub-networks and groups. In addition, networks are mostly at intergovernmental levels rather than at scientific levels on the ground. For example, New Partnership for Africa's Development (NEPAD) and the Southern African Development Community (SADC) are working on similar problems at regional and continental levels. The Organization for African Unity International Bureau for Animal Resources is concerned with pastoral and livestock issues such as disease throughout a continent where pastoralism is a primary land use. There is a need for greater input from ecological scientists into such organizations, given the potentially important effects of patterns and pathways of development on ecological sustainability.

Recently, networks and meta-networks of ecological scientists have been forming in southern and eastern Africa. These include ELTOSA (Environmental Long Term Observatories Network of Southern Africa) being a meta-network working at the international level, and SAEON (South Africa Environmental Observatory Network), a country-level network and member of ELTOSA, linking nodes within the country. The NSF ILTER has been and continues to be involved in promoting LTER networks in Southern Africa and elsewhere, forming a basis for SAEON and subsequently ELTOSA.

Changing land use and land cover, including changes in disturbance regimes, ecosystem drivers, and their consequences (deforestation, desertification, rangeland degradation, bush encroachment, urbanization, altered hydrological regimes, changing agricultural practices, altered regional fire regimes) represent the most extensive and arguably the most important environmental change phenomenon in the SSA region. Many of the other key environmental issues (e.g. water issues and wildlife population conservation issues) stem from land use and land cover change, but these major themes are not well linked and the research addressing them is not well networked.

Much important land use and land cover change (LULCC) research has been and is currently being conducted in Africa. Some of this work originated in the 1980's with the establishment of national and regional remote sensing centers supported through national and international (e.g. FAO, UNEP) agencies. Some of these centers are active in monitoring land use change and all have extensive archives of data. These centers can provide invaluable resources of technical expertise and data for studies of land use dynamics in the region. Much of the on-going research is identifying and monitoring critical ecosystem characteristics and services that are rapidly undergoing change. **The current status is that most LULCC research has been focused on describing and quantifying patterns of land cover change, but an adequate understanding of the important drivers of change and the ecological or socioeconomic consequences of land use and land cover change is still lacking.** Additional effort will be required to achieve a mechanistic and predictive understanding of LULCC in SSA. U.S. funding agencies have been supportive and continue to support ecological research carried out by U.S. scientists in Africa. For example, NSF is currently funding several Biocomplexity or Ecosystem Studies projects. NASA is funding research on fire ecology in southern Africa. USAID is funding applied ecological research under the Global Livestock Collaborative Research Program.

There have been increasingly strong linkages and collaborative LULCC research projects between southern Africans and Americans since the early 1990's. Certain linkages go back further, as some eminent SSA ecologists received training in the U.S. and some U.S. researchers have roots in SSA. Over the last decade many strong linkages have formed between ecologists in SSA and the U.S. through workshops, exchange visits, training, and collaborative research. Some of these linkages have revolved around key ecosystems and sites such as Kruger National Park. Others have developed through global ecosystem research networks such

as the International Geosphere-Biosphere Progam(IGBP), Scientific Committee on Problems in the Environment, IGBP Global Change in Terrestrial Ecosystems, IGBP Land Use and Cover Change, and more recently the NSF International Long-Term Ecological Research program.

Earth & Climate Science

The past two decades have seen significant advancement in geosciences research in SSA, however there are still large disparities among countries and regions. South Africa has more well funded and coordinated research programs compared to other SSA countries. Significant research has been conducted to understand the characteristics of climate variability over SSA. In addition, driven in large part by the continent's wealth in minerals, much geological research has been going in most countries. However, most of this research is funded by private companies, which often dictate research objectives. The present state of Earth and Climate science research in SSA may be summarized as follows:

(a)) With regard to climate variability, a wide range of diagnostic studies have been conducted in the region and thus a broad base of knowledge and understanding of the dominant factors driving SSA climate variability has been achieved. The unique geological characteristics of the SSA sub-continent have also attracted much research and are now well understood. African Monsoon Multidisciplinary Analysis (AMMA) is an integrated multidisciplinary project that aims at addressing both fundamental scientific questions related to the understanding of the West African Monsoon (WAM) variability and practical issues related to prediction and applications. AMMA will help to fill some of the major remaining gaps but similar efoorts need to be initiated over the rest of the SSA region.

(b) The very limited inter-disciplinary collaborative research in SSA has raised considerable concern because geosciences are quite interconnected and collaboration among scientists across the disciplines could help reinforce and enhance understanding of the peculiar geological and climate processes over different regions of the sub-continent. There is lack of clear application strategies for geosciences research findings to relevant socio-economic sectors.

(c) Most of the research institutions lack basic computing infrastructure and capabilities that could expedite information and data retrieval/exchange via the Internet. Furthermore, the teaching of geosciences in many SSA universities, apart from South Africa, does not incorporate relevant courses for training in fundamental computer skills. This makes it hard to have a viable student exchange program in the geosciences and as such U.S. students are often interested in visiting African Universities for cultural-exchange only.

(d) Limited climate change adaptation/mitigation mechanisms (policies) have been developed by many SSA countries, although the region is potentially one of the most vulnerable to extreme climate anomalies and climate change. In particular, there are very few climate change adaptation and mitigation studies ongoing in many SSA countries, with the exception of South Africa where a comprehensive climate change impact assessment program has been developed.

(e) Information sharing among many SSA geoscientists is very limited. Many of the research findings are never published in peer-reviewed journals with wide readership, and there are a limited number of well-established journals in SSA sub-continent where local scientists could publish their work. Furthermore, most countries have very stringent data sharing policies that inhibit free flow of geophysical information/data among SSA scientists.

(f) In many SSA countries, ground based (in situ) observing systems have been diminishing with time because there is limited financial support for maintaining the data networks. This makes it difficult to properly characterize and understand various physical processes associated with regional climate variability over SSA. Inadequate data also inhibits proper evaluation and/or calibration of satellite and other remote-sensed data.

There are few synoptic stations (network) for recording daily precipitation, temperature, and other data, especially in Central, East and West Africa. Without adequate data, the climate system of Africa cannot be adequately quantified or understood. Africa's climate observing system is the poorest in the world and it is deteriorating. The observational networks are declining and are below international standards. There are 1,152 World Weather Watch stations in Africa giving a station density of one per 26,000 Km2, 8 times lower than the WMO minimum recommended level. This shortage of data is exacerbated by an uneven distribution, with vast areas of central Africa unmonitored, and having the lowest reporting rate in the world. The reporting of upper air data is even worse. Consequently, the climate system of the central African convective region and the Sahel are poorly understood.

Historical (palaeo) studies - There are limited paleoclimatic data on a regional basis in Africa. Paleoclimatology provides a longer perspective on climate variability that can improve the understanding of the climate system and help predict future climatic changes as a result of global warming. Evidence for paleoclimatic change can be obtained by the study of natural phenomena that are climate dependent. In Africa, very few paleoclimatological studies exist that can be used to understand past climates so as to model the future.

Modeling climate change - Problems relating to use of modeling in understanding climate change in Africa are threefold; 1) inaccurate climatic models, 2) uncertainty in model predictions, and 3) limited capacity in the use of models. Models are essential in forecasting and understanding future climatic changes. Global Climate Models (GCMs) are commonly used to make long-term climatic predictions as well as to study seasonal and inter-annual climate variability. GCMs, linked with Regional Climate Models (RCMs), enable the understanding of the workings of a given climatic system. However, most of the models have been developed at major climate research centers outside Africa and not from the African climate perspective. These models may not adequately represent the climate of the African region. Climate models developed from AOGCMs are very coarse and hide important regional variations in Africa's climate. There is also the need to develop regional climate models and sub-regional models at the scale that would be meaningful to decision-makers. GCMs capture

the El Niño Southern Oscillation very well in the Pacific Ocean, but have significant deficiency in capturing ENSO impacts in southern Africa. Therefore models developed and tailored to the African continent are still needed for effective climate predictions. Noteworthy are also the great uncertainties in climatic assessments using models. Although GCMs have extensively been used to project future climates, the confidence in results from such models is still questionable. Climate models represent a simplification of the climate system, but climatic systems can at times be too complex to model accurately on a regional scale. Climate models thus have to be validated or tested with real-time observations. South Africa is the only country developing and running global climate models for operational seasonal forecasts. The development and use of models by other countries has been hindered, primarily due to the prohibitive costs of running models and lack of expertise in climate modeling.

Another concern is inadequate knowledge for the SSA region of the role of natural and anthropogenic aerosols. In order to have an adequate predictive understanding of future climate change from anthropogenic forcing it will be necessary to include all factors including anthropogenic sulphate aerosol and reductions in stratospheric ozone concentrations. The interrelationships between biological processes and climate change are not well known. For example the functional relationship between carbon sequestration under different land use types and climate change is not quantified. Comparison of GCMs to observations during the 20th century is a good way for evaluating them. It is also important that the modeling community interact with scientists in Africa to provide guidance on biases that any specific model may have and the potential causes of these biases.

Forecasting - Seasonal forecasting is a very important time scale of climate information for Africa. Several National Meteorological Centers (NMCs) in Africa now issue seasonal climate forecasts on an operational basis. Climatic forecasting in Africa is fairly good for limited periods and the utilization of these forecasts is limited. The failure to develop a comprehensive profile of users has resulted in considerable gaps between the information that is likely to be useful to farmers and other land managers, and that provided and disseminated by these services. There is therefore need to involve not just forecasters, but also those who are working on climate applications, using forecasts based on different methods and lead times.

Capacity - Africa also lacks adequate capacity to analyze climatic records. There is limited technical understanding of climate in Africa and expertise in handling climate issues within Africa. For example, Africa has the lowest level of published activity of climate science in the world, manifesting gaps in capacity to study climate changes. An analysis of affiliations of leading authors of papers in two leading climate journals (2002- 2004) revealed only 2 scientists from Africa as compared to 416 from North America.

IT/Communications/Data Management

Though Internet access and available bandwidth are improving, obtaining or exchanging data over the Internet is still difficult in most countries in the region. To obtain satellite images, it is currently easier to email a colleague and ask him/her to send maps and large data sets on a CD or DVD. If one tries to download meteorological or geophysical data and maps during normal working hours, workstations often hang or crash, or links get saturated, making it infeasible for interactive work. African scientists often must wait until the time of minimum traffic to transmit data successfully. In February 2005, the World Bank published a report about university networks in the region, entitled, "African Tertiary Institution Connectivity Survey Report (ATICS), which is part of an African Virtual University (AVU) initiative funded by the World Bank. Eighty three institutions from 40 countries participated in providing information for the survey. The report can be obtained at http://www.atics.info/.

African scientists cited many difficulties obtaining data from other scientists and governmental agencies. Getting permission from governmental agencies to use their data requires navigating many bureaucratic obstacles, and obtaining the data may require the labor-intensive task of visiting an agency and leafing through data books. Much existing indigenous data is not digitized. Between disciplines it is very difficult to get data sets (i.e. African meteorological data sets for an ecologist seeking it for his/her field research area). Data sets may also be prohibitively expensive for scientists. Government agencies may initially release portions of data sets for a free, but then require additional payment for subsequent portions of the data set. Agencies often view data as a source of revenue because they operate on a cost-recovery basis.

Networks

For better science, networks allow us to conduct more powerful comparisons across multiple sites, glue ideas and people together, and identify different researchers addressing a common problem. For more efficient logistics, networks allow scientists to share protocols, analytical tools, and equipment. In order to achieve critical mass, networks glue sparsely distributed colleagues together from different countries. We need networks linking scientists-to-scientists , local communities/land users-to-scientists, policy makers-to-scientists, and all three together. There has been significant work in economics on networks and how to get information to local groups. When considering developing new networks it is desirable to study the existing networks. A list of some of the African networks is given below:

AERC: African Economic Research Consortium
AETFAT: African Plant Taxonomy Association
AFEA: African Finance and Economic Association
AFRIFLUX: Promoting Research on Ecosystem Function in Africa
AHEAD: Animal Health for the Environment and Development
APINA: Air Pollution Information Network of Africa
BENRON: Botswana Environment & Natural Resources Observatory Network
CARPE: Central African Rainforest Project
CODESRIA: Council for Economic and Social Research in Africa
CTFS: Center for Tropical Forest Science.
EAFRINET: East African Network for Capacity Building in Taxonomy
ELTOSA: Environmental Long-Term Observatories Network of Southern Africa
GSSA: Grassland Society of Southern Africa

IDEAL: International Decade of the East African Lakes
LUCID: Land-use Change Impacts and Dynamics, East Africa
NAFRINET: North African Network for Capacity Building in Taxonomy
ORSTOM: Organisation de Recherche Scientifique outré Mer
REBAC: Central African Botany Network
RIEM: Ecological and Environmental Network of Mozambique
SAFNET: Southern Africa Fire Network
SAFRINET: Southern African Network for Capacity Building in Taxonomy
SAHRA: University of Arizona, digital abstracts on water throughout the world
SANTREN: Southern African Environmental Network
SAPES: Southern African Policy and Economic Studies
SAVANA: Southern African Virginia Networks Association
WAFRINET: West African Network for Capacity Building in Taxonomy
WATERNET: Water/Land Training Network

Most of these networks are discipline based. The challenge is to find how they can be linked together to promote new interdisciplinary research collaboration addressing important scientific and management questions. There are also few interdisciplinary networks. One example is the LUCID network in East Africa, with interdisciplinary focus on causes, processes and consequences of land-use and land cover change. Constraints on networking revolve around geographic coverage, lack of fast internet access via email and other problems. Central Africa particularly needs more networking, but there is also a need for linking different regions of Africa. There is a lack of email access in many African countries, and other forms of communication facilities available are also slow. There is a need to connect and engage young African scientists, beginning with those who have obtained a B.Sc university degree level of education. NSF could play an important role of helping to provide funding (e.g. for students) for longer periods of time, to support continuity in the network's activities. There is a need for better flow of information between scientists and local communities, and scientists and policy makers.

B. Unique Scientific Opportunities in the Sub-Saharan Africa Region

In the global context, SSA represents a unique geographic region, comprising a great diversity of ecosystems and people. With respect to biological, atmospheric, and earth sciences it presents several unique opportunities and resources for advancing knowledge and addressing important regional and global environmental problems. With respect to the social sciences, it is a unique region with strong linkages among ecology, sociology, and economics, where environmental integrity and the welfare of human communities are very directly and strongly coupled, and where rapid economic transition is driving rapid environmental change. The key conclusions of the workshop regarding research needs and scientific opportunities in the SSA region are the following:

First, the workshop identified the following important scientific issues and scientific opportunities unique to the SSA region. Given the regional and global importance of these issues, and the unique opportunities that the SSA region presents to address them, these are specific areas where research investment in the SSA region is most likely to yield significant new scientific understanding of key environmental processes and problems. We recommend that the NSF encourage multidisciplinary collaborative research in these areas:

Earth and Atmospheric Sciences

Africa as whole presents unprecedented wealth of research opportunities in earth and climate sciences. In terms of climate, Africa (tropical rainforest) is the second largest source of mid-tropospheric latent heating in the whole world. As such, understanding climate variability and predictability over the continent in general, and in SSA in particular, may also lead to better understanding of certain aspects of the global climate (circulation) system. Africa is also one of the tropical regions with glacier-capped mountains which are important and unique sanctuaries of paleoclimate records and hence a treasure that can be utilized in detection, attribution and impacts of global climate change. Endowed with complex terrain (e.g. the East Africa Great Rift Valley system) and having enormous mineral resources, SSA also provides unparalleled research opportunities in geology, geophysics and mineralogy.

- *Improved understanding of atmospheric processes toward improved climate models* - Due to a unique combination of factors such as seasonal sources from biomass burning, annual sources from industry, and atmospheric characteristics, research in the SSA region provides significant opportunities for increased understanding of the sources, transport, and effects of atmospheric aerosols and radiative foraging and other key processes influencing regional and global climate.

- *Multi-scale and multi-disciplinary collaborative research* - West African monsoons, African easterly waves and squall systems that have both direct and indirect linkages to adverse tropical weather developments in regions as far as the southeastern U.S. present great opportunity for mutually beneficial multi-scale, multi-disciplinary collaborative research between U.S. and Africa scientists.

- *Improved understanding of geological processes and their influence on ecosystems* - The East Africa rift system provides one of the best laboratories for understanding the interplay of deep geological processes and surface processes, and their historical impact (paleoenvironments). Africa has the largest mantle seismic anomaly, and SSA has the largest wetland in the world (the Okavango, Botswana), providing unique opportunities for study of the role of tectonics on hydrology. SSA also provides strong opportunities for addressing important fundamental questions in geosciences, such as the changing earth magnetic field, and connections between geomorphology and patterns of biodiversity distribution.

- E*nvironmental impacts of mineral resource extraction and processing* - SSA provides significant opportunities for the study of mining, the geology of precious metals, environmental impacts of mineral extraction, and economic geology. There is growing interest in the impacts of acidic mine water on global warming, and SSA provides unique opportunities to study the interrelationships between mineral resource processing and climate change. Southern Africa and central Africa contain the world's largest mineral-rich tracks of land and still use outmoded technologies for basic geological mapping and exploration that in turn leads to serious environmental degradation. Hence, application of the latest environment friendly geological and mineralogical research technologies remains under-exploited over the SSA sub-continent.

- I*mproved understanding of causes, patterns, and consequences of climate change* - SSA is characterized by extremely steep climatic gradients (30-fold change in precipitation over 200 km distance) across 6 climatic zones (e.g. Namib Desert, Kalahari, and Okavango Delta). Such steep climatic gradients provide high response sensitivity and the best opportunities for studying ecosystem responses to climate change. The SSA region and other African regions also provide excellent opportunities for studying the role of ocean warming on climate variability and climate change. For example, Mount Kilimanjaro and Kenya in East Africa provide superb opportunities for understanding the effect of radiative forcing/global warming on accelerated glacial retreat, and coring within the East Africa Great Rift Valley System provide valuable information for paleoclimate studies.

Biological Sciences

- *Biodiversity dynamics* - The tremendous diversity of biota and ecosystems in SSA provide unique opportunities for improved understanding of controls and patterns of biodiversity and fundamental ecological processes – The subcontinent encompasses forests, savannas, grasslands, deserts, perennial and ephemeral rivers, wetlands, lakes, warm coral reefs, cold upwelling currents, and tropical to sub-Antarctic islands. Unique biological aspects of the SSA environment include:

  a) spatially extensive grazing ecosystems with high biodiversity mammalian fauna with large effects on ecosystem function

  b)high rates of biodiversity discovery (e.g. Madagascar has one of the world's highest rates of new taxa discovery)

  c) unique and highly diverse floras and faunas (e.g. SSA includes four global biodiversity hotspots)

  d) highly diverse, heterogeneous, and rapidly changing terrestrial ecosystems, landscapes, and land use patterns (e.g. Miombo woodlands transformation, central African forest transformations, savanna transformation)

  e) spatially extensive gradient of coastal zone environments, the most dynamic aspect of terrestrial/marine interactions, providing significant opportunities for understanding coastal zones and coastal zone processes

  f) numerous regional examples of exotic/invasive species

  g) unique human-wildlife-livestock interfaces.

- *Rapid changes in disturbance regimes and other ecosystem drivers* within the SSA region provide significant opportunities for study of relationships among ecosystem diversity, stability, functioning, and human livelihoods. The SSA region is unique in its wide spectrum of systems from "pristine" to highly human-modified and in the pace of regional environmental change (e.g. rapidly changing land cover).

- *Unique long-term experiments* in the region (particularly in South Africa), some spanning more than 5 decades, provide excellent opportunities for studying long-term ecological processes including long-term effects of fire, grazing, and mega fauna re-introductions on terrestrial ecosystem functioning and biodiversity.

- The Eastern Africa's large inland lakes (Victoria, Malawi, Tanganyika, etc) provide unique natural laboratories where a consortium of geologists, climatologists/ palaeoclimaologists, ecologists, biologists and social scientists could conveniently converge to study multi-scale processes on the lakes and regional ecosystems as exemplified by the IDEAL's multidisciplinary studies conduced over the past decade and a half.

Social Sciences

- *Influence of ecosystem functioning, diversity and stability on human livelihoods* – SSA is a region of mostly developing countries where human livelihoods are uniquely and strongly coupled to biodiversity conservation and ecosystem integrity. These diverse and strongly coupled human-natural ecosystems provide unique opportunities for addressing fundamental scienctific questions such as the role of biodiversity in ecosystem stability, ecosystem services, and sustainable livelihoods.

- *Wildlife and human interactions* - The SSA region provides numerous unique opportunities for increased understanding of the human/wildlife/livestock interface, including diseases, introduced diseases and zoonoses (e.g. impact of zoonotic disease on human resources)

- *Environmental consequences of urbanization* - Rapid urbanization is a key transformation occurring within the SSA region. For example, rapid changes such as the unplanned urbanization of some major cities has created unique research opportunities to better understand effects of urbanization on local and regional ecosystem integrity, and conversely the changes in political landscape and socio-economic factors driving urbanization.

- *Anthropology* - Africa provides unique opportunities for increasing knowledge of human evolution, anthropology, and the history of human-environment interactions.

- *Causes, patterns, and consequences of ecosystem transformations (savannas, forests)*

and changing land use, particularly with respect to impacts on human livelihoods – Given the variation among regional countries in economic development, the SSA region provides unique opportunities to address the socio-economic and environmental consequences of changing land use under different (1st and 3rd world) economic paradigms, and the effects of commercial and communal land use on land cover and biodiversity.

- Economic shocks (health [HIV, malaria], climate etc.) and effect on poverty dynamics and the environment in agricultural and pastoral systems. Studies within the SSA region can yield valuable insights and new understanding of relationships between poverty, human health, and resource use in the developing world, and the impact of climate change and other environmental change phenomena on human health.

- Implications of high population diversity (ethnic, cultural, socio-economic) for regional environmental impacts and ecosystem integrity. Populations in SSA are differentiated by numerous categories such as age, gender, ethnicity, and socio-economic status that influence their interactions with the environment and resources. Further, people have commitments to institutions such as family, clan, religious institutions, and political party that are real, strong, and durable and influence decision-making and the regional environment.

C. Key Issues and Challenges

Ecology and conservation science is critical and exceedingly relevant in the African context. Conservation science is of general importance in those parts of the world where biodiversity is high and under imminent threat of demise, typically from commercial exploitation or as a result of increasing human populations in areas where resources are limiting and poverty reigns. Innovative research is needed to address the present disconnect between human needs and natural ecosystems and their services. The wellbeing of peoples in the short term, and of the earth's natural systems in the long term require that we find ways to bridge the ecological and sociological components of the complex systems in which they co-occur. First and foremost, basic inventories of the biological, physical, and sociological components of these complex systems are needed. Then the role of biodiversity in ecosystem function needs to be determined along with human economic and social needs. Currently, there is lack of a strong knowledge base with respect to social scientific questions, and a need to develop conceptual guidelines and a common language among researchers in various disciplines for addressing scientific questions.

Current conservation planning and implementation in Africa are often poorly informed by good science. Further, conservation topics are often not regarded as a "real" science, when studies are applied in focus and goal-driven rather than hypothesis-driven. Such "Popperian" science is generally far too limiting a paradigm for investigating the behavior of multifaceted systems. Planning and actions need to be better informed by investigations that take a complex systems view of the interactions among all the system components. Important concerns with regard to addressing biodiversity issues in the context of changing human land-use include global climate change and accompanying aridification, and environmental change caused by the intensification of non-sustainable land-use practices. Meaningful choices in ecosystem management require the development of more sophisticated, science-based land-use tools than those currently available. Finally, the real scientific challenge is to think beyond proximate processes and their implications in the short term to ultimate processes and how human managed systems will adapt to change and sustained habitation. Biodiversity serves as the miner's canary indicating the current state of these vital processes necessary to maintain ecosystem health. Our best hope at this stage for developing the kinds of policies and actions needed to address the globally and regionally important environmental issues is support for cutting edge research in the field of ecosystems management using approaches pioneered through current programs, such as the NSF's biocomplexity studies program.

1. Science Themes and Research Needs

The workshop identified several research areas pertaining to the environment as important in the contexts of increasing scientific understanding of important regional and global environmental change phenomena and conservation issues, meeting important societal needs of the SSA region, and of mutual scientific interest to the U.S. and SSA. We discuss these scientific issues and research priorities below. There is considerable overlap among these research areas and, as discussed above we wish to emphasize the critical need for multi-disciplinary research integrating the biological, physical and social sciences and engineering. For the purpose of this report, we have organized the key research areas and themes as follows: a) Ecology (including issues of biodiversity, ecosystem functioning, land-use and land cover change, and human livelihoods), b) Water issues and water resources, c) Climate (including atmospheric sciences, climate modeling, and atmosphere-biosphere interactions), and d) Social Sciences (including linkages between socio-economics and ecology – socio-economic drivers of environmental change, effects of human activities on the environment and effects of environmental change on human communities).

a. Ecology: (Ecosystem Functioning, Biodiversity, and Land Use)

Key Scientific Issues and SSA Ecological Research Needs:

Biodiversity dynamics and conservation: This includes inventory of biological components, patterns of rare/threatened species and invasive species, and population dynamics and management of keystone species. Much basic work on inventory, geographic distributions, assessment, and monitoring of temporal changes in micro- and macro-flora (and vegetation maps), and micro-, meso-, and mega-fauna in SSA is needed. Wildlife populations and distributions are not adequately characterized. Foundational research assessing biodiversity dynamics (loss of biodiversity, invasion of exotic species) and links between biodiversity and ecosystem functioning is needed. SSA provides unique and diverse opportunities to study these linkages at multiple levels, from top predators, to diverse herbivore assemblages, to soil organisms. The SSA region also provides excellent research opportunities directed toward greater understanding of the connections between geomorphology and patterns of biodiversity distribution. While there are governmental or para-governmental Departments of Wildlife, Wildlife Services, and Departments of the Environment, these organizations are very limited in their abilities to provide adequate information about status and trends of biodiversity.

Ecology of Animal and Human Disease: Human and animal diseases are important issues in Africa. For example, AIDS has many ecological ramifications through altering human population sizes and age/sex structures and through losses of people who have indigenous natural resource management knowledge and who can transfer that knowledge to the next generation. Animal diseases are important in both wildlife and livestock populations. Diseases are spread between domestic animals and wildlife, increasingly so as human and domestic animal populations expand and come into contact with wildlife. Wildlife populations can be negatively affected by diseases carried by domestic animals and vice versa .

Biotic Invasion: Invasive exotic species are an increasing threat in Africa, as elsewhere in the world. Increased connectivity through international transport of humans and cargo is likely a primary contributor. Invasive species are appearing in some of the most remote locations of Africa, including protected areas. More must be known about the potential consequences, methods of reducing the threat, and ways of mitigating the threat where it cannot be reduced. Invasions of exotic species in SSA provide grand experiments to study fundamental aspects and attributes of successful invaders and invasible communities.

Ecosystem responses to anthropogenic environmental change: Human populations continue to expand, coming into increasing conflicts with the functioning and biodiversity of natural ecosystems. Ecological research will not decrease human population growth, but it can identify the ecological consequences, and it can be used to find ecologically benign development pathways. Much of the research along these lines is now cast in terms of Land Use and Land Cover Change (LULCC). These changes need to be quantified and predicted, but basic ecological/ecosystem research needs to be carried out to determine how land use change alters biodiversity and ecosystem structure, function, and services. This understanding will form the basis of any predictive capacity. Urbanization is rapid and represents a key LULCC change throughout the SSA region, and greatly increased research directed toward understanding and predicting the consequences of urbanization for ecosystem function and biodiversity is needed (see below).

LULCC research can provide very relevant information to scientists, land managers, and policy makers. Sharing research results outside of the scientific community, however, is usually inadequate. Difficulties include the lack of a common "language" or medium among groups to communicate the results, and presentations of scientific findings are not typically geared towards decision-making. Land managers may expect more or different types of information than scientists can actually provide. LULCC scientists in Africa need to make more of an effort to share their research findings with decision makers to assist in the policy making process. Another issue of concern is the danger of interpreting data collected remotely without sufficient ground information. A large group of international scientists are conducting LULCC "pattern to process" analyses without sufficient knowledge or understanding of the reality based on the ground truth, assuming that they can "see" socioeconomic and ecological processes remotely. For example, agent-based modelers attempting to explain LULCC patterns without the need for ground observations. Socioeconomic drivers, however, tend to be site-specific, which makes generalizing or scaling-up from a few points difficult. However, field work and ground truthing in Africa is particularly time consuming and expensive. The development of a common theoretical perspective to shape analyses can also help address this problem. From the ecological perspective, ecological information for selected test sites such as the LTER sites could be made available for downloading. Scaling-up methodological and conceptual advances need to be made. A critical issue for the LULCC community is thus, "How can we better scale-up?" LULCC scientists are poorly networked, and there is currently little progress in pulling together data and information from different scales and from different locations to conduct synthetic studies.

In addition to LULCC issues, other major environmental shifts such as climatic change will likely occur due to anthropogenic and natural causes. The responses of ecosystems and biodiversity to these changes are far from being understood or predictable. What will be the responses of ecosystems to global warming, elevated CO2, more frequent and more severe storms, more or less rainfall, more variability, and droughts? These potential stresses could enhance negative consequences of human population growth and land conversion. Together, they could lessen ecosystem resilience and increase ecological vulnerability. Moreover, the climate changes, which are already underway in many regions of the SSA region could exceed the thresholds of adjustment and permanently alter the cyclical recovery trends of the region's biocomplexity.

Environmental change and transformations in savannas: Savannas and grasslands represent the most extensive terrestrial ecosystems in SSA. They are ecosystems undergoing rapid transformation and are also the most important in supporting human livelihoods throughout most of the region. Significant research attention to dynamic processes involved in environmental transformations of savannas (altered grazing and fire regimes, bush encroachment, biotic invasions, and interdisciplinary ecological and socio-economic aspects) and their ecological and societal consequences is needed. Vegetation changes in response to fire, grazing, climate, and land use must be better understood. Vegetation dynamics in Africa are likely to be particularly complex due to non-linear responses and multiple interacting factors. Savanna dynamics and tree-grass interactions are fundamental, and in particular need of research. African savannas are well known for their dynamic responses to fire, herbivory, and climate. A considerable portion of Africa's wildlife and plant species diversity is harbored in savannas and other similarly dynamic African ecosystems.

Environmental change and transformations in central African tropical forests: Understanding of the ecology of central African forest ecosystems is also severely limited, particularly relative to tropical forest ecosystems on other continents. Furthermore, environmental change and transformations in these systems is occurring at a rapid pace. There is an urgent need for significant basic research on the biological, physical, and sociological components and processes in central African forests, and quantification and understanding of changes to forest ecosystems and their ecological and societal consequences.

b. Water: (Aquatic Systems, Hydrology, and Water Resources)

There is great need to understand link between biodiversity and ecosystem function and sustainability, particularly with respect to implications for hydrology and the quantity and quality of water resources. There are significant socio-political issues surrounding water resources in SSA, yet currently there is limited science behind water policy within countries of the region. Water issues also represent a key trans-boundary environmental issue in SSA, in that many major lakes border multiple countries and all major rivers run through many countries (e.g. water resources of the Okavango are affected by and affect Angola, Namibia and Botswana; pumping of Lake Victoria water for mines has international consequences). Areas in need of study include preservation of fresh-water ecosystem functioning, aquatic biodiversity, and impacts on human development. There are a host of scientific problems in both fresh- and salt-water bodies where more studies are needed. A greater integration of social and scientific issues related to water is also needed in SSA (e.g. NSF's CUAHSI initiative).

River Basins and Wetlands: Basic research addressing variability and predictability of river basin regimes, and implications for major climatic phenomena such as climate change, El Niño and other complex phenomena on watersheds is needed. The (chaotic) unpredictability of river basin regimes indicate that the science is still poorly understood, and this clearly requires interdisciplinary research to blend climate research, modeling, analysis of policy and socio-economic trends as well as long term intended purposes for the water. The science is still in its infancy as the translation even of such a major phenomenon as an El Niño into its implications for a watershed is notoriously complex, and less pronounced phenomena may even be more difficult. The science and data are both clearly inadequate.

An important issue related to water resources management concerns decreases in wetlands as they are developed for agriculture, and its consequences. Retention time in wetlands decreases, impairing their function in improving water quality, and in seasonal water storage, resulting in lower base flows and greater stress to surrounding agriculture during dry periods. There are conflicts between industrial and agricultural needs. There is often limited or uncorroborated science behind water policy. For example, in Jinja (Uganda) there is a policy that only 25% of wetlands can be converted to agriculture.

Integration of Environmental Engineering: Many regional environmental problems in SSA such as altered hydrological regimes, altered land use patterns, and mitigation of environmental impacts of mining, water and energy development and other activities have both ecological and engineering solutions. Engineering solutions applied at a smaller-scale can also address some issues of sustainable resource management and community development. Water distribution, quantity and quality, and other water issues are areas with high potential for developing engineering solutions to environmental problems, and strategies for more effective linkage between ecology, engineering, and other disciplines must be developed. Integration of engineering is a key need, particularly in the domain of hydrological engineering (e.g. distributing water resources to the people while conserving and sustainably managing aquatic and terrestrial ecosystems, water and sewage treatment plants, resolving conflicting demands of industrial and agricultural water needs). Environmental engineering within the U.S. now rarely engages the design of sewage treatment or water processing facilities since such plants are already established and students only do pro forma modeling work while actual design construction and implementation are needed all over Africa. The reality of water needs and issues in SSA can foster cutting edge science and engineering, as U.S. designs are based on either expensive or tried-and-true technology, while cost constraints and regulatory freedom would allow much more innovative designs to be developed in most SSA countries. In some countries water treatment plants are excellent, but there are greater problems with sewage treatment plants (e.g. in Uganda, where discharge goes into Lake Victoria which is also the source for drinking water. This causes a gradual, but continuous increase in treatment costs for producing potable water). There are several other water issues within the region with environmental engineering applications (e.g. desalinization, energy sources to access water, Cape Verde uses, diesel to power pumping for agriculture).

Interactions between U.S. and SSA scientists in the domain of hydrological engineering seem to be few. Privatization

of water, getting water to people, is a major concern in South Africa, Namibia and Botswana. In Tanzania there have been some successes. Nevertheless, a new illegal enterprise, tapping into water systems both for use and resale has proliferated as the price of water increases. Illegal tapping into water supplies adversely affects pressure and the profitability of privatization so there will be significant economic consequences that may even affect the viability of the firms in the near future. Tanzania is currently doing studies on pricing sewage and potable water. In Tanzania, water and sewer authorities have been merged so that the responsibility is now in one institution, so that sewage based pollution and provision of potable water can now be more readily seen to be in conflict and solutions can be more easily reached.

Water and Human Health: Water and human health is a key issue throughout the region, and there is great potential for research on health issues connected to water both in urban and rural areas. Dengue fever is carried by a mosquito that requires clean water to reproduce, and so it thrives in urban areas with a piped water supply or plentiful containers that catch rainwater. Water and health currently comprise the largest part of the Botswana budget. The new field of emerging contaminants focuses on water contaminants coming from industry, mining or human activities that have major health implications both in urban and rural areas. In SSA these emerging contaminants may in fact be better seen as both recurring and fully emerged contaminants. The scientific study of the socio-cultural dynamics of health and disease (as opposed to research focused on clinical or purely epidemiological processes) is an area in which significant advances can be made by the NSF joining forces with NIH or other agencies (c.f. USGS now has developed what it refers to as a medical geology program).

Land-water-geological interface processes: A greater understanding of the effects of these processes on carbon, nutrient, water cycling, and the trade-off between recharge rate, groundwater salinity, and water table elevation is needed. As recharge increases two competing factors may emerge and affect the hydrology of the discharge region: 1) The groundwater residence time could decrease which can lead to a decreased concentration of dissolved solids in the groundwater; and 2) the water table elevation in the discharge region may also increase (i.e., create a shallower water table). Under drought conditions the groundwater becomes more saline, exacerbating plant water stress and further reducing vegetation productivity. With increased rainfall, the water table tends to rise but may become more dilute. There may be some recharge rates that could cause both elevated water table and elevated salinity. Construction of water table height vs. salinity curves may be a good starting point to initiate this kind of research.

Monitoring and Data Collection: Data collection needs to be shaped by the scientific agenda. Data collection is woefully insufficient.Moreover, new standards around the world focus on watersheds as the unit of analysis and little data in SSA have been collected at this scale. Consequently, data collection is in urgent need of improvement. It is generally accepted that the East African and SADC countries have experienced decline in data quality since mid 1980s, due to lack of instrument spare parts, failure to renew or keep up monitoring instruments, and in other cases (Mozambique, Angola) civil war and the proliferation of land mines. There is a need for long term monitoring focusing both on water quality and quantity as well as water needs in as much as quantity and quality are intrinsically related to and dependent on changing human needs (industrial, mining or potable). This requires developing some clear and realistic scientific scenarios for at least the medium term (involving biology, metereology, and human dynamics) if any sense can be made of the data collected.

c. Climate (Climate Change, Atmosphere-Biosphere Interactions)

During the past decade major advances have been made in the prediction of the SSA regional climate (CLIVAR, 1999). Certain sectors are more ideal for collaboration because they are highly sensitive to climatic conditions, and are in a high state of preparedness to embrace the use of climate information. Life sciences (i.e., crop science, entomology, plant pathology) are potential areas of opportunity because they already involve a great deal of interdisciplinary and international aspects. Food security is a leading factor in regional political instability. Research might be needed to determine key climatic phenomena and their roles in relation to food security decision-making, key information inputs for such decisions, and the relative significance of climate information within current decision-making structures. In public health, Vector-borne viral diseases such as Dengue Fever, Malaria, Yellow Fever, Meningitis and West Nile Virus are the world's leading causes of death (Githeko et al, 2000; Kiwanuka-Tondo and Snyder, 2002). The World Health Organization considers Dengue Fever, spread by the Aedes Aegyti mosquitoes, to be the most important insect-borne viral disease, potentially affecting 2.5 billion people in over 100 countries, a large proportion of whom are in the SSA region. Current models focus on global relationships between climate and development, population dynamics, and potential distribution of mosquitoes. Predictive models are in their infancy and a broad range of potential improvements constitutes major collaboration opportunities in climate. The environment, and in particular, climate, affects water resources and pollution, energy production, wildlife proliferation, wildfire control, fisheries, livestock industry, forestation, soil conservation, and many other natural resources issues in specific regions of the world. Further collaborative research would yield effective management strategies for applications such as in agricultural drought and water resource management. Other forms of collaboration could benefit defense, homeland security (including agricultural and public health vulnerability assessment), economic development, tourism, or other sectors. Collaborative activities involving risk management and decision modeling have potential to make major impacts on social-economic development. In 2000, the U.S. Agency for International Development (USAID) responded to 74 natural disasters abroad, a significant percentage of which was in the SSA region. Emergencies involving civil conflict complicated by natural disasters account for an increasing share of

the USAID budget. Therefore, USAID is increasing its emphasis on applying preparedness and mitigation lessons learned to deal with these emergencies. Consequently, financial institutions have large stakes in the emerging science of environmental information. As component models mature, there is increased interest in coupling groundwater flow models, climate models, ecological models, and social-economic models, to predict how the wetlands around large lakes of the SSA region respond to climate change.

There is still limited understanding of the various physical processes associated with climate variability over SSA, and great uncertainties in assessments using currently available models (e.g. GCM). Such understanding is crucial to improve predictability and climate change impact assessments in different regions over the sub-continent. Increased research focus on this area will greatly enhance our understanding of causes, patterns, and effects of climate variability and climate change in SSA and other regions. Increased multi-disciplinary focus on the land-water-atmosphere interface and biosphere-atmosphere interactions is needed. Current aerosols and fossil impact models perform poorly due to inadequate knowledge of processes and interactions. For example, vegetation cover change associated with changing land use in turn impacts vegetation-atmosphere interactions. Another specific example, and link to environmental change issues is the growing interest in the impacts of acidic mine water on global warming processes. More research is needed on climate-biosphere (e.g. land use changes)-atmosphere (e.g. Ozone layer changes, aerosols) interactions. Current aerosols and fossil impact models perform poorly due to inadequate knowledge and understanding.

d. Social Sciences: Socio-bio-Physical Linkages

In SSA there are very strong linkages between ecological and socio-economic aspects of environmental issues. Human community sustainability is much more directly linked to ecosystem health and environmental conservation in SSA than in many other regions. Much of the ecological research within SSA is driven principally by societal needs for sustainable, science-based resource management. Sociological factors such as regional political instability; human population movements related to regional wars, refugees; communal grazing land policies etc. strongly influence the environment. Environmental degradation is often attributed to population pressures, but this assumption has been questioned and the direct and indirect drivers of many environmental change phenomena are poorly known. Populations are differentiated by categories such as age, gender, socio-economic status that influence their interactions with the environment and resource base. Furthermore, people have commitments to institutions such as family, clan, religious institutions, and political party that are real and durable and influence decision-making. This high population diversity presents unique challenges, and unique opportunities, for the integration of bio-physical and social sciences in understanding environmental and societal issues in SSA.

Urbanization is a key component and driver of environmental change in the SSA region. Multiple facets of urbanization (e.g. population size and spatial distribution, energy, fuel, food production and distribution, water, construction materials, waste disposal) need to be studied. In addition, the HIV-AIDS epidemic in SSA is currently the major regional social/human welfare issue (> 1/3 of the population affected in several countries) and significant attention and resources are currently being devoted to address this human tragedy. The HIV-AIDS epidemic currently represents a major barrier to capacity building within the region. Furthermore, as noted above, many environmental issues in SSA are clearly trans-boundary (e.g. water resource issues, consequences of large animal population migrations, invasive exotic species and biodiversity dynamics, effects of regional climate change). Effective regional networking and international collaboration is crucial for addressing these key regional issues.

The historical dimension is also crucial in the SSA environment, as the patterns, rates, and consequences of contemporary environmental changes can only be understood in reference to historical and pre-historical patterns. For example, understanding the significance of contemporary seasonal enhancement of tropical tropospheric ozone concentrations due to vegetation fires in SSA requires knowledge of history of human fire use and fire patterns on the continent. At the global scale, such information is critical for clarifying industrial vs. pre-industrial contributions to tropospheric ozone formation and predicting ecosystem responses. Fire in the SSA environment provides a good example illustrating the necessity to link ecology (fire x grazing x soil interactions regulating fuel loads), social sciences (cultural history and contemporary fire use patterns) and atmospheric sciences (emissions transport and climate) to address environmental problems affecting large regions or the entire biosphere (pan-tropical southern hemisphere tropospheric ozone).

The majority of Africa's people are engaged in land-based livelihoods (e.g. farming, pastoralism, ecotourism) so environmental issues are critical. Factors such as declining nutrient base, changes in water quantity, quality and reliability, land degradation and soil fertility declines, flora and fauna dynamics, and climate variability and change all pose significant threats to land-based livelihoods in SSA and in other developing regions of the globe. Land-based livelihood systems in SSA are located in, and influenced by, a political economy. Thus, numerous socio-political-economic factors operating at different scales have strong influences on the environment.

The workshop identified an issue concerning linkage of social sciences with LULCC research. The issue concerned a common, unstated assumption embedded in much LULCC research—that land use change is associated with negative ecological consequences. What is interpreted as environmental degradation may sometimes reflect simply a shift to different stable state ecosystem. Much LULCC research focuses on ecological processes and ignores the livelihood aspects of the identified land use change. If the land use change is associated with the needs of local people being met, then perhaps the change should not be interpreted as solely negative. There was thus a plea that the LULCC research community examines not only the socio-economic causes of land use change, but also the consequences on people and their

livelihoods. Indeed, a suggestion was made that we need an "L" for livelihoods in LULCC analyses to include livelihood aspects of both causes (drivers) and impacts of LUC. Livelihood aspects need to be integrated with LULCC driving forces and impact assessment analyses.

Many LULCC studies in SSA are related to wildlife, such as habitat and migration corridors, but they downplay the socio-economic aspects of the system. The question was posed, "How can we better include people as well as wildlife as part of the ecosystem in these analyses?" There has been a shift recently among scientists and conservationists towards including socio-economic analyses, but much still needs to be done. For example, a lot needs to be known about the role of wildlife living outside of parks for the economies of the local communities. More basic research on livelihood aspects of wildlife is needed. An extensive research effort in SSA is focused on primates. This research group involves several U.S. and international scientists, is multi-disciplinary (sociology/anthropology, ecology, animal behavior, etc.) and has important links to environmental issues in the SSA region, specifically the conservation of rare and endangered species. A critical issue concerns how these various issues are defined. Different stakeholder groups have different concerns/priorities; e.g. National Parks (biodiversity science, wildlife NGOs) and adjacent livelihood systems. Is the wildlife "community" willing to pay full opportunity costs for wildlife conservation? In addition to differential priorities, there are differential influences of wildlife conservationists versus local communities and livelihoods.

A clear consensus and primary conclusion of the workshop was a recognition of the crucial linkages among biological, physical, and socio-economic components of the environment in SSA and the critical need for multi-disciplinary research that effectively integrates the social sciences with the biological and physical sciences to address the above issues. Research on coupled human systems (socio-ecological systems) is central. Continued exploration of appropriate and effective theoretical frameworks for analyzing interactive societal and biophysical systems is also needed (e.g. political ecology, landscape ecology, panarchy). More programs are needed such as NSF's Biocomplexity in the Environment – Coupled Human-Natural Systems Program.

2. Operational Issues
a. Strengthening Collaboration

A common theme that ran through most of the group discussions concerned the need for real, substantive collaboration with SSA scientists and institutions, and for research to be conducted in a way that is suitable and appropriate with regard to the context of the country or countries involved. This obviously includes the need for intellectual exchange and data sharing, but also involves the equally important need to ensure adequate support for SSA participants in research endeavors (including training, financial and material support, etc.). U.S. scientists must be fully committed to respecting these principles and addressing these needs when working in the region, and there are significant potential consequences of failure to take them into consideration in designing and carrying out research in the region. Instances in which foreign scientists (including Americans) had encountered difficulties because they neglected to meet their collaborative obligations and/or failed to respect some important aspect of local laws, regulations, customs or values are all too common.

Unfortunately, the negative impacts of such incidences are not isolated; they can (and do) extend by association to other foreign researchers, again including Americans. This presents a challenge to U.S. scientists working in SSA who are committed to real collaboration, but it likewise represents an important strategic consideration for NSF. Inadequate support for our SSA research partners or a lack of sensitivity to local values may impede the ability of the U.S. Scientific Community as a whole to conduct research in the region or the continent of Africa as a whole. The importance of this consideration should not be underestimated. It is critically important that NSF be able to ensure that the research conducted by U.S. scientists will meet these basic criteria. Specifically, research projects must, where appropriate, be able to:

- Provide resources for counterpart participation
- Offer training and capacity building opportunities for host-country scientists, students and technical staff
- Demonstrate that the research, in addition to meeting the criteria of scientific excellence, also has relevance and/or applicability in the local/regional context

This is not a matter of simply being altruistic; helping friends and collaborators. It is a fundamental strategic consideration, and if we fail to address it, there could be very undesirable and far-reaching consequences for U.S. research in SSA.

Discussion concerning collaboration between U.S. and SSA scientists focused on the importance of involving SSA scientists in research being conducted on Africa. This can be a difficult issue in some areas. For example, in LULCC research, remote sensing data on Africa is available outside of Africa, and foreign scientists can attempt to interpret these data with little input of African scientists. NSF projects necessarily focus on supporting the activities of U.S. scientists, and African scientists who typically have little of their own support are often insufficiently involved in NSF funded research. There is also tension between U.S. and SSA collaborators arising from the NSF research focusing on basic science questions, while SSA scientists need to provide policy-relevant information to their wider community. Several problems were mentioned that are associated with this situation. These include a tendency of foreign researchers to not share their research findings with their African colleagues especially when the research findings are viewed to be of a sensitive nature and the U.S. scientist fears that he/she may actually lose his or her research clearance. Some U.S. researchers act as if their research topic is a secret and do not share their plans with the national research community or the local community, yet sharing what we are doing and why it is necessary would ensure support from the local authorities and others.

Many U.S. researchers do not seek true intellectual collaboration. Rather, they only involve SSA counterparts after the research is planned or underway, may hire local research assistants but not in-

volve relevant African scientists, or may limit their interaction to providing data to the host at the conclusion of the project. True collaborative research beneficial to Africa needs to fully engage local scientists as full partners in the research and should also involve both local scientists, and local communities, where appropriate, in driving the research questions and plan. Often, the technical specialists conducting research in Africa are not nationals of the host country since local expertise is not available.

NSF-funded science, in addition to being relevant to U.S. needs, can and should also be relevant, where possible, to the critical needs of the countries in which American scientists work. Specifically, research proposals for studies to be conducted in SSA (and indeed in all foreign countries) should address and embrace the following points:

- The need for training and capacity building
- Opportunities to establish/reinforce partnerships (national/international; among and between disciplines, etc.)
- Sustainability of the research beyond the period of requested NSF support through establishment of strong and balanced intellectual collaboration with SSA scientists
- Relevance of the research to the SSA host country's needs and priorities
- Replicability of the research methods, protocols and hypotheses elsewhere, especially in Africa

b. IT/Communications/Data Issues

African scientists experience difficulties communicating with each other and with colleagues abroad due to lack of computers, fast internet connectivity(narrow bandwidth), and appropriate information technology (IT) infrastructure. Prioritization policies regarding when individuals may access the Internet are needed so that sufficient bandwidth is available during working hours for research purposes, such as downloading large spatial data sets. The lack of Internet resources available to SSA institutions has resulted in SSA researchers being essentially invisible to the rest of the research community. U.S. scientists seeking African intellectual collaborators are likely to find few names from a web search because SSA university web sites often do not list faculty members, instead dedicating all web resources to providing information to the student population. Lack of broad bandwidth and human resources limit the ability of universities in SSA to generate and maintain detailed web sites and databases.

Another barrier to communication and collaboration between SSA environmental scientists is the physical isolation of many researchers due to the nature of their projects. Field stations may be remote and have no internet access whatsoever. People and data sets can be widely distributed in the environmental research realm, unlike in other disciplines where most research is conducted in a centralized laboratory setting.

In order for research enterprises to flourish at emerging international sites there must be enabling network infrastructure, well-trained local support, ready access to new technologies, and ongoing educational opportunities for local engineers and technologists. Infrastructure development is presently limited in SSA by a lack of well-trained personnel with UNIX or Linux system administration skills, web/hostmaster skills for local content development, managing routing infrastructure skills, and knowledge of network monitoring/NOC practices, real-time monitoring devices in the field that are connected to the Internet, network security, and Internet administrative procedures. Other human resource issues that need to be addressed are a lack of gender equity and female network engineers, staff retention, and school curricula to foster ICT skills early on. University/Research Institute's IT environment is constrained by limited campus infrastructure (electricity, generators, UPS devices), computing labs for researchers, lecturers, and students, language barriers hindering collaboration, content development in African languages, end user support/Help Desk for IT applications, software, and database management. Other issues hindering IT development in Africa are difficult regulatory environments/regulatory barriers, weak telecoms regulation, lack of local initiative/lack of empowerment, excessive dependence on external funding sources, lack of governmental support, sustainable funding models for opex , and lack of national and/or regional cooperation.

Opportunities for capacity building in IT in Africa are available. For example, environmental scientists and computer scientists from Taiwan and the United States (the North Temperate Lakes Long Term Ecological Research site in Wisconsin and the San Diego Supercomputer Center) are partners on a project to deploy wireless sensor networks in lakes in both countries to gather real-time data on lake metabolism. This study demonstrates the use of sensor networks in environmental research to gather data at remote sites, and African partners are solicited. IT educational opportunities are available, such as through the Partnership for Higher Education in Africa Internet Society (http://www.isoc.org/), which offers training in networking. The United States Telecommunications Training Institute (http://ustti.org) offers communications and IT infrastructures training throughout the developing world. Education/training programs are organized and/or funded by: Network Startup Resource Center, Internet Society, African Network Operators Group, International Development Research Center, WiderNet, World BankinfoDev, UNESCO, UNDP, NIH training of techs at malaria research sites, various open source software groups, INTIF/la francophonie, UNECA, MacArthur, Ford, Carnegie and Rockefeller Foundations. There are many ad-hoc efforts in specific disciplines. UNECA and its African Information Society Initiative have put in place, with the help of the Ford Foundation, the Academia Research Network. For details, see http://www.uneca.org/aisi/academia.htm

Improved infrastructure and increased available bandwidth would enable international researchers to document and publish more local, indigenous data. This includes demographic, climatic, environmental, health, and other data, which are useful to scientists. The improved communications resulting from these efforts will enhance Internet access to data for scientists and engineers on both ends of the connectivity spectrum; this ulti-

mately helps attract a wider variety of ideas, information, talent, and resources to solving problems. E-Learning opportunities will be greatly enhanced when bandwidth to Africa increases.

Environmental research questions require the synthesis of many types of data, such as wildlife movements, meteorology, geophysical, socio-economic, atmospheric, soils, plant and animal population dynamics, and genomics/systematics (biota inventory) data. For instance, a single study estimating net primary production in grasslands may utilize data from flux towers, remote sensing, meteorology, and plot-scale vegetation measurements. Such data are collected at many different locations, by many organizations and individuals (including agencies, university researchers, national labs, and field stations), but there is no data registry or clearinghouse of data available regionally in sub-Saharan Africa to foster data discovery. Data discovery and data access are both extremely limited in the absence of websites listing data resources, policies requiring that data be made available free of charge, and efforts to digitize the wealth of historical indigenous African data sets.

The African research community lacks a culture of data sharing. Some organizations are trying to change this. For instance, the U.S. State Department promotes "free and open data exchange" when involved with a project. NOAA is currently involved in a data rescue and digitization process. If a country wishes to participate in the project, it must agree to make the digital data freely available after the conversion. But they are not expected to share the original source of the data (microfiche, paper files, etc.) NOAA is exploring ways to help the sponsoring organization develop a mechanism to create value-added information for which they can charge a fee, i.e. for software to search the digitized data set so that the agency can provide very specific info (diagrams, maps, charts), and for which the recipient would be willing to pay. Programs such as RANET (http://www.ranetproject.net), supported by NOAA and many other organizations, make data available to rural areas in Africa. In order to improve day-to-day resource management, RANET increases the technical capacity of National Hydro-Meteorological Services to increase access to weather, climate, and related information in remote and resource poor populations.

Another proposal to improve data sharing was to promote free data exchange between and within official government agencies and the scientific community, while continuing to charge private firms (i.e. fruit plantations, engineering firms, commercial mining firms, etc.). The many actors that are involved in environmental research (government agencies, field scientists, funding agencies; international scientific organizations (such as the World Meteorological Organization (WMO)) can also put pressure on country governments to participate in free and open data exchange. Governments need to be convinced that that long-term free data exchange is ultimately a good thing.

c. Networks

Sub-Saharan Africa is already well networked;there are many networks of social scientists throughout the continent; there are also other non-scientific networks (NEPAD, SADC, ASARECA). But most of these networks are disciplinary based. The presently unanswered questions are: How can these networks be engaged? How do we link these networks together to create a few, useful interdisciplinary networks addressing important scientific and management questions? Currently, there are few interdisciplinary networks. One example is the LUCID network in East Africa, an interdisciplinary network focused on causes, processes and consequences of land-use and land cover change. Some geographic areas have more coverage than others. In particular, Central Africa needs more networking, but there is also a need to have pan-African networks that link the different regions of Africa. Communications facilities are also slow. There is need to connect and engage young SSA scientists beginning with those who have obtaibed BSc honors level of education and above, to give a sense of collegiality. Ways should be explored on how NSF could help with long-term funding , for supporting students and continuation of networks. Other needs include, a framework for organic growth and connection of informal networks and better flow of information between scientists and local communities, and scientists and policy makers

SSA scientists were encouraged to consider adopting some of the successful models of research partnerships developed between some South American and U.S. scientists. For, example, in Brazil, with enormous support from the government, the National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais, INPE) has developed mechanisms of involving specialists from different disciplines to participate in multi-disciplinary research in space and atmospheric sciences. This has made it easy and more feasible to develop joint research programs with other outside agencies or collaborators.

Barriers and Needs: Researchers currently have no forum for identifying and prioritizing research needs that require collaboration and that will attract NSF or other international funding. There is a need for a systematic approach, possibly involving workshops and meetings, guided by an overall strategic framework. This requires international support, both financially and intellectually. Programs such as SCOPE and IGBP are relevant models. Similar efforts focused on Africa or regions of Africa would be helpful.

NSF and U.S. funding agencies in general lack information and awareness about the importance of ecological issues and needs for research in Africa, and how these issues are relevant for citizens in the U.S. and across the globe. Simply put, ecological research in Africa needs to be highlighted to a greater degree. The lack of coordinated support from NSF and USAID for ecological research and environmentally sustainable development is a significant barrier. We realize that each agency is sovereign, and each has its own policies and agenda. USAID is under the Department of State while NSF is not. However, it is very disappointing that there cannot be more synergy to facilitate effectivescientific research and more scientifically based development. USAID aims to improve human well-being and environmental sustainability and NSF research can provide the scientific basis for doing that. Conversely, NSF desires broader impacts, but can only provide very limited funding to realize the full societal impact of its funded research. There is a need for a better working relationship between NSF and USAID. A system that financially and bureaucrati-

cally facilitates NSF research in Africa is needed. For example, USAID has developed agreements and protocols for easing import restrictions, allowing tax exemptions, and facilitating visa applications. If one is working for USAID these benefits are available. If one is working on an NSF-funded project, they are not.

There is a need for NSF to draw up a program to support collaborative research between the U.S. and SSA. An example of such a program is the one that has been developed between Europe and Africa, the EU Initiative For Africa. At present there is no similar program in the U.S., and therefore there is no initiative for moving forward.

Multidisciplinary databases are lacking. For example, there are few integrated sources of information on plants, animals, humans, and climate at given locations. This kind of database would greatly facilitate the multidisciplinary, integrated research necessary to solve important regional and global environmental problems. There is a need for accessible integrated databases comprised of spatial and non-spatial data for vegetation, soils, biodiversity, megafauna, and human activities.

d. Equipment and Infrastructure

There is a need for good infrastructure, which is a prerequisite for good science in SSA. The term infrastructure as used in the present context means facilities and instrumentation for carrying out ecological/ecosystem research. There are several key issues regarding how to share equipment from one African country with another. Ideally, researchers should develop mutual trust through collaboration and share equipment (e.g. science has no borders) but equipment is difficult to transfer and use across borders. There is a need to open borders among countries in common regional political alliances (e.g., SADC countries). In addition, the hurdles involved in obtaining research permits and import permits can be seriously limiting, as government procedures are often arduous and difficult to maneuver. Local institutions can assist in overcoming difficulties, including being able to temporarily import research equipment that would otherwise be blocked or delayed at the borders. Support for developing shared facilities is required, as well as mechanisms to transfer expensive equipment to African institutions when a project is completed.

e. Training Activities and Programs

One of the key issues identified was how international programs for U.S. students might be used to benefit SSA partners as well, and contribute to the needs of SSA countries. A second issue identified was the challenge of providing more opportunities for international experiences for U.S. students. Alternative models need to be explored to enhance the accessibility of programs providing international experience to U.S. students. Training programs need to be strengthened for multiple target groups including undergraduate and graduate students, technicians, and exchange of senior scientists. Consideration of training and capacity building need not (and should not) be limited to students, post-doctoral researchers and scientific colleagues. Activities designed to ensure the needed capacity among technical and support staff are, in many instances, equally important to the success of research endeavors, and must not be overlooked. Training at the technical level, and programs that provide opportunities for professional people to receive upgrade training are crucial as technology in many areas relevant to environmental sciences, monitoring, IM and IT are rapidly changing. Too often "training" is viewed as only "academic training", and while this is undeniably important, a broader consideration of training programs in relevant technologies is essential for sustained high quality research in SSA.

There are a number of problems and limitations regarding collaborative training programs that must be addressed. To be sustainable, there must be an appropriate fit between U.S. and SSA training programs i.e. the U.S. programs must not result in additional demands on African institutions. The differing time tables and academic calendars of U.S. and African institutions must be considered. Training programs in many SSA institutions are constrained by poor infrastructure and/or restricted expertise available. Care must be taken to fully budget the expenses of the host institution into the program and accommodate expedient payments. In many cases, NSF funding can be used very effectively by the hosting African institution to leverage additional funding from NGOs, African government organizations, and through public-private partnerships to cover African needs for equipment, other infrastructure, and personnel.

In addition, legal issues must be addressed. The fear of litigation by American research students related to health and safety liability issues is real among SSA institutions. In many exchange programs, there is a strong disparity in monetary compensation for U.S. students and their SSA student colleagues, causing serious problems with morale and hindering collaboration and professional relationships. There are similar monetary inequities in cost recoveries for operating scientific field research campaigns and/or field schools between hosting and receiving institutions.

Other specific issues and problems raised concerning training programs include:

- Most programs occur at an institutional/personal level and are not overseen or supported by a larger coordinating structure/program/vision: hence impacts may be not as large as they could be (in the case of development goals in SSA). Needs are often driven by the 'parochial' needs of individual institutions.

- There are general concerns with reciprocity of programs. The question of what benefits will the SSA host institution that accommodates USA students receive is real and must be addressed better (step I: better budgeting).

- Experiences between European and SSA institutions should be more closely investigated (e.g. In some collaborative programs with Swedish institutions, an SSA student trained in Sweden can be provided with facilities he/she requires when he/she returns to the home country).

- With the events of 9/11/2001 in the U.S., serious issues regarding international travel regulations and restric-

tions, visas, etc have arisen that stand to result in loss to the U.S. of a sizeable part of the international educational market.

- The way training is approached needs to be investigated. Different aims should be defined for:

  - the direct training of students (mostly undergraduate programs)

  - training linked to international research projects.

- There is a need for NSF to define a broader vision that is very specific about the capacity building needs in the U.S. (e.g. minority programs in S&T) and the SSA region, that can be addressed with exchange programs

- Programs in which complementary skills in student groups from the U.S. and Africa are combined are successful.

- More American post-docs/post-grads/sabbatical scientists should get involved in SSA academic institutions and research centers to make a significant difference to skills & training of Africans while abroad

  - e.g. Uni Venda (Historically Disadvantaged University): visiting researchers mix research with teaching. They get to know Africa and students learn.

  - e.g. Botswana's Okavango Research Centre would welcome graduate students and post-doctoral scientists to bring and gain experience, working in the unique and special environment of the Okavango Delta.

- There is a need to develop a scientific 'collaborative arena' that emphasizes a mutual relationship among equals, where SSA partners are trained, but also are trainers. Innovative solutions need to be developed from within Africa, including seeking opportunities for funding for research collaboration both ways, and involving other agencies that can enlarge the programmatic scope (e.g. Fullbright, START, Regional Center for Southern Africa).)

D. Recommendations

1. Science: Research Priorities and Key Questions and Issues

The workshop identified five important scientific issues and themes of regional and global importance and relevant to the environment and societal needs in sub-Saharan Africa. It is recommended that the NSF increase support for the following priority research areas and topics for collaborative U.S.-SSA research and training. Examples of specific research needs or recommendations under each area are indicated.

A. Atmospheric Processes, Climate Modeling, and Climate Change

- Studies that increase understanding of key processes influencing regional and global climate, climate variability, and the patterns and consequences of climate change

- Research addressing changing atmosphere-biosphere interactions in SSA and their role in climate change

- Projects and programs to rescue meteorological and geological data at risk of being lost over time.

- Research leading to a better mechanistic and predictive understanding of impacts of climate change on the ecology of disease and other aspects of human health

B. Biodiversity Dynamics

- Basic inventories, distributions, and dynamics of the biota of the region, including micro- and macro-flora and fauna.

- Research on biodiversity dynamics and conservation in SSA, including loss of biodiversity and invasion of exotic species.

- Research assessing relationships between biodiversity and ecosystem functioning, focusing on different levels from top predators to soil microbial communities

- Studies of the relationships between geomorphology and biodiversity distribution

C. Animal and Human Disease

- Research that addresses the causes, epidemiology, and consequences of animal and human disease in a multidisciplinary context (ecological and human consequences)

- Studies of the role of human-wildlife-livestock interactions as they pertain to human and animal disease

- Studies of the impact of zoonotic disease on human resources

D. Land-use and Land-cover Change (LULCC)

- Quantification of current LULCC patterns and prediction of future changes

- Studies addressing the implications of LULCC for biodiversity, ecosystem functioning, and human livelihoods

- Local, regional and global impacts of mineral resource extraction and processing

- Impacts of urbanization on human and natural ecosystems (see also below)

- Environmental change and transformations in savanna ecosystems

- Environmental change and transformation in central African forest ecosystems

- Research focusing on synthesis of LULCC studies, and analyses that scale-up from the local to regional level.

E. Water Resources

- Research addressing the variability, predictability, and ecosystem functioning of river basins and wetlands, focusing on complex system-based analysis

- Studies on the human implications of climate change for the availability of source water for humans

- Environmental engineering research aimed at improving regional water distribution, quality and quantity

- Research directed toward understanding the influence of freshwater ecosystem functioning on human development and preservation of freshwater systems

- Multi-disciplinary research addressing trans-boundary water issues of lake and river basin systems (see also below)

- Long-term monitoring of water quality and quantity within the SSA region based on watershed units of analysis

- Research addressing water and human health, including emerging contaminants, water based infectious diseases, and the socio-cultural dynamics of health and disease

2. Training Activities

- Exchange scholar programs: Increased graduate training opportunities for SSA students in the U.S. are recommended. NSF should consider increasing funding for the exchange scholar programs in environmental sciences for young SSA scientists so that they can spend some time receiving training in U.S. institutions and interacting with U.S. scientists. It is recognized that more meaningful collaborations are often borne out of such exchange scholar programs.

- Support proposals whose activities and broader impacts include significant and sustainable training opportunities for the following target groups: undergraduate and graduate students, technical-level training, technical professionals, and collaborative training including reciprocal exchange of experiences of senior scientists; and training benefits to the host country, and opportunities for new partnerships. Build partnerships between U.S. and African students by incorporating peer mentoring as an integral part of student exchange programs.

- Support training programs that bring experts and students to Africa to train students in Africa: A specific recommendation is to develop a "Teach in Africa" program to provide opportunities for U.S. graduate students or post-docs to assist in teaching programs in African universities, providing both valuable teaching and training experience for U.S. students and direct benefit to African institutions. Support U.S. researchers and post-graduate students to develop curricula to assist African institutions in transferring information to rural communities and to provide training.

- Distance learning: Make courses at U.S. institutions available to SSA students/scholars through distance learning and web-based technology (e.g. internet courses and video-conferencing). Support the development of training modules for young SSA scientists in relevant disciplines (geosciences, atmospheric sciences, ecology, etc.) via these technologies.

- Help with the process of coordinating training programs, and building strategic alliances between the many agencies and organizations funding training programs in IT and network engineering. Encourage more regional training and information sharing programs, i.e. someone from Ghana or Nigeria with expertise in a particular area can help train a colleague in East Africa and vice versa.

- Outreach training: Support outreach training programs in disciplines relevant to the environment in SSA. Training in LULCC analyses is important to have more SSA trained specialists in this field to address regional LULCC issues. LULCC technologies are rapidly changing so mid-career training is important. The Long Term Ecological Research (LTER) network provides outreach training in data management, metadata standards, databases, and how to build a web site and make data sets available. Other organizations, such as National Libraries of Medicine/National Institutes of Health, also offer bioinformatics training which includes information management and IT instruction. Numerous other ad hoc training activities are occurring throughout the continent. These opportunities should be used as models or platforms for expanding such capability to the entire SSA region.

- Establish additional African, for-profit field schools for U.S. students in several areas of SSA, following the model of the University of Dar es Salaam's (Tanzania) 8-week summer field school (a program for U.S. and east African students administered by the African institution). Similar programs are also run in Kenya and Uganda.

- Create a directory of training opportunities in SSA (modeled after the OBFS directory of summer field courses as U.S. field stations), and a directory of programs at American Institutions for access by Africans

3. Enhancing Multidisciplinary Approaches: Integration of Biological, Physical, and Social Sciences

A consensus of the workshop participants was the general recommendation that increased support should be given to research programs on the environment in SSA that strongly integrate social science and the bio-physical sciences. Studies that seek to understand linkages between biodiversity, ecosystem function and sustainability, and human societies should be strongly encouraged. The workshop also recommended additional efforts in modeling and a strengthening of modeling capability in several of the areas outlined below (e.g. regional climate change, LULCC, social sciences). Furthermore, increased support is recommended for research that seeks to not only understand patterns, processes, and provide mechanistic explanations of environmental phenomena, but also contributes to developing solutions to regional SSA and global environmental problems including key regional needs for sustainable land-based human livelihoods.

- The workshop panels strongly recommended continued focus on the linkage of human and ecological processes, and expanded support for programs such as the Biocomplexity Program and Coupled Human-Natural Systems. This link is particularly crucial in SSA where so much of the population is directly dependant on the land and where the environment is rapidly changing

- High priority should be given to research on the environment in SSA that demonstrates a strong integration of biogeophysical and social/behavioral/economic approaches

- Support proposals whose broader implications include demonstrating direct contribution to resolving societal issues related to the environment in SSA and those fully engaging SSA collaborators and other SSA stakeholders in the research process.

- Support multi-disciplinary research focused on the various dimensions of urbanization, including population size and distribution, energy, fuel, food production, water, waste disposal, and changes in political landscapes

- Strongly support multidisciplinary research on the multitude of transboundary environmental issues in the SSA region, incorporating ecology, climatology, hydrology, biodiversity, engineering, and human dimensions such as socio-political issues of competing stakeholders

- Provide funding to support the formation of new interdisciplinary networks (e.g. support the formation of a network around each of the following five topics: water, land use/land cover change, climate change and atmosphere-biosphere interactions, biodiversity/conservation, geology/evolution, each emphasizing integration of the human dimension and social sciences

- Support research aimed at developing effective theoretical/conceptual frameworks for analyzing interactive societal and biophysical systems (e.g. political ecology, landscape ecology, panarchy)

4. OPERATIONAL ISSUES

In addition to discussion of interdisciplinary scientific approaches and key research needs and priorities, the workshop proposed a number of mechanisms and recommendations for fostering stronger and more balanced intellectual collaboration between U.S. and SSA scientists and more effective communication and networking. Below we outline a number of specific recommended mechanisms including, development of appropriate networks; information management systems and other cyber-infrastructure; specific program and agency linkages and partnerships; research/personnel directories and bibliographies; enhanced physical infrastructure; capacity building; and suggested mechanisms for funding.

a. IT and Data

- Foster Data Sharing: We recommend that NSF develop a policy concerning data sharing. NSF projects should leave research data in the host country. A policy could be established such as that adopted by the LTER network, where data are made available to the public after a certain length of time or after initial publishing. There could also be different levels of data access. Programs exist that promote data sharing. For instance, the U.S. State Department promotes "free and open data exchange" when they are involved in projects. Further, NOAA is currently involved in a data rescue and digitization process. If a country wishess to participate in the project, they must agree to make the digital data freely available after the conversion. But they are not expected to share the original copies of the data (microfiche, paper files, etc.) NOAA is exploring ways to help the sponsoring organization develop a mechanism to create value-added information for which they can charge a fee, i.e. for software to search the digitized data set so that the agency can provide very specific info (diagrams, maps, charts), and for which the recipient would be willing to pay. Develop or fund programs to show how freely sharing available data can improve collaboration, i.e. the open sharing of meteorological or geophysical data to improve climate monitoring and prediction.

- Support data rescue: Support data rescue efforts to help retrieve data scattered in many different institutions that are not yet digitally available, and promote access to these indigenous African data. Fund projects and programs aimed specifically to help rescue environmental data (e.g. geological and meteorological data currently archived in hard copies and at the risk of being lost). This was emphasized as a priority project for funding since most of the in situ data has been diminishing with time over many countries in SSA.

- Support the creation of online data registries and clearinghouses for archiving data. There is a particular need to include information on social sciences, and for projects and data from francophone and lusiphone countries.

- NSF could fund a science server in each country that operated continuously, so that email communications are more reliable.

- Develop test sites with available ecological information available for downloading to assist with ground-truthing. The ILTER sites could be such sites targeted for support.

- Increase support to enlarge the existing Africa Network Operators' Group (AFNOG programs).

- Where they exist, help strengthen government-sponsored National Information Centers.

- Sponsor a follow-on meeting in SSA of U.S. and SSA network specialists and scientists for the purpose of improving network infrastructure and technical support services in specific geographic areas of interest to the scientific community.

- Support information management policies that require standardization of data and metadata formats, QA/QC, proper data archival, and data sharing. (IM policies of the U.S. LTER network may be a good model)

b. Infrastructure

- NSF should support the expansion of digital libraries. NSF could also approach relevant professional societies and publishers to share journals online at low or no cost with collaborators in SSA. All publications that are supported through NSF funding should be made available on-line, with hard copies sent to libraries of the SSA host institutions.

c. Strengthening

U.S.- SSA Collaboration and Networking

- Database/Directory of SSA Research and Training: There is a need to create a list of SSA universities, departments, scientists and projects being conducted, including lists/maps of physical facilities, environmental monitoring facilities and their locations, and an inventory of research equipment in SSA and its location. The universities, departments and staff are listed on the web, but information about their research areas, programs, etc. is very limited. We recommend that NSF support the development and regular maintenance of such a database. This could be co-funded by NSF and an agency or institution in SSA. One model that was proposed is to support a SSA student/scientist at an SSA organization to develop this database, with a good theoretical basis, perhaps under the 'digitial divide' and the way people overcome barriers. Such a regional directory/database could be based at the African Academy of Sciences, based in Nairobi, linked to International Foundation for Science (IFS) and the Third World Academy of Science (www.aasciences.org). Alternatively, the directory could be based at the southern African ILTER network (ELTOSA).

- Inter-agency Partnerships: To an extent possible, NSF should formally partner with other funding agencies to increase support for training and capacity building in SSA universities and research institutions with a view to creating a critical mass of scientists based in Africa. Thus, the NSF and other funding agencies should encourage support for collaborative research involving scientists based in existing regional institutions in order to strengthen the research tenets already built-in at such institutions. Furthermore, established formal programs for co-funding of collaborative U.S.-SSA research projects by the NSF and other agencies whose missions allow support for SSA scientists based in local institutions would help to create more mutually sustainable partnerships between U.S. and SSA scientists. It is strongly recommended that the NSF seek formal partnership with other agencies and foundations (both U.S. and international) that have strong and complementary commitments to African science and development (e.g. USAID, Fulbright, Kellogg Foundation, Ford Foundation, Rockefeller Foundation). NSF could also encourage potential partner foundations to structure funding to complement NSF funding. At the international level, possible formal partnerships could be developed between NSF and development agencies (World Bank, IMF, GTZ, NORAD, etc.). Development agencies are transforming the African landscape through multimillion-dollar programs, so they have a central role in determining outcomes of human interactions with their environments. Development efforts should be informed by good scientific research. Conversely, science-funding agencies such as NSF could have broader impacts by leveraging development funds. Such partnerships are strongly recommended, given the strong linkages between sustainable ecosystem function, biodiversity, human livelihoods, and development in the region. Along these lines, NSF should establish a relationship with USAID involving formalized agreements for co-funding. NSF can work with USAID for in-country spending. Efforts should be made to have more effective donor partitioning so as to reduce overlap and duplication. For example, GTZ may be duplicating an effort by USAID in the same area, while it would be more effective for GTZ and USAID to agree to work in different areas or on different, but synergistic issues. NSF and other science agencies should work with development agencies in institution building for long-term sustainability.

- NSF SSA Research Program: Develop a strong sub-Saharan Africa program within NSF/OISE. Establish a separate NSF funding program within OISE specifically to support collaborative environmental research and training between the U.S. and SSA. The EU initiative for Africa, and the CRSP of USAID are examples of how this could be carried out.

- Increase awareness among NSF program officers, panelists, and reviewers about African ecological research. NSF must recognize that science in SSA is often at a more basic level because basic groundwork has not been laid. For example, much basic descriptive work such as biotic inventories, etc. needs to be done as a foundation for research addressing key environmental questions. This does not mean that the quality standards for science in SSA should be lower, but rather recognizes that the state of the science in the region lags behind, and that in many cases, foundational descriptive research efforts such as bio-inventory work is indeed cutting edge research in the region. There is some catching up to do. There are also important differences between working in SSA and the U.S. in terms of what can be accomplished in a given amount of time or with a given amount of funding. Costs of doing research can be greater in SSA in some ways, and they can be lower in others. Progress can often be expected to be slower due to logistics, bureaucratic hurdles, and social complexities.

- Proposal requirements: Require that all proposals for work in SSA clearly demonstrate strong and balanced intellectual collaboration, and document how SSA collaborators will be fully engaged as partners in several or all stages of the research enterprise. Review of proposals based on broader impacts should give considerable weight to the potential benefits to host country, sustainability, collaborative training activities, and opportunities for development of new collaborations and partnerships. This will help ensure that collaborative research will be designed with the input of both partners from the inception of research ideas and submission of the proposal for funding.

- Seed grants and/or supplements: Enhancement and augmentation of existing collaborative research through supplemental funding or extension of project periods specifically for activities that build and enhance sustainable intellectual collaboration. Alternatively, establish a program of seed grants to plan and establish new collaborative partnerships at the institutional level (similar to the goal of the NSF's Research Coordination Networks [RCN] program, but for more specific goals and activities, and at the individual and institutional level, or expansion of current Planning Activities grants available through OISE).

- Establish networks of ecological/ecosystem scientists to facilitate idea sharing, and regional/network-level research projects and assessments. Enhanced networking through US-SSA scientific meetings. Expansion of NSF-RCN support. This needs to be expanded to include support to non-U.S. institutions and workshops. All networking needs to include not only African universities but other national and international research institutions. Specifically, supported conferences on key issues or themes (e.g. LULCC in SSA) to review what studies have already been conducted, what data has already been pulled together, and what needs attention. Such conferences could initiate appropriate networks to facilitate communication.

- Develop a system that facilitates NSF-funded research programs through tax/duty exemptions, facilitated visa applications, and other measures to save costs and reduce bureaucratic hurdles. USAID operations are facilitated in this way, often with MOU's between USAID and participating countries. Discussions and negotiations are required to reach agreements on MOU's.

- Establish an African Center for Environmental Analysis and Synthesis (ACEAS) that would help to bring scientists from multiple disciplines together from Eastern, Southern, and Western Africa. The NSF-supported National Center for Ecological Analysis and Synthesis (NCEAS) is an excellent model for such a center. The ACEAS would have a more multidisciplinary mission, and would also have a focus on collaborations between U.S. and African scientists, with support from NSF.

d. African Support and Capacity Building

- In addition to data sharing, establish policies to promote sharing of research results and applications with African communities and policy makers (e.g. encourage publishing in regional journals; require submission of copies of results, reports, and publications to host country and institutions). Identify and promote successful models for transferring scientific data and literature to SSA researchers. We need to share research results with communities and policy makers, and involve SSA scientists and communities from the early planning stages of research projects. A funding mechanism is needed, perhaps as part of every grant, for students and scientists to return the information to SSA science institutions, local communities, and policy makers (Some countries require this to receive research permission, but others do not). Provisions for this could be a required component of NSF grant proposals.

- NSF-Africa Regional Alliances: NSF, as well as U.S. institutions should formally and fully engage with regional networks such as ICPAC, SADC and NEPAD. Collaborative research programs, networks, and science centers could be supported by regional bodies such as ICPAC(IGAD Climate Prediction and Applications Center, http://www.icpac.net), SADC (Southern African Development Community; www.sadc.int), NEPAD (New Programme for African Development; www.nepad.org), or OAU, with added support from the NSF for working groups and U.S. participation. Regional alliances of bodies such as SADC, EAC, or African Academy of Sciences could be formed to promote co-sharing of research costs among themselves, and to increase chances of NSF co-funding. SADC and NEPAD can enhance and endorse projects that align with their already well-established goals and strategies. Although these bodies currently don't fund research, they have high value as framework. NEPAD is moving toward becoming a funding agency in Africa (currently funded by RSA, Nigeria & Senegal) and could potentially formally partner with the NSF to fund multidisciplinary collaborative research in SSA. The Regional Centre of Southern Africa (RCSA) also works throughout SADC.

- The African Academy of Sciences and U.S. National Academy of Sciences could commission a joint "SSA International Science Committee" to identify scientifically based research priorities, along the lines of the NAS Grand Challenges in Environmental Biology committee and report. An assessment should be carried out to determine what exists in the way of capacity, networks, information, and infrastructure. This assessment, together with the research needs assessment, would form the basis of a strategy for optimal allocation of resources.

- Fund projects aimed at improving Internet connectivity in SSA countries and training local network engineers and system administrators who build and support the networks.

- Support data rescue efforts to help retrieve data scattered in many different institutions that are not yet digitally available and promote access to these indigenous African data.

- Purchase of multi-user equipment should be incorporated into projects to improve the capacity of SSA institutions when a project is completed. Equipment could remain in host country as long-term loans. Leveraging should also be applied to obtain sufficient funds for expensive equipment

- Adopt a model where control/initiatives initially come from out-country projects and resources, then gradual transfer of responsibility to in-country institutions.

V. Appendices

Appendix A: List of Participants

John Adedoyin
Department of Physics
University of Botswana
Private Bag UB0022
Gaborone, Botswana
Phone: (267) 355-2126
Fax: (267) 390-7252
Email: adedoyin@mopipi.ub.bw

Michael Adewumi
Director, Alliance for Earth Sciences, Engineering and Development in Africa (AESEDA)
222 Walker Building
University Park, PA 16802
Phone: (814) 863-7598
Email: m2a@psu.edu

Alfonso Alonso
Director for Conservation and Development
Smithsonian Institution/MAB Program
P.O. Box 37012
Q-3123 MRC 705
Washington, DC 20013-7012
Phone: (202) 633-4780
Fax: (202) 786-2557
Email: aalonso@isi.edu

Jean Altmann
Department of Ecology & Evolutionary Biology
Princeton University
235 Guyot Hall
Princeton, NJ 08544-1003
Phone: (609) 258-6820
Fax: (609) 258-7892
Email: altj@Princeton.edu

Richard Anyah
North Carolina State University
Marine, Earth and Atmospheric Sciences
P.O. Box 8208
Raleigh, NC 27695
Phone: (919) 513-0243
Fax: (919) 515-7802
Email: Richard_anyah@ncsu.edu

Estella Atekwana
Department of Geological Sciences & Engineering
School of Materials, Energy & Earth Resources
University of Missouri-Rolla
Rolla, MO 65409
Phone: (573) 341-6104
Fax: (573) 341-6935
Email: atekwana@umr.edu

Tom Bassett
Department of Geography
University of Illinois, Urbana-Champaign
607 S. Matthews Avenue, #220
Urbana, IL 61801
Phone: (217) 244-3200
Fax: (217) 244-1785
Email: bassett@uiuc.edu

Maria Beebe
WSU Center to Bridge the Digital Divide
120 N. Stevens St., Suite 200
Spokane, WA 99201
Phone: (509) 358-7947
Email: beebem@wsu.edu

Jacinta Beehner
Postdoctoral Researcher
Department of Ecology and Evolutionary Biology
Princeton University
Princeton, NJ 08544
Phone: (215) 868-2003
Email: jbeehner@princeton.edu

Mulugeta Bekele
Department of Physics
Addis Ababa University
P.O. Box 1176
Addis Ababa, Ethiopia
Email: mbekele@phys.aau.edu.at

Solomon Bililign
Professor
Department of Physics
North Carolina A&T State University
Greensboro, NC 27411
Phone: (336) 334-7733
Fax: (336) 334-7423
Email: bililign @ncat.edu

Badege Bishaw
Oregon State University
Corvallis, OR 97331
Phone: (541) 737-1000
Email: badege.bishaw@orgeonstate.edu

Jared Bowden
Marine, Earth and Atmospheric Sciences
North Carolina State University
P.O. Box 8208
Raleigh, NC 27695-8208
Fax: (919) 515-7802
Email: jhbowden@ncsu.edu

David Campbell
Associate Dean for Research and Graduate Studies
Michigan State University
203 Berkey Hall
East Lansing, MI 48823
Phone: (517) 432-3436
Fax: (517) 355-1912
Email: djc@msu.edu

Bill Chang
Senior Program Manager
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Email: wychang@nsf.gov

Mike Coughenour
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, CO 80523
Phone: (970) 491-5572
Email: mikec@nrel.colostate.edu

Marilyn Crane
Association Liaison Office for University Cooperation in Development
1307 New York, Ave., Suite 500
Washington, DC 20005-4701
Phone: (202) 478-4700
Fax: (202) 478-4715
Email: CraneM@aascu.org

Richard Crouthamel
NOAA
14th Street & Constitution Avenue, NW
Washington, DC 20230
Phone: (301) 713-0645
Email: Richard.Crouthamel@noaa.gov

Harmony Dalgleish
Kansas State University
Division of Biology
Email: hjdal@ksu.edu

Francisco Dallmeier
Director, SI/MAB Program
Smithsonian Institution
National Zoological Park
Monitoring and Assessment
of Biodiversity Program
P.O. Box 37012
Washington, DC 20013-7012
Phone: (202) 633-4782
Fax: (202) 786-2557
Email: fdallmeier@ic.si.edu

Adriaan deGraaf
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Email: adegraaf@nsf.gov

Richard Dick
Professor of Soil Microbial Ecology
Ohio State University
2021 Coffey Road
Columbus, OH 43210-10855
Phone: (614) 247-7605
Fax: (614) 292-7432
Email: Richard.Dick@oregonstate.edu

Paul Dirks
School of Geosciences
University of the Witwatersrand
G110 (Geosciences Bldg.)
Pbag 3, Wits2050
Johannesburg, South Africa
Phone: 27-11-7176547
Fax: 27-11-7176579
Email: dirksp@geosciences.wits.ac.za

Fernando Echavarria
U.S. Department of State
Space & Advanced Technology Staff
OES/SAT, SA-23, Suite #410
1990 K Street, NW
Washington, DC 20520
Phone: (202) 663-2395
Fax: (202) 663-2402
Email: EchavarriaFR@state.gov

Debra Egan
Fulbright Program CIES/IIE
Council for International
Exchange of Scholars
Institute of International Education
Assistant Director (Africa/Western
Hemisphere)
3007 Tilden Street NW Suite 5L
Washington DC 20008-3009
Phone: (202) 686-6230
Email: degan@cies.iie.org

Doug Gatchell
Program Director
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Phone: 703-292-8962
Email: dgatchell@nsf.gov

Amadou Gaye
Laboratoire de Physique de l'Atmosphere
Simeon Fongang
Ecole Superieure Polytechnique
UCAD
BP 5085 Dakar-Fann SENEGAL
Phone & Fax: (221) 825 93 64
Email: atgaye@ucad.sn

Nick Georgiadis
Mpala Research Centre
Director
P.O. Box 555, Nanyuki
Phone: 254 (0) 62 32752
Fax: 254 (0) 62 32750
Email: njg@mpala.org

Wayne Getz
Department Environmental Science
Policy & Management
University of California at Berkeley
201 Wellman Hall
Berkeley, CA 94720-3112
Email: getz@nature.berkeley.edu

Abraham (Abe) Goldman
Department of Geography
University of Florida
P.O. Box 117315
Gainesville, FL 32611-7315
Phone: (352) 392-0494
Fax: (352) 392-8855
Email: agoldmn@geog.ufl.edu

Steve Goldstein
Email: steve.goldstein@cox.net

Kwabena Gyimah-Brempong
Department of Economics
University of South Florida
Tampa, FL 33620
Phone: (813) 974-6520
Fax: (813) 974-6510
Email: KGYIMAH@coba.usf.edu

Steve Hamburg
Brown University
Associate Professor of Environmental
Studies Department: Center for Environ-
mental Studies
Box 1943,
Providence, RI 02912-1943
Phone: (401) 863-1261
Email: Steven_Hamburg@Brown.edu

Niall Hanan
Natural Resource Ecology Laboratory
(NREL)
Colorado State University
Fort Collins, CO 80523
Phone: (970) 491-0240
Fax: (970) 491-1965
Email: niall@nrel.colostate.edu

Craig Harris
Department of Sociology
Michigan State University
429A Berkey Hall
East Lansing, MI 48824-1111
Phone: (517) 355-5048
Email: Craig.Harris@ssc.msu.edu

David Hartnett
Professor
Division of Biology
Kansas State University
Manhattan, KS 66506-4901
Phone: (785) 532-5925
Email: dchart@ksu.edu

Joel Hartter
3141 Turlington Hall
Department of Geography
Gainesville, FL 32611

Emmanuel Haruperi
Mntungwa Communication Solutions
71 Iris Road
Norwood, Johannesburg
South Africa
Email: haruperi@mweb.co.zw

Kevin Hayes
Bureau of Economic Growth,
Agriculture and Trade (EGAT)
U.S. Agency for
International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523-4600
Phone: (202) 712-1356
Email: khayes@usaid.gov

Dewayne Hendricks
Dandin Group
43730 Vista Del Mar
Fremont, CA 94539-3204
Email: Dewayne@dandin.com

Joh Henschel
Executive Director
Gobabeb Training& Research Centre
P.O. Box 953,
Walvis Bay, Namibia
Phone: 264-64-694198
Fax: 264-64-6941
Email: jhenschel@drfn.org.na

Martin Hewitt
USAID
Location: RRB 3.09-101
U.S. Agency for International Development
1300 Pennsylvania Ave., NW
Washington, DC 20523-3900
Phone: (202) 712-1531
Email: MHewitt@usaid.gov

Rosalyn Hobson
USAID/VCU
Virginia Commonwealth University
601 W. Main Street 244
Richmond, VA 23284
Phone: (804) 828-8308
Email: rshobson@vcu.edu

Deborah Husbands Fealing
Williams College

Steve Huter
Network Startup Resource Center
(NSRC)
University of Oregon
Eugene, OR 97403-1212
Phone: (541) 346-3547
Email: sghuter@nsrc.org

Julio Ibarra
Florida International University
11200 SW 8th Street
Miami, FL 33199
Phone: (305) 348-4105
Fax: (305) 348-1422
Email: Julio@fiu.edu

Greg Jenkins
Howard University Program in Atmospheric Sciences (HUPAS)
Department of Physics and Astronomy
Thirkield Building
2355 Sixth Street NW
Washington, DC 20059
Phone: (202) 806-5172
Email: gjenkins@howard.edu

Andrea Johnson
Carnegie Corporation of New York International Development
437 Madison Avenue
New York, NY 10022
Phone: (212) 207-6288
Fax: (212) 223-9822
Email: aj@carnegie.org

Barney Kgope
South African National Biodiversity Institute
Private Bag X101
Pretoria 0001, South Africa
Phone: 27 12 843 5000
Fax: 27 12 804 3211
Email: kgope@sanbi.org

Baraka Kinabo
Grad Research Assistant
University of Missouri-Rolla
Geological Science and Engineering
1870 Miner Circle
125 McNutt Hall
Rolla, MO 65409
Phone: (5730 341-4616
Email: bdk6x2@umr.edu

Doug Klotter
Florida State University
Researcher, Meterology
P.O. Box 4520
0431A Love Building
Tallahasse, FL 32306
Phone: (850) 644-4022
Email: klotter44@netscape.net

Kabineh Konneh
NOAA
14th Street & Constitution Avenue, NW
Washington, DC 20230
Phone: (301) 427-2374
Fax: (301) 427-2222
Email: Kabineh.Konneh@noaa.gov

Larry Landweber
Email: landweber@aol.com

Frances Li
Senior Staff Associate
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Phone: (703) 292-8710
Fax: (703) 292-9067
Email: fli@nsf.gov

Chris Light
Academy for Educational Development
1825 Connecticut Ave., NW
Washington, DC 20009-5721
Phone: (202) 884-8000
Email: clight@aed.org

Evaristo Liwa
Division of Ocean Sciences, and Office of International Science and Engineering
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Phone: (703) 292-4492
Email: eliwa@nsf.gov

Elizabeth Losos
Center of Tropical Forest Science
Smithsonian Tropical Research Institute
1100 Jefferson Drive, Suite 3123
Washington, DC 20560
Phone: (202) 633-4015
Fax: (202) 786-2819
Email: elosos@stridc.si.edu.
Email: losose@si.edu

Porter Lowry
Curator, and Head
Africa an Madagascar Department
Missouri Botanical Garden
P.O. Box 299
St. Louis, MO 63166-0299
Phone: (314) 577-9453
Fax: (314) 577-9596
Email: Pete.Lowry@mobot.org

Elizabeth Lyons
Regional Program Coordinator (Acting)
Africa, Near East and South Asia (ANESA)
Office of International Science
and Engineering
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Phone: (703) 292-7256
FAX: (703) 292-9176
Email: elyons@nsf.gov

John Mack
International Telecommunications Investment
P.O. Box 567
Upper Marlboro, MD 20773-0567
Phone: (301) 627-2188
Fax: (301) 627-2188
Email: jlmack@erols.com

Steve Macko
Professor, Environmental Sciences
University of Virginia
P.O. Box 400123
Clark Hall
Charlottesville, VA 22904
Phone: (434) 924-6849
Email: sam8f@virginia.edu

Hector Magome
Executive Director, Conservation Services
SANParks
P.O. Box 787
Pretoria, 0001 South Africa
Phone: 27124265217
Fax: 2712465517
Email: hectormagome40@hotmail.com

Lackson Marufu
Air Chemistry Group
Department of Meterology
University of Maryland
College Park, MD 20742
Phone: (301) 405-5355
Fax: (301) 314-9482
Email: marufu@atmos.umd.edu

Nonhlanhla Matshazi
Mntungwa Communication Solutions
71 Iris Road
Norwood, Johannesburg
South Africa
Phone: 27 11 483 1822
Fax: 27 11 483 1349
Email: nonhlanhla@mntungwa.co.za

Warren Matthews
Office of Information Technology
Georgia Institute of Technology
258 Fourth Street
Rich Building
Atlanta, GA 30332-0710
Phone: (404) 385-6087
Email: warren.matthews@oit.gatech.edu

Evelyn Mbede
Geology Department
Box 35052
Dar es Salaam
Tanzania
Phone: 0748 527310
Email: embede@uccmail.co.tz

Stephen Mbuligwe
Louisiana Water Resources
Research Institute
Environment Engineering Wetland
Research Laboratory
Louisiana State University
3221 CEBA
Baton Rouge, LA 70803
Phone: (225) 578-6027
Fax: (225) 578-5043
Email: smbuli1@lsu.edu

Myra McAuliffe
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Email: mmcaulif@nsf.gov

Terrence McCabe
University of Colorado
Boulder, CO 80309
Phone: (303) 492-0583
Phone: (303) 492-0443
Email: tmccabe@colorado.edu

Ellinor Michel
Department of Zoology
The Natural History Museum
Cromwell Road
SW7 5BD London, UK
Phone 44-207-942-5516
Email: ellm@nhm.ac.uk

Scott Miller
Associate Director for Science and
Curator of Entomology
National Zoological Park
National Museum of Natural History
Washington, DC
Phone: (202) 633-1036
Fax: (202) 786-3141
Email: millers@si.edu

Salome Misana
Geography Department
University of Dar es Salaam
P.O. Box 35049
Dar es Salaam, Tanzania
Phone: 25522-2410500-8 xt. 2335/2337
Fax: 255-22-2410393
Email: smisana@ud.co.tz

Cliff Missen
WiderNet Project
University of Iowa
Phone: (319) 335-2200
Email: missenc@widernet.org

Charles Mlingwa
Tanzania Wildlife Research Institute
P.O. Box 661
Arusha, Tanzania
Phone: 255-27-2548240/2509871
Fax: 255-27-2548240
Email: tawiri@habari.co.tz

Christine Morfit
Association Liaison Office
American Association of State Colleges
and Universities
1307 New York Ave., NW
Washington, DC 20005
Email: MorfitC@aascu.org

Gerald Mtalo
University College of Lands and
Architectural Studies
P.O. Box 35176
Dar es Salaam, Tanzania
Phone: 255-022-2775248
Email: mtalo@uclas.ac.tz

Marsha Naidoo
University of Michigan
Ann Arbor, MI 48109
Phone: (734) 764-1817
Email: marsha001@absamail.co.za
Email: marshan@umich.edu

Johnson Niba
Association Liaison Office for University
Cooperation in Development (ALO)
1307 New York Avenue, NW Suite 500
Washington, DC 20005
Phone: (202) 478-4700
Fax: (202) 478-4715
Email: nibaj@aascu.org

Sharon Nicholson
Heinz and Katharina Lettau
Professor of Climatology
Meteorology Department
Florida State University
Box 4520
Tallahassee, FL 32306-4520
Phone: (850) 644-4022
Fax: (850) 644-9642
Email: nicholson@met.fsu.edu
Email: sen@met.fsu.edu

Andrew Nyblade
Department of Geosciences
Pennsylvania State University
University Park, PA 16802
Phone: (814) 863-8341
Fax: (814) 863-7823
Email: andy@geosc.psu.edu

Laban Ogallo
Co-ordinator
Drought Monitoring Centre Nairobi
P.O.Box 10304, 00100-Nairobi
Nairobi, Kenya
Phone: 254 20 578340
Fax : 254 20 578343
Email: laban.ogallo@meteo.go.ke

Gary Olson
Assocate Dean for Research School of Information
University of Michigan
1075 Beal Avenue
Ann Arbor, MI 48109-2112
Phone: (734) 763-5644
Fax: (734) 647-8045
Email: gmo@umich.edu

Jennifer Olson
Department of Geography
Michigan State University
415 Natural Science
East Lansin, MI 48824-1115
Phone: (517) 432-9998
Email: olsonjj@msu.edu

Steve Osofsky
Wildlife Conservation Society
Senior Policy Advisor, Wildlife Health
WCS AHEAD Coordinator
Phone: (703) 716-1029
Fax: (703) 716-1029
Email: sosofsky@wcs.org

Craig Packer
Department of Ecology,
Evolution and Behavior
University of Minnesota
1987 Upper Buford Circle
St. Paul, MN 55108
Phone: (612) 625-5729
Fax: (612) 624-6777
Email packer@cbs.umn.edu

John Pardue
Director, Louisiana Water Resources Research Institute
Dept. of Civil & Environmental Engineering
Louisiana State University
Baton Rouge, LA 70803
Phone: (225) 578-8661
Fax: (225) 578-5043
Email: jpardue@lsu.edu

Tad Park
Department of Anthropology
P.O. Box 210030
Tuscon, AZ 85721-0030
Phone: (520) 621-2632
Fax: (520) 621-2088
Email: tpark@u.arizona.edu

Johan Pauw
South African Environmental Observation Network
211 Skinner Street
P.O. Box 1758
0001 Pretoria
T (++27) 12 392 9371
F (++27) 12 320 7803
Email: johan@saeon.ac.za

Alice Pell
Professor, Dept. of Animal Science
Cornell University
Ithaca, NY 14853
Phone: (607) 255-2876
Email: ap19@cornell.edu

Kevin Penn
The Institute for Genomic Research
9712 Medical Center Drive
Rockville, MD 20850
Phone: (301) 795-7000
Fax: (301) 838-0208
Email: kpenn@tigr.org

Mark Petri
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439
Phone: (630) 252-2000
Email: mcpetri@anl.gov

Stuart Piketh
Climatology Research Group
University of the Witwaersrand
1 Jon Smuts Avenue
Bernard Price Building Rm 101
Braamfoutein
Gauteng, South Africa
Private Bag 3
WITS 2050
Fax: 37-11-717-6535
Email: stuart@crg.bpb.wits.ac.za
Ana Preston
Email: apreston@internet2.edu

Louise Rademan
South African National Parks
P.O. Box 787
Pretoria 0001
South Africa
Phone: 27 012 428 9111
Fax: 27 012 426 5500
Email: louiser@sanparks.org

Achille Raselimanana
Biodiversity Programme Officer
WWF Madagascar & West
Indian Ocean Programme Office
P.O. Box 738 - 101 Antananarivo
Madagascar
Phone: 261 20 22 348 85
Phone: 261 20 22 304 20
Mobile: 261 32 04 761 05
Fax: 261 20 22 348 88
E-mail: ARaselimanana@wwf.mg

Robin Reid
International Livestock Research Institute
P.O. Box 30709
Nairobi, 00100, Kenya
Fax: 650-833-661 (USA direct)
Email: r.reid@cgiar.org

Don Riley
Professor, Decision Information Technologies
University of Maryland
4469 Van Munching Hall
College Park, MD 20742
Phone: 301-405-8855
Fax: 301-405-8655
Email: drriley@umd.edu

Sue Ringrose
Associate Professor
HOORC-University of Botswana
Private Bag 285, Maun, Botswana
Phone (267) 6861833
Fax: (267) 6861835
Email: sringrose@orc.ub.bw

Julia Rottier
U.S. Department of State
Foreign Affairs Office
European Affairs
2201 C Street NW
Washington, DC 20520
Phone: (202) 647-3649
Email: RottierJM@state.gov

Julia Royall
Special Expert, International Program
National Library of Medicine, National Institutes of Health
8600 Rockville Pike, Building 38,
Bethesda, MD 20894
Phone: (301) 402-2808
Fax: (301) 496-4450
E-mail: jroyall@nlm.nih.gov.

Roger Ruggles
Department of Civil and Environmental Engineering
Lafayette College
Easton, PA 18042-1775
Phone: (610) 330-5442
Fax: (610) 330-5059
Email: rugglesr@lafayette.edu

Lucie Rugo
Programme Officertaxonomy
and Invasive Alien Species
Secretariat of the U.N. Convention on Bilogical Diversity
393, rue St-Jacques-Suite 300
Montreal, Quebec, H2Y 1N9
Phone: 514-287-8718
Fax: 514-288-6588
Email: lucie.rogo@biodiv.org

Sandra Russo
Director, Program Development and Federal Relations
Associate Director, Transnational and Global Studies
International Center
Box 113225
University of Florida
Gainesville, Fl 32611
Tel: 352-392-5834
Fax: 352-846-2768
Email: srusso@ufic.ufl.edu

George Sadowsky
Executive Director
Global Internet Policy Initiative (GIPI)
Internews, Inc.
1640 Rhode Island Avenue, N.W.
Washington, DC 20036
Phone: (202) 833-5740 ext. 200
Phone: (203) 329-3288
Fax: (203) 547-6020
Email: george.sadowsky@attglobal.net

Mahesh Sankaran
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, CO 80523-1499
Phone: (970) 491-1964
Email: mahesh@nrel.colostate.edu

Mary Scholes
School of Animal, Plant
and Environmental Sciences
P Bag 3
WITS 2050, South Africa
South Africa
Phone: 27-12-8412045
Fax: 27-12-8412689
Email: mary@biology.biol.wits.ac.za

Fred Semazzi
Professor
North Carolina State University
Marine, Earth & Atmospheric Sciences
Box 8208
4144 Jordan Hall
Raleigh, NC 27695
Phone: (919) 515-1434
Fax: (919) 515-7802
Email: fred_semazzi@ncsu.edu

Richard Teague
Professor, Rangeland Ecology & Management
Texas Agricultural Experiment Station
Box 1658
Vernon, TX 76385
Phone: (940) 552-9941
Fax: (940) 553-4657
Email: r-teague@tamu.edu

Moses Tenywa
Makerere University
Department of Soil Science
P.O. Box 7062
Kampala
Phone: 256-77-827710
Fax: 256-41-531641
Email: soilscience@agric.mak.ac.ug

Wassily Thiaw
NOAA
14th Street & Constitution Avenue, NW
Washington, DC 20230
Email: Wassila.Thiaw@noaa.gov

Duncan Thomas
STRI
Research Associate
37309 Kings Valley Highway
Philomath, OR 97370
Phone: (541) 929-4155
Email: duncanwt@aol.com

Bonnie Thompson
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Email: bhthomps@nsf.gov.

Kevin Thompson
The National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
Email: kthompso@nsf.gov

Winston Trollope
Head, Dept. of Livestock
and Pasture Science
Faculty of Agriculture
and Environmental Science
Universtiy of Fort Hare
Private Bag X1314
Alice, 5700
South Africa
Email: wtrollope@ufh.ac.za

Wendy Turner
University of California, Berkeley
Berkeley, CA 94720
Email: wturner@nature.berkeley.edu

Paul Uhlir
Office of International S&T
Information Programs
The National Academies
500 Fifth Street, NW
Washington, DC 20001
Phone: (202) 334-2807 Ext. 1531
Fax: (202) 334-2231
Email: Puhlir@nas.edu

Kristen Vanderbilt
Sevilleta LTER
Depatment of Biology
University of New Mexico
Albuquerque, NM 87131
Phone: (505) 277-2109
Fax: (505) 277-5355
Email: vanderbi@sevilleta.unm.edu

Hassan Virji
American Geophysical Union (AGU)
START
2000 Florida Avenue N.W.
Washington, DC 20009-1277 USA
Phone: (202) 462-6900
Email: hvirji@agu.org

Sarah Walker
Graduate Student
University of Virginia
P.O. Box 400123
Charlottesville, VA
Phone: 434-924-4303
Email: sw2t@virginia.edu

Yeqiao Wang
Associate Professor
Department of Natural Resources Science
University of Rhode Island
Kingston, RI 02881-0804
Phone: (401) 874-4345
Fax: (401) 874-4561
Email: yqwang@uri.edu

Emmanuel Wango
Institute of Primate Research
P.O. Box 24481
Karen, Nairobi
Kenya
Phone: 254-2-882571/4
Fax: 254-2-882546
Email: prof.wango@www.ipr.or.ke

Christopher Williams
Natural Resources Ecology Lab
Colorado State University
Fort Collins, CO 80523
Phone: (970) 491-1101
Email: Christopher.Williams@colostate.edu

George Wittemyer
University of California, Berkeley
Berkeley, CA 94720
Email: georgew@nature.berkeley.edu

Dan Wubah
Professor & Special Asst. to the President
James Madison University
Phone: (540) 568-4506
Email: wubahda@csm.jmu.edu

Pius Yanda
Institute of Resources Assessment
University of Dar es Salaam
PO Box 35097
Dar es Salaam, Tanzania
Phone: 255-22-2410144
Fax: 255-22-2410393
Email: yanda@ira.udsm.ac.tz

Anne Yoder
Department of Ecology and
Evolutionary Biology
Yale University
P.O. Box 208105
21 Sachem Street, ESC 370a
New Haven, CT 06520
Phone: (203) 432-4606
Fax: (203) 432-5176
Email: anne.yoder@yale.edu

Appendix B : Sample Invitation Letter

Dear Colleague,

On behalf of the organizing committee, I am pleased to invite you to a workshop for Enhancing Collaborative Research on the Environment in Sub-Saharan Africa (SSA), which will take place in Arlington, VA (very close to Washington, D.C.) from Monday, January 24 through Wednesday, January 26, 2005.

PLEASE LET ME KNOW IMMEDIATELY VIA REPLY E-MAIL THAT YOU HAVE RECEIVED THIS E-MAIL. You have more time to answer the invitation (see below), but I need to know that you received it!

The workshop is being funded by the U.S. National Science Foundation (NSF) and will be held at the NSF headquarters. Professor David Hartnett (Kansas State University) and I, working in close collaboration with NSF's Office of International Science and Engineering, are coordinating the arrangements for this workshop. The meeting is intended to facilitate interactions among the U.S. scientific community working in the SSA region, SSA scientists, and agencies, private foundations and organizations that work and fund science projects in SSA. It will involve U.S. researchers supported by several NSF directorates, and representing many disciplines (e.g., ecology, atmospheric sciences, earth sciences, anthropology, geography, and environmental engineering). The meeting participants will produce a report for NSF that makes recommendations on how to strengthen research collaborations between U.S. scientists and scientists in Africa, how to build an effective, sustainable international community of scholars that can effectively address important research questions in the area of the environment in the SSA region, and how to catalyze the integration and synthesis of results across disciplines, geographic regions and hierarchical levels in this part of the world.

The meeting will include fifty to sixty participants from the U.S., approximately twenty participants from Africa collaborating on NSF-funded research projects, officials from NSF and from other U.S. government agencies, as well as representatives from foundations and organizations that funds scientific projects in Africa. A list of the meeting participants will be made available to you as soon as it is finalized.

This is a truly inter-disciplinary effort dealing with a wide range of questions, some of which are of continental dimensions and global implication. The invited participants have therefore been selected because of their unique combination of academic leadership, disciplinary breadth and depth, and logistical expertise in the key disciplines to be represented at the meeting. You have been invited because we feel that you can bring valuable insight to the deliberations of the meeting, representing both your discipline, as well as your part of Africa. We hope that you will be able to accommodate this important meeting in your busy schedule.

A detailed meeting agenda will be e-mailed to you as soon as it is finalized. Since this is a truly community activity, extensive and inclusive consultations are being made in the formulation the final agenda. The main sessions of the meeting will include:

--An opening session that reviews NSF's research activity in SSA, emphasizing both the scientific dimensions as well as the mechanisms of funding;

-- Two poster sessions, one for scientists to present ongoing research projects and a second for presentations by U.S. and African funding agencies;

--At least two plenary lectures describing exemplary projects and models of collaboration and networking;

--Several sessions of working groups focusing on: (i) identification of major areas of research opportunity and environmental topics of mutual interest to the U.S. and SSA countries; (ii) discussion of interdisciplinary approaches and potential program linkages; (iii) identification of opportunities to widen the funding

base beyond NSF, particularly to provide funding for the African researchers, (iv) discussion of opportunities to involve students and young scientists in SSA research, and (v) discussions of operational and logistical issues involved in collaborations, including issues of communication and data.

--A final synthesis session on Wednesday to consolidate workshop recommendations and materials for the meeting's report and action plan.

--For a subset of participants, an extra session on Thursday, January 27 devoted to information management, computer resources and technologies issues among this community of researchers.

This meeting is appropriately called a workshop because we expect all participants to help with the work of the meeting. Participants will need to attend all three days of the meeting and,

--provide current academic vitae (no more than 4 pages) to be included in the workshop's database;

--present a poster on the research being conducted by themselves, students and collaborators;

--help to moderate or write up results of the working group sessions for the report to NSF and for inclusion in the workshop summary that will be published on the web.

The meeting will be held at the National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230, near Washington D.C. Our grant from NSF will cover your travel, accommodation, and subsistence costs for the meeting. An information package for travel and hotel arrangements will be mailed to you upon receiving your acceptance to the invitation.

Please send your acceptance/decline by November 29th, 2004:

Via e-mail at <mailto:ssameeting@ncsu.edu>ssameeting@ncsu.edu

Or by FAX at +919 515-7802

If you will be participating in the workshop, please send your current academic vitae (no more than 4 pages, and preferably in Microsoft Word) with your acceptance by e-mail to:ssameeting@ncsu.edu>ssameeting@ncsu.edu.

If you have any questions about this meeting, you can reach me by calling +919-515 1434.

We are sending the first notice/invitation of this meeting via e-mail, but will follow it with an official invitation printed on North Carolina State University letterhead. If you have not received this paper invitation within 2 weeks of this e-mail, please contact me and I will make arrangements to re-mail or FAX you the invitation.

For your information, a list of the invitees from Africa who have already accepted our invitation to is appended below. We are expecting to hear from a few more invitees and this list will be updated in due course. If you presently have (or have had) collaboration with any of them in your NSF-funded research you are encouraged to contact them to explore possible opportunities to enhance interaction during and after the workshop.

On behalf of the organizing committee, I would like to express our appreciation for your consideration to participate in the SSA workshop. We look forward to your acceptance of this invitation and to seeing you in the U.S. in January 2005. Should you have questions concerning the subject of this communication or the workshop in general, please do not hesitate to call or contact me.

Yours sincerely,

Fredrick. H. M. Semazzi, Ph. D.
Professor, Department of Mathematics & Department of Marine, Earth & Atmospheric Sciences
North Carolina State University

cc: Professor David Hartnett (Kansas State University)
cc: Dr. Elizabeth Lyons (National Science Foundation)
Mr. Evaristo Liwa (National Science Foundation)

Appendix C : Framework for Working Group Discussions

SSA Workshop
Outline of General Framework for Working Group Discussions

(Each working group will use the following three general areas as a framework for discussion. The specific questions and topics of focus will vary among sessions and groups)

1. Current Assessment:

What programs, networks, infrastructure are already in place?

What ongoing programs or projects would benefit from greater collaboration and synergy?

What current activities and mechanisms are working well?

What is the status of our knowledge base in this area?

What is the current status of communication and networking (within the region and between U.S. and SSA)

2. Identification of Key Issues, Challenges, and Opportunities

Capacity building – what are the needs regarding intellectual capital?

What are the factors hindering collaboration?

Linkages among programs, countries, regions

Cross-discipline linkages – e.g. incorporating social sciences, engineering

Identification and prioritization of research needs and opportunities

Identification and prioritization of training needs and opportunities

Scale of projects and programs needed (individual, institutional, national, regional)

Physical infrastructure needs

3. Identification and Prioritization of Recommeded Actions and Enhancements

Recommended new initiatives, infrastructure, activities, and networking

Specific ways to foster more effective communication and collaboration

Identification, prioritization, and implementation of specific mechanisms (e.g. networks, IM systems, cyber-infrastructure, specific program linkages, digital libraries/bibliographies, program and personnel directories, multi-disciplinary degree and training programs, funding mechanisms, new partnerships, new linkages among agencies and organizations, regular meetings/symposia focused on SSA region)

Appendix D : List of Acronyms

AERC:	African Economic Research Consortium
AETFAT:	African Plant Taxonomy Association
AFEA:	African Finance and Economic Association
AFNOG:	Africa Network Operators' Group
AFRIFLUX:	Promoting Research on Ecosystem Function in Africa
AHEAD:	Animal Health for the Environment and Development
AMMA:	African Monsoon Multidisciplinary Activities
APINA:	Air Pollution Information Network of Africa
ASARECA:	Association for Strengthening Agricultural Research and in Eastern Central Africa
ATICS:	African Teritiary Institution Connectivity Survey Report
AVHRR:	Advance Very High Resolution Radiometer
AVU:	African virtual University
BENRON:	Botswana Environment & Natural Resources Observatory Network
CARPE:	Central African Rainforest Project
CODESRIA:	Council for Economic and Social Research in Africa
CTFS:	Center for Tropical Forest Science. Smithsonian Tropical Research
EAFRINET:	East African Network for Capacity Building in Taxonomy
ELTOSA:	Environmental Long-Term Observatories Network of Southern Africa
ENSO:	El Nino Southern Oscillation
EON:	Environmental Observatorics Network
EU:	European Union
FAO:	Food and Agriculture Organization of the United Nations
FCCC:	Framework Convention on Climate Change
FEWS:	Famine Early Warning System
GCMS:	Global Circulation Models
GHA:	Greater Horn of Africa
GPCC:	Global Precipitation Climatology Centre
GPS:	Global Positioning System
GSSA:	Grassland Society of Southern Africa
GTZ:	German Agency for Technical Co-operation(Deutsche Gesellschaft für Technische Zusammenarbeit)
IDEAL:	International Decade of the East African Lakes
IGAD:	Intergovernmental Authority on Development
ICPAC	IGAD Climate Prediction and Applications Center
IGBP:	International Geosphere-Biosphere Program
ILTER	International Long-term Ecological Research Network
IMF:	International Monetary Fund
IOSEP:	International Opportunities for Scientists and Engineers Program
IPCC:	International Panel of Climate
IT:	Information Technology
IUCN:	Specialist Groups
LOOPS:	Locally Owned and Operated Partnerships
LTER:	Long-Term Ecological Research
LUCID:	Land-use Change Impacts and Dynamics, East Africa
LULCC:	Land Use and Land Cover Change
MAP:	Mean Annual Precipitation
MODIS:	Moderate Resolution Imaging Spectroradiometer
NAFRINET:	North African Network for Capacity Building in Taxonomy
NASA:	National Aeronotics and Space Administration
NCDC:	National Climatic Data Center
NCEAS:	National Center for Ecological Analysis and Synthesis
NCEP:	National Centers for Environmental Predictions
NDVI:	Normailized Difference Vegetation Index
NEPAD:	New Partnership for African Development
NIH:	National Institutes of Health
NORAD:	North American Aerospace Defense Command
NSF:	National Science Foundation

OISE:	Office of International Science and Engineering
ORSTOM:	Organisation de Recherche Scientifique outré Mer
RANET:	RAdio & InterNET for the Communication of Hydro-Meteorological and Climate Related Information
RCSA:	Regional Center for Southern Africa
REBAC:	Central African Botany Network
REGCM3:	Regional Climate Model Version 3
RIEM:	Ecological and Environmental Network of Mozambique
SACCAR:	Southern African Centre for Co-operation in Agriculture and Natural Resources Research and Training
SADC:	Southern African Development Community
SAEON:	South African Environmental Observatory Network
SAFARI:	Southern African Regional Science Initiative
SAFNET:	Southern Africa Fire Network
SAFRINET:	Southern African Network for Capacity Building in Taxonomy
SAHRA:	University of Arizona, digital abstracts on water throughout the world
SANTREN:	Southern African Environmental Network
SAPES:	Southern African Policy and Economic Studies
SAVANA:	Southern African Virginia Networks Association
SCOPE:	Science Controversies On-line: Partnerships in Education
SSA:	Sub-Saharan Africa
START:	SysTem for Analysis, Research and Training
TANAPA:	Tanzania National Parks
TAWIRI:	Tanzania Wildlife Research Institute
TRMM:	Tropical Rainfall Measuring Mission
UCAD:	Université Cheikh Anta Diop de Dakar
UNDP:	United Nations Drought Programme
UNECA:	United Nations Economic Commission for Africa
UNEP:	United Nations Environment Programme
UNESCO:	United Nations Educational, Scientific and Cultural Organzation
USAID:	United States Agency for International Development
USLE:	Universal Soil Loss Equation
WAFRINET:	West African Network for Capacity Building in Taxonomy
WATERNET:	Water/Land Training Network
WMO:	World Meteorological Organization

Appendix E : List of References

Lawton, J. H., 1999: Are there general laws in ecology? Oikos 84: 177–92.

Biggs, H. J., G.I.H. Kerley and T. Tshighuvo, 1999): A South African long-term ecological research. network: a first for Africa? S. Afr. J. Sci. 95, 244–245.

Henschel J.R. and J. Pauw, 2002: Environmental observatories: LTER à-la-Africa. In Rebirth of Science in Africa: A shared Vision for Life and Environmental Sciences, eds H. Baijnath and Y. Singh, pp. 149–159. Umdaus Press, Pretoria.

WCRP, 1999: ICPO Publication Series No.29

Githeko AK, S. W. Lindsay, U. E. Confalonieri, J. A. Patz, 2000: Climate change and vector-borne diseases: a regional analysis. Bull World Health Organ, 78:1136-1147.

Kiwanuka-Tondo, J. & Snyder, L. B, 2002: The Influence of Organizational Characteristics and Campaign Design Elements on Communication Campaign Quality: Evidence from 91 Ugandan AIDS Campaigns. Journal of Health Communication, 7(1): 59-77.

Zeleza, P.T. 2002. Transnational scholarship: building linkages between the U.S. and Africanist community and Africa. African Issues 30: 69-75.

Appendix F : Poster Titles

1. Adedoyin, Akintayo. **Mechanism of Climate Change within the Kalahari Transect of Southern Africa: Impacts on the Environment and Social Life**

2. Amarillo, J., R. Oleski, R. Ruggles and L. Kajubi. **A Spatial and Temporal Analysis of Land Uses Affecting Lake Victoria's Wetlands**

3. Atekwana, Estella A., Baraka D. Kinabo, John P. Hogan, Henri A.B.Kampunzu and Motsoptse P. Modisi. **Early Structural Evolution of the Okavango Rift Zone, NW Botswana**

4. Bassett, Thomas J. and Koussa Koné. **Networks and Niches: The Political Ecology of Mobile Livestock Raising in Northern Côte d'Ivoire**

5. Baum, J., D. Klotter and R. Crouthamel. **The African Upper Air Data Rescue Project**

6. Campbell, David, Salome Misana, Jennifer Olson and Pius Yanda. **Climate-Land Interactions Project (CLIP) in East Africa**

7. Coughenour, Michael, Kathy Galvin, Craig Packer, Steve Polasky, Mark Ritchie and Bob Holt. **Biocomplexity of the Greater Serengeti - Humans in a Biologically Diverse Ecosystem**

8. Dick, R. P., A. Badiane, M. Sene, M. Khouma,, S. Ndiaye, Jay Noller and Maria Dragila. **Regulation of Hydrologic and C Cycles by Native Shrubs in Soils of Sub-Sahelian Africa**

9. Georgiadis, N. and N. Olwero. **Evaluation and Applications of Remotely Sensed Vegetation Indices as Rainfall Data Surrogates in Drylands**

10. Getz, Wayne, Johan du Toit, Craig Tambling, Markus Hofmeyer, Shirli Bar-David, James Lloyd-Smith, Maria Sanchez, Paul Cross, Andy Lyons, Sadie Ryan, Wendy Turner and George Wittemyer. **A Quantitative Focus on Wildlife Conservation and Diseases in Africa**

11. Goldman, Abe, Michael Binford, Jane Southworth, Colin Chapman, Lauren Chapman, J. Terrence McCabe and Paul Leslie. **Consequences of Parks for Land Use, Livelihood Diversification and Biodiversity in East Africa**

12. Harris, Craig K. **Dynamics of Change In the Lake Victoria Fisheries**

13. Henschel, Joh and Mary Seely. **Gobabeb Environmental Observatories Network**

14. Jenkins, Gregory S., Amadou Gaye and Bamba Sylla. **Collaborative Regional Climate Modeling Studies and AMMA Field Experiment Efforts**

15. Macko, Stephen A., Robert J. Swap, Thomas A. Szuba, Harold Annegarn, Bane Marjanovic, Francisco Vieira and Rui Brito. **Real-Time Interactive Environmental Teleducation Between the United States and Southern Africa**

16. McCabe, J. Terrence and Paul Leslie. **Livelihood Diversification among the Maasai of Northern Tanzania: Cultivation, Migration and the "New Thinking" in Ecology and Ecological Anthropology**

17. Mlingwa, Charles. **Implementation of a New Wildlife Research Agenda in Tanzania**

18. Morfit, Christine, Kay Ikranagara and Tony Wagner. **Association Liaison Office for University Cooperation in Development**

19. Nicholson, S.E. and D. Klotter. An **Overview of African Research in the FSU Climatology Lab**

20. Nicholson, S.E., B. Some and co-authors. **A Workshop for the Validation of TRMM Satellite Estimates of Precipitation over Africa**

21. Nyblade, A. and P. Dirks. **AfricaArray**

22. Osofsky, Steven A., Michael D. Kock, William Karesh, Robert A. Cook, David H. M. Cumming and Richard Kock. **Moving Conservation AHEAD (Animal Health for the Environment and Development): Progress at the Intersection of Program and Policy**

23. Packer, Craig. **Ecological Research in Tanzania**

24. Pauw, J. C. **Developing South Africa's Environmental Observation Network (SAEON)**

25. Pauw, J. C. and Joh Henschel. **Monitoring and Understanding Long-Term, Large-Scale Environmental Change Across Southern Africa**

26. Pell, A.N., J.M. Kinyangi, S.O. Ngoze, D.R. Brown, C.B. Barrett, L.E. Blume, J.G. Gamara, C.J. Lehmann, P.P. Marenya, H.A. Markewich, A.O. S.J. Riha, D.M. Mbugua, Odenyo, L.V. Verchot and J. Wangila. **Dynamics of Poverty and Soil Degradation on Smallholder Farms in Central and Western Kenya**

27. Piketh, S.J., L. B. Otter and K. E. Ross. **Sources and Impacts of Atmospheric Aerosols over Southern Africa**

28. Reid, Robin S.F. Mohammed Y. Said, Joseph Ogutu, Shem Kifugo, Andrew Muchiru, Sandra van Dijk, N. Thompson Hobbs, Jeff Worden, Shauna Burnsilver and Helen Gichohi. **Landscape Interactions Between Pastoral People and Wildlife in East Africa: Competition, Synergies or Both?**

29. Reilinger, Robert, Simon McClusky, Philippe Vernant, Woladai Ghebreab and Biniam Haileab. **Global Positioning System (GPS) Constraints on Arabia-Africa-Eurasia Plate Interactions and Inter-plate Deformations: Developing a Physical Basis for Earthquake Hazard Assessment**

30. Sankaran, Mahesh, Niall Hanan, Jayashree Ratnam and Robert Scholes. **Determinants of Woody Cover in African Savannas: Is Tree-Grass Coexistence Disturbance Dependant?**

31. Scholes, Mary. C. **Biogeochemistry of Semiarid Savannas and Plantation Forests in Southern Africa**

32. Semazzi, Fredrick, Richard Anyah, Jared Bowden and Robert Mera. **Climate Research over the Greater Horn of Africa (GHA)**

33. Sitoe, A., B. Guedes, J. Argola, F. Tchaúque, A. Muhate and J. Monteiro. F**orest Cover Change and its Implications to the Conservation of Forest Resources: Case Study of the Beira Corridor**

34. Smith, Richard, and Lucie Rogo. **BioNET-INTERNATIONAL: the Global Network Taxonomy for Taxonomy**

35. Swap, R. J., L. Estes, H. Sabea, C. Terni, H. Annegarn, C. Ford, W. Twine, V. Netshandamu,P. Omara-Ojungu, K. Vaz, N. Ribeiro and F. Eckardt. **The University of Virginia 'People, Culture and Environment of Southern Africa' Summer Study Abroad Program – An Example of a Collaborative International Educational Program**

36. Tenywa, M. M., M. J. G. Majaliwa, E. J. Wasige, A. Lufafa, M. K. Magunda, R. Lal, J. Gowing and P. L. Woomer. **Sustainable Watershed Management in Uganda: Opportunities and Challenges**

37. Thomas, D. W., R. Condit, E. C. Losos, B. Bishaw, D. Hibbs, G. B. Chuyong, C. Ewango, D. Kenfack, T. Hart and J. R. Makana. **Building Central Africa's Capacity in the Understanding and Monitoring of Forest Dynamics**

38. Trollope, W. S. W. and L. A. Trollope. **Fire - A Key Factor in the Ecology and Management of African Grasslands and Savannas**

39. Uhlir, Paul F., Julie M. Esanu and Amy Franklin. **Making Digital Science Productive and Meaningful in the Developing World**

40. Vanderbilt, Kristin. **Ecoinformatics Training: Toward Data Sharing and Collaborative Research**

41. Wang, Y.Q. (Yeqiao), Gregory Bonynge, Jarunee Nugranad, Michael Traber, Vedast Makota, Amani Ngusaru and James Tobey. **Impacts of Land Cover Change along the Tanzania Coast: A Case Study of Geographic Information for Sustainable Development**

42. Williams, Christopher A., Niall Hanan, A. Scott Denning, Joseph Berry, Robert Scholes, Jason Neff and Jeffrey Privette. **Africa and the Global Carbon Cycle: Field Networks and Model Studies of African Carbon Exchange**

43. Yaindl, C., R. Oleski, R. Ruggles, D. Brandes, A. D. Kney and L. Kajubi. **Impact of Agricultural Techniques on Wetland Processes - Uganda, Africa: Treatment Reliability and Hydraulic Strategies**

44. Yoder, Anne D., Carol Hanley, Achille Raselimanana and Steven M. Goodman. **An Integrative Approach to Understanding Biodiversity in Madagascar**

Poster Abstracts

1 - Mechanism of Climate Change within the Kalahari Transect of Southern Africa: Impacts on the Environment and Social Life

Akintayo Adedoyin
University of Botswana, Department of Physics, Gaborone, Botswana Email: adedoyin@mopipi.ub.bw

It is well documented that since the late 60's different parts of sub-Saharan Africa have experienced devastating droughts. The attendant inter-annual variability of rainfall and the shifts in the dynamics of the major rain-producing systems have also been the subject of much research work. This variability is closely linked with other global climatic conditions like the El-Niño (ENSO) phenomenon. The mechanisms for this inter-annual variability are discussed in relation to the modulating effects of continental rain-belt mode, large-scale atmospheric circulation and sea-surface temperature (SST) patterns. Observations show that above-normal (below-normal) Kalahari rainfall is usually accompanied by the southward (northward) displacement in the rain-belt mean axis, and there is a concurrent increase (decrease) in the total rainfall. Also, above-normal (below-normal) Kalahari rainfall is accompanied by dominant negative (positive) anomalies of 700 hPa heights over southern Africa. The correlation between sub-Saharan Africa rainfall patterns and global 700 hPa heights is therefore investigated with a two-layer model of the atmosphere. Results show that the most unstable perturbations occur when the interface between tropical Africa tropospheric air masses is at 700 hPa. The zones where tropical Africa monsoon winds attain this critical precipitating depth of 700 hPa are determined by global SST anomalies. These anomalies are shown to influence the shift in the axis of squally activities during dry ENSO events, thereby depriving normally wet areas of the main rain-producing mechanism. Implications of observed variabilities on water resources, agriculture, energy, health-related issues and the tourism industry are discussed.

2 - A Spatial and Temporal Analysis of Land Uses Affecting Lake Victoria's Wetlands

Jay Amarillo, Rachael Oleski, and Roger Ruggles
Lafayette College

Lammeck Kajubi
Makerere University

Over the past ten years Lake Victoria in Africa, the second largest freshwater lake in the world has begun to show signs of stress due to anthropogenic influence documented by indicators such as biochemical oxygen demand (BOD) and various nutrients (i.e., nitrogen and phosphorous). The increased concentrations of the nutrients may help to explain the increased growth of water hyacinth (Eichhornia crassipes). In addition, metals such as lead and cadmium have been reported at levels of concern in Lake Victoria.

To address these issues of increasing pollutants in and around Lake Victoria a cooperative study between Makerere University, Uganda, Africa and Lafayette College, Easton PA, U.S. has been established through a National Science Foundation (NSF) program - International Opportunities for Scientists and Engineers Program (IOSEP). The overall study consists of four components:

1. A study of transition through a historical assessment of land use utilizing remotely sensed images
2. Rapid monitoring of the wetland-lake interface on Lake Victoria
3. Comprehensive chemical, hydrologic and sedimentation assessment of selected Kampala and Jinja, Uganda wetlands.
4. Wetland construction research examining innovative agricultural techniques, treatment reliability and hydrologic strategies.

This particular study, the analysis of land uses affecting Lake Victoria's wetlands, addresses components 1 and 2 of the overall IOSEP study. An information system to support on-site studies was developed by faculty and students at Lafayette College prior to traveling to Africa. This system included delineation of watershed boundaries, digitizing maps, obtaining and analyzing satellite imagery and integration of all information into a geographical information system.

Over the summer of 2004 a team of faculty and students from both Makerere University and Lafayette College began to study land use around Lake Victoria and to monitor water quality in the Lake. Water quality measurements were taken in Murchison Bay, the portion of Lake Victoria adjacent to Kampala, the capitol and largest city in Uganda. Water quality in the bay, the source of drinking water for the city, was found to be heavily impacted by increasing population, land use changes and limited wastewater treatment systems. The results of this study will be used to develop recommendations for further study.

3 - Early Structural Evolution of the Okavango Rift Zone, NW Botswana

Estella A. Atekwana, Baraka D. Kinabo and John P. Hogan
University of Missouri-Rolla, Department of Geological Sciences and Engineering.

Henri A. B. Kampunzu and Motsoptse P. Modisi

University of Botswana, Department of Geology

High resolution magnetic and gravity data from the nascent Okavango Rift Zone (ORZ) in northwest Botswana has been used to investigate the earliest stages of continental rifting. Three of the questions that we are currently investigating through our studies of the ORZ are as

follows: 1) To what extent is the development of continental rifts influenced by preexisting structures present in the basement? 2) How does the initial distribution of faults associated with the earliest stages of rifting link together to define and bound discrete rift basins? 3) How then do these faults and their associated basins evolve to form a continental rift system?

Preliminary results data from the ORZ suggests three main fault directions: 1) northeast-southwest (045- 070), 2) northwest- southeast (310 - 315) and 3) west-northwest-eastsoutheast (280- 290). The 045- 070 structures occur both within the rift zone and throughout the surrounding basement. They also form the main bounding fault system of this incipient rift. The NE - SW orientations of the fold axes and foliation of the basement rocks mirror that of the main bounding faults of the rift basin. Thus, our preliminary interpretation is that the basement fabric plays an important role in localizing the development of faults within the stress regime present during the initiation of continental rifting. Additionally, the greatest throw (~300- ~600 m) occurs along the Kunyere (NW dipping) and Tsau faults (SE dipping), defining a full graben as observed on 2 3/4 –d gravity models. This differs from the half-graben model typical of most continental rift zones. Thus it appears the basin geometry was strongly influenced by the position of the pre-exiting faults. Evidence of fault linkage is seen along some of the faults. Linked segments of faults are well defined and extend for up to 200 km. We suggest from this result that fault linkages and propagation occurred very early and prior to significant basin development. We conclude that basement fabric seems to be a controlling factor at least in the early stages of basin architecture and structural evolution of ORZ.

4 - Networks and Niches: The Political Ecology of Mobile Livestock Raising in Northern Côte d'Ivoire

Thomas J. Bassett and Koussa Koné
Department of Geography, University of Illinois, Urbana-Champaign Email: bassett@uiuc.edu

This research project takes a political ecological approach to explore the social and ecological processes structuring the spaces and scales of mobile livestock raising in northern Côte d'Ivoire. The new pastoralism literature emphasizes the ecological determinants of herd mobility. The opportunistic grazing model that informs this literature argues that livestock management practices are highly structured by environmental instability and contingent events. The literature assumes that pastoralists possess perfect environmental knowledge and unhindered access to rangelands in managing their herds. The thesis of this research project is that there is a disconnect between the temporal and spatial distribution of grazing resources and actual grazing patterns. Herd mobility is not as finely tuned to the environmental heterogeneity of savanna environments as the new pastoralism literature suggests. Our research shows that herd movement patterns are more strongly related to social, political and economic considerations than to rangeland condition.

This poster presents the results of a three-year field study (2002-2004) that recorded the herd movements of eight pastoral households. Field methods included tracking herd positions using GPS devices and administering a questionnaire every ten days to herders on the political ecological dynamics of herd mobility. Our research confirms the general view that herd mobility is an important livestock production strategy in savanna environments. However, our findings show that the diversity of herd movement patterns is largely determined by a multitude of social (labor control), political (access to land), pastoral (herd size) and agro-ecological processes (disease, agricultural calendar, fallows). Some herders go on long distance treks while others move within a more circumscribed area. Many herders return to the same rangelands year after year. Others shift direction and duration for personal or political reasons. Herd movement patterns demonstrate the importance of social, political and economic considerations as much as ecological opportunities and constraints. The poster presents a political ecological model of herd mobility that better illustrates these social and biophysical dimensions of livestock raising in West African savannas.

5 - The African Upper Air Data Rescue Project

J. Baum, D. Klotter and R. Crouthamel
NOAA Climate Database Modernization Program, Florida State University Email: klotter44@met.fsu.edu

In this set of projects the interest is on preserving and using data from African meteorological stations. Numerous radiosondes and pilot balloon (pibal) measurements have been made over the decades throughout the continent, with the data tabulated and stored. However, this data has stayed in storage for long periods of time and is in danger of being lost forever. Also, at present, little of this information is available to potential users, as it is in written form and not computerized. The purpose of the Africa Upper Air Data Rescue Project is to go to several countries in Africa and, through a multi-step process, preserve and digitize the data so that nothing more will be lost and all data will be available for use. This has entailed traveling to these countries and instructing the local met department so that they can create digital photo images of the pibal forms, collect the images onto CD's and ship copies to NCDC. As funds become available, the images will be digitized to a computer friendly format and saved to library databases. Six African countries have contributed to this effort and Malawi's radiosondes have recently been finished and are in the process of being returned.

6 - Climate-Land Interactions Project (CLIP) in East Africa

David Campbell, Salome Misana, Jennifer Olson and Pius Yanda
Michigan State Universit;, University of Dar es Salaam; International Livestock Research Institute, Makerere University; NOAA, Purdue Universiy; University of East Anglia Email: djc@msu.edu

The intensity and spatial reach of contemporary human alterations of the Earth's land surface are unprecedented.

Land use and land cover change (LULCC) are among the most significant of these human influences. Many studies demonstrate the influence of LULCC on local and regional climate. Meanwhile, climate change is expected to significantly affect people and ecosystems due to warmer temperatures and altered precipitation patterns. While significant research has focused on global climate modeling and socioeconomic drivers of land use change, an integrated assessment of coupled human-climatic systems is required to address the question: What is the magnitude and nature of the interaction between land use and climate change at regional and local scales?

An international, multi-disciplinary team including social, ecological, atmospheric and statistical scientists from the U.S, Kenya, Tanzania, Uganda and the U.K., is addressing this question by exploring the linkages between LULCC and climate change. This project is among the first to complete the loop of land use/climate/land use impacts assessment. Its contribution is in analysis of the linkages between components—how does land use change affect climate and how will climate change affect land use? These linkages are being examined through characterizing and modeling agricultural systems, land use, the physical properties of land cover and the regional climate. East Africa, with its variety of ecosystems, wide range of tropical climatic conditions, areas of rapid land use change and a population vulnerable to climatic variability, is the location of the research.

7 - Biocomplexity of the Greater Serengeti - Humans in a Biologically Diverse Ecosystem

Michael Coughenour and Kathy Galvin
Colorado State University

Craig Packer and Steve Polasky
University of Minnesota

Mark Ritchie
Syracuse University

Bob Holt
University of Florida

This poster summarized the aims of an NSF Biocomplexity project that is underway. The Serengeti is a complex ecosystem with pervasive linkages between human welfare and the functioning of a diverse natural system. To study the coupling of natural ecosystem functioning and human decision-making in the greater Serengeti, four modeling approaches will be used. 1. Process-rich, spatially explicit ecosystem simulation models will be developed to predict changes in plant and animal communities, human use of landscapes at different scales. 2. Agent-based models will incorporate individual decision-making rules in a spatially explicit environment 3. Analytical models of community modules will explore interactions among 5-10 key species~ and 4. Macro-ecological models will describe system patterns and processes as functions of major resource inputs, such as rainfall and soil nutrients. These models will explore emergent dynamics of the Serengeti at various organizational scales.

The theory of complex systems proposes that emergent properties can arise from relatively simple underlying mechanisms propagated in space and time. Thus the vulnerability of humans and sustainability of biodiversity in the Serengeti may be driven by a few critical constraints that operate independently of individual components. These constraints arise from fundamental laws/principles in psychology, biology, chemistry and physics that constrain key biological processes and human decisions. Alternatively, complex systems may be sensitive to small differences in initial conditions and show a tendency to switch between alternative states. This sensitivity suggests that biodiversity and human welfare may be highly contingent on details such as individual behavior, the identity of the species participating and the precise spatial arrangement of interactions among humans, plants, animals and diseases. The Serengeti provides a unique opportunity to test this hypothesis since its component parts are so conspicuous and its dynamical patterns have been measured for 40 yrs. Finally, emergent system properties may be contingent on just a few critical components, which would imply that the Serengeti can be understood from networks of interaction among a few key species of plants/animals and humans.

8 - Regulation of Hydrologic and C Cycles by Native Shrubs in Soils of Sub-Sahelian Africa

Richard P. Dick
Ohio State University

A. Badiane M. Sene M. Khouma and S. Ndiaye
Institut Sénégalais de Recherches Agricoles, Senegal

Jay Noller and Maria Dragila
Oregon State University

Desertification and degradation of soils in Sub-Sahelian Africa is serious and likely reducing agricultural productivity and there is interest in storing C in soils of these landscapes. Assessing soil degradation and C sequestration potential is spatially and temporally complex in this semiarid landscape. We have identified a largely unrecognized component of the semi-arid Sahel; woody shrubs (Piliostigma reticulatum and Guiera senegalensis) that voluntarily regrow in farmers' fields after the summer cropping season, which appear to be more important than trees or organic inputs such as animal manures in regulating C inputs/sequestration and hydrologic processes. Under current management, farmers cut and burn the shrub biomass each spring that may not be the most effective way of managing this organic residue. Also, we theorized that these shrubs might do "hydraulic lift" of water from wet sub soils to the dry surface. This could drive rhizosphere processes in "dry" soil such as nutrient mineralization/C cycling and possibly provide small amounts of water to shallow rooting crops. Our overall goal is to determine the unrecognized role of shrubs as key determinants in sequestration of C, water relations and soil degradation mitigation in the semiarid ecosystem of Senegal that is representative of much of Sub-Sahelian Africa. The approach includes: (1) rapid participatory surveys of rural communities; (2) landscape spatial analysis of shrubs; (3) detailed studies of how shrubs control C/N/P cycling, soil microbiology and soil physical properties; (4) studies of water relations of shrubs and soils; and (5) modeling C cycling relative to shrub management over decadal periods.

9 - Evaluation and Applications of Remotely Sensed Vegetation Indices as Rainfall Data Surrogates in Drylands

Dr. Nicholas Georgiadis and Nasser Olwero
Mpala Research Centre,
Email: njg@mpala.org

In African drylands, vital ecological and economic processes are, by definition, driven largely by rainfall, including agricultural and livestock production, household and regional economies, wildlife and ecosystem dynamics. Rainfall data are needed to run ecological simulations and improve economic projections for drylands, but gauged data are typically lacking or inadequate. Remotely sensed indices have long been available to estimate rainfall (e.g. products from Meteosat) and monitor vegetation responses to rainfall (e.g. products from AVHRR) over vast areas. But these data and even their derivatives (e.g. FEWS), are severely under-used, due to lack of awareness about or confidence in the data, lack of access to the internet and high cost of software to handle spatial datasets.

The Ewaso Ecosystem in northern Kenya, a region characterized by steep altitudinal and climatic gradients, is richly endowed with long-term rainfall records and ideally suited to an evaluation of gauged rainfall surrogates. Using a modeling approach we show that low-resolution Meteosat rainfall estimates for this system are both inaccurate and biased. However, vegetation indices at both low resolution (8 km pixels from AVHRR) and higher resolution (250m pixels from MODIS) provide highly informative rainfall surrogates. Up to 84% of the intra-annual variation in observed NDVI can be accounted by simple models estimating NDVI solely from rainfall. We use these models to demonstrate systematic changes across the rainfall gradient in 1) rainfall use efficiency and 2) the responsiveness of vegetation to a standardized rainfall event.

Management applications of NDVI data in this system include:

1. comparison of vegetation productivity under different land use regimes;
2. using NDVI to drive a simulation model of zebra population dynamics;
3. using integrated NDVI to evaluate food availability for a declining hartebeest population;
4. using changing patterns of NDVI to predict the timing and location of crop raiding by elephants.

With faster internet access there is potential to use these vegetation indices to better understand ecosystem productivity, monitor and plan changes in land use and predict vegetation responses to climate change. We seek research partnerships to achieve these goals.

10 - A Quantitative Focus on Wildlife Conservation and Diseases in Africa

Wayne Getz
Environmental. Scence,. Policy and Managment. (ESPM), University. of California at Berkeley and Mammal Research. Insitute. (MRI), Univ. of Pretoria, South Africa
Email: getz@nature.berkeley.edu

Johan du Toit and Craig Tambling
MRI, University of Pretoria, South Africa

Markus Hofmeyer
Game Capture Unit, Kruget National Park, South Africa

Shirli Bar-David, James Lloyd-Smith, Maria Sanchez, Paul Cross andy Lyons, Sadie Ryan, Wendy Turner and George Wittemyer
ESPM, University of California at Berkeley

A group, under the direction of Wayne Getz at UC Berkeley (Getz Lab), drawing graduate students from the ESPM and Biophysics Programs at Berkeley and the MRI graduate program at the University of Pretoria, focuses on developing new quantitative techniques to address problems in epidemiology and conservation biology across Africa. The largest project of the Getz Lab at this time is a study of the spread of Bovine TB in African Buffalo in the Kruger National Park, South Africa. This project is funded by the NSF/NIH Ecology of Infectious Disease Program and administered in collaboration with the MRI, headed by Johan du Toit, at the University of Pretoria. The field component of the project is directed by Paul Cross, a graduating Ph.D. student from the Getz Lab and is overseen by Markus Hofmeyr for the Kruger National Park, Scientific Services group of SANParks (South African National Parks). Also, in South Africa, the Getz Lab helped develop and establish a South African Department of Science and Technology funded Center of Excellence for Epidemiological Modeling and Analysis (SACEMA: http://www.aims.ac.za/sacema/) and has been active in setting up SACEMA based programs to study the HIV pandemic and the resurgence of TB in Africa.

Three members of the Getz Group have established projects outside of South Africa. George Wittemyer, in collaboration with Iain Douglas Hamilton's, the Kenyan based, Save the Elephants (STE: http://www.savetheelephants.org/) and the Kenya Wildlife Service, is studying the social behavior and ecology of elephants, with regard to park management and elephant conservation objectives in Kenya's Samburu National Reserve. Andy Lyons in collaboration with Development Services Initiative, a Zambian NGO, is evaluating the efficacy of community-based wildlife management programs in southern Zambia with a view to developing more effective programs through widespread use of IT technologies. Wendy Turner, in collaboration with the Etosha Ecological Institute, is setting up a program to study gastrointestinal-parasite/anthrax interactions and their role in regulating the plain's herbivores of Etosha National Park. Finally, the Getz Lab is involved in multi-institutional initiatives to obtain funding from the AHEAD program at Wellcome Trust to study human/live-stock/cattle interactions with regard to the epidemiology of bovine TB in southern and East Africa, as well as the spread of disease through movement of animals promoted by the establishment of transfrontier parks, particularly the Greater Limpopo Transfrontier Conservation Area at the confluence of the South African/Mozambican/Zimbabwean borders.

11 - Consequences of Parks for Land Use, Livelihood Diversification and Biodiversity in East Africa

Abe Goldman, Michael Binford and Jane Southworth
University of Florida, Email: agoldmn@geog.ufl.edu

Colin Chapman and Lauren Chapman
McGill University

J. Terrence McCabe
University of Colorado

Paul Leslie
University of North Carolina

This interdisciplinary collaborative research project examines the interactions among land use, land cover, peoples' livelihoods and biodiversity in landscapes surrounding Kibale National Park in western Uganda and Tarangire National Park in northern Tanzania. These landscapes are zones of dynamic demographic and land use change, including considerable agricultural expansion and intensification and in some instances, extensive in-migration from other areas. They also often represent zones of competition among ethnic groups and between objectives of the national government and of local land users. At the same time, the areas around the parks remain important habitats for biodiversity, including migratory species as well as those resident in the park or in forest fragments and other undomesticated habitats outside the formal boundaries of the park.

Two complementary research questions are the focus of the project: (1) How does the presence of a park affect agricultural land use and other livelihood strategies surrounding the park? (2) How do the extent, character and intensity of agriculture affect biodiversity outside the park, measured by the distribution of key indicator plant and animal taxa? Two overarching propositions relate to these: (a) the presence of a park will stimulate processes that lead to islandization of the park; and (b) the relationship between biodiversity and agriculture in the landscape surrounding a park is neither dichotomous nor linear, but will be positive under certain land use conditions and negative under others.

The study, which began in summer 2004, includes analysis of satellite imagery to identify landscape patterns and land cover change in recent decades; social science research to analyze the impacts of the parks on land use and risk, livelihoods, differentiation and migration; and biodiversity surveys to assess the presence of key indicator taxa outside the parks and analyze interactions among land cover, land use and biodiversity in those areas.

12- Dynamics of Change In the Lake Victoria Fisheries

Craig K. Harris
Department of Sociology, Michigan State University

The past 50 years have been extremely turbulent times for the fisheries of Lake Victoria. What stability there may have been 100 years was disrupted by gradually increasing human extraction of fisheries resources and then greatly disturbed by the introduction of a highly efficient top predator, the Nile perch (Lates niloticus). The Lake Victoria fishery is a tightly coupled human-biogeophysical system. The expansion of the Nile perch stocks created opportunities for profitable investment in harvesting, transporting and processing Nile perch for export. The consumption of the intermediate occupants of the trophic structure by the Nile perch and the export of large fractions of the harvested Nile perch, forced domestic consumers to move farther down the food web and to rely more heavily on small shrimp (Caradina spp.) and small "sardines" (Rastrineobola spp.), which in turn diminishes the forage base for the intermediate consumers. Socioeconomic pressures to maximize return on investment have motivated the owners and managers of physical capital in the fisheries to accelerate fisheries production by fishing more extensively and more intensively, by harvesting fish of smaller sizes and by extending the export fishery to tilapiine species (Oreochromis spp.). This accelerated extraction and production has led to concerns that a crash may be imminent.

As the lake with the second largest surface area in the world and the lake from which the Nile River emanates, Lake Victoria was a target for European explorers. As European colonial powers established plantations and colonial cities, fish from the Lake provided protein for agricultural and urban laborers. Independence for the three riparian nations (Kenya, Tanzania and Uganda) roughly coincided with the appearance of the Nile perch in the fisheries of Lake Victoria. The development of processing and exporting capability was motivated in significant part by the decline of the North Atlantic cod fisheries and the consequent need for a basic whitefish for food service institutional purposes. Although some fish was exported to the Middle East, to Asia and to North America, Europe was the predominant destination for Nile perch and tilapia exports. The dependence on Europe as a buyer for the fish exports gave the European buyers great influence on the extractive and processing activities. The European markets wanted whole fillets of a certain size, even though that size fish might be unlikely to have reached sexual maturity.

These changes in the Lake Victoria fisheries have been accompanied by the elaboration of a management superstructure. On top of the national fisheries departments and research institutions have been piled a regional fisheries organization and a World Bank project. Fisheries science in the region has come to be dominated by external donors, especially the World Bank and the European Union. But the management and the science that result from these arrangements often fail to consider the full range of interests in the Lake Victoria fisheries.

13 - Gobabeb Environmental Observatories Network

Joh Henschel and Mary Seely
Gobabeb Training and Research Centre, Walvis Bay, Namibia, Email: jhenschel@drfn.org.na

The Environmental Observatories Network Program of the Gobabeb Training and Research Centre straddles an extremely steep climatic gradient, ranging from hyperarid to arid, with a 300-fold increase in mean rainfall. Monitoring focusing on climatic variability, ephemeral river basin management, biodiversity and natural resource management has been

conducted for over 40 years. A range of ecological, climatological, geomorphological and socioeconomic variables are being monitored at Gobabeb. As a SADC Centre of Excellence, the Gobabeb Centre links research that furthers the understanding of an extreme environment to training so as to increase knowledge and skills that facilitate sustainable management of drylands. This African Training and Research Center is an ideal platform for collaborative programs with undergraduates, postgraduates, post-doctorates and visiting scientists coming coming from American academic and research institutions.

14 - Collaborative Regional Climate Modeling Studies and AMMA Field Experiment Efforts

Gregory S. Jenkins

Howard University Program in Atmospheric Sciences (HUPAS) Email: gjenkins@howard.edu

Amadou Gaye and Bamba Sylla

Cheikh Anta Diop University (UCAD) –Laboratory for Atmospheric Physics-Simeon Fongang (LPASF)

For the past 3 decades there has been a downward trend on wet season (June-September) rain totals. The causes of below normal rain has been linked to sea surface temperature anomalies (SSTAs), land-use change, natural variability and possibly anthropogenic climate change. The use of global climate models (GCMs) have helped to identify the role of SSTAs in the Indian, Pacific and Atlantic Oceans in producing negative precipitation anomalies. Here we show results from a regional climate model that has been driven by NCEP reanalysis from 1960-2002. The results suggest that SSTAs are forcing atmospheric conditions which are passed through the lateral boundary condition creating model simulated below normal rain totals for the 1970s, 1980s and 1990s. Additional model results will be presented. In order to understand how atmospheric conditions are linked precipitation processes, however, in situ measurements will be required. In 2006, the African Monsoon Multidisciplinary Activities (AMMA) experiment will take place in West Africa. Howard University will partner with UCAD for precipitation, microphysics, aerosol and radiation measurements in Senegal. The objectives and proposed set of measurements are presented at the SSA workshop.

15 - Real-Time Interactive Environmental Teleducation Between the United States and Southern Africa

Stephen A. Macko, Robert J. Swap and Thomas A. Szuba

University of Virginia, Department of Environmental Sciences, Charlottesville, VA 22903, USA Email: sam8f@virginia.edu

Harold Annegarn and Bane Marjanovic

University of the Witwatersrand, Johannesburg, South Africa

Francisco Vieira and Rui Brito

University of Eduardo Mondlane, Maputo, Mozambique

International education is a natural extension of global economies, global environmental concerns and global science. While faculty and student exchanges between geographic areas permit for educational experiences and cultural exchanges for the privileged few, distance learning offers opportunities for educational exchanges under any circumstance where time, expense, or location otherwise inhibit offering or taking a particular course of study. However, there are severe pedagogical limitations to traditional Web-based courses that suffer from a lack of personalized, spontaneous, exchange between instructor and student. The technology to establish a real time, interactive teleducation program exists, but to our knowledge is relatively untested in a science classroom situation, especially internationally over great distances. In a pilot project during the 2001-02 academic year, we offered a real-time, interactive class at three separate universities, which communicated instantaneously across an ocean at a distance of greater than 8,000 miles and seven time zones. The course, Seminar on the Ecology of African Savannas, consisted of a series of 11 lectures originating in either Mozambique (at the University of Eduardo Mondlane), South Africa (University of the Witwatersrand) or the United States (University of Virginia). We combined ISDN, internet and satellite linkages to facilitate the lectures and real time discussions between instructors and approximately 200 university students in the three countries. Although numerous technical, logistical and pedagogical issues—both expected and unexpected—arose throughout the pilot year, the project can be viewed as overwhelmingly successful and certainly serves as proof-of-concept for future initiatives, both internationally and locally. This review of our experience will help to prepare other students, faculty and institutions interested in establishing or developing international education initiatives.

16 - Livelihood Diversification among the Maasai of Northern Tanzania: Cultivation, Migration and the "New Thinking" in Ecology and Ecological Anthropology

J. Terrence McCabe

Department of Anthropology and the Environment and Behavior Program at the Institute of Behavioral Science, University of Colorado, Boulder Email: tmccabe@Colorado.edu

Paul Leslie

Department of Anthropology and the Carolina Population Center, University of North Carolina, Chapel Hill

In this poster we summarize results from recent NSF funded research focusing on the process of livelihood diversification among the Maasai of northern Tanzania. During the last 50 years the Maasai have adopted cultivation in a series of "waves", the most recent being in the 1990's. In addition, Maasai have recently begun to seek work in urban areas, building of their reputation as warriors by working primarily as guards. We also explore how this research articulates with the 'New Thinking" in ecology and ecological anthropology which incorporates issues such as non equilibrium ecosystems, unpredictability and complexity. We collected information on changing demographic patterns, household economic status, livestock holdings,

labor availability and cultural models of success over time. Our results demonstrate an increasing human population and livestock population that has fluctuated around a mean is an important component in the overall explanation for livelihood diversification, but that the process is also influenced by increasing rates of poverty, modernization and the way that people view themselves.

17 - Implementation of a New Wildlife Research Agenda in Tanzania

Charles Mlingwa
Tanzania Wildlife Research Institute, P.O. Box 661, Arusha, Tanzania Email: tawiri@habari.co.tz

The Tanzania Wildlife Research Institute was established in 1980 with the aim of conducting and supervising wildlife research and related activities in country. In 1999 the Institute drew up a New Wildlife Research Agenda to guide its work towards enhancing conservation of wildlife in Tanzania. The drawing up of the new agenda included participation of stakeholders namely national and international researchers both from natural and social sciences, wildlife managers, policy-makers, development supporting agencies and the general public. I present here progress made in the implementation of the research agenda in terms of on-going research programs/projects and call for increased collaboration with the Institute in this work.

18 - Association Liaison Office for University Cooperation in Development

Christine Morfit, Kay Ikranagara and Tony Wagner

Association Liaison Office for University Cooperation in Development1307 New York Ave., NW, Suite 500 Washington, DC 20005 Email: wagnera@aascu.org

The Association Liaison Office for University Cooperation in Development (ALO) assists the U.S. higher education community build their relationship with the U.S. Agency for International Development (USAID) and offers exciting opportunities for higher education institutions to be involved in international development. By internationalizing, the U.S. higher education community can bring the energy, creativity and entrepreneurship that exist on campus to bear on important global challenges and international development activities enhance the excellence and relevance of institutions in other countries and contribute to international and intercultural understanding.

A major focus of ALO activity has been the institutional partnership program. Since 1998, ALO has awarded 243 partnership awards worth over $43 million for work in 61 countries around the world. Of these, 84 grants worth more than $16 million have been awarded to support partnerships with African institutions.

The poster presented at the SSA workshop will feature a brief description of ALO and highlight some of the successful partnerships that have worked in the region on topics of interest to the workshop. These will be presented as examples of the types of opportunities available to workshop participants through ALO programs.

An example of a partnership that will be highlighted is the Montana State University, L'Institut D'Economie Rurale special initiative partnership in Mali. This partnership is addressing the need to build an integrated agricultural field research, extension and graduate education program in Mali. The partnership will develop a stronger collaboration between teaching and research through a "technology incubator center," joint research projects and shared teaching and dissemination program.

19 - An Overview of African Research in the FSU Climatology Lab

S.E. Nicholson and D. Klotter
Florida State University Email: sen@met.fsu.edu

This poster describes the various areas of research carried on in the Climatology Lab at FSU. Virtually all projects center on Africa. They span a diverse set of subdisciplines, including various aspects of basic climatology and climate dynamics, remote sensing, hydrology, land-atmosphere interaction, air-sea interaction, paleoclimatology and historical climatology. Within these disciplines, the research falls into three major area: the dynamics of tropical climate, long-term variability and earth system science. The poster indicates the papers published in each area, the major findings of the lab for each area and select examples of major results for each basic area of research.

20 - A Workshop for the Validation of TRMM Satellite Estimates of Precipitation Over Africa

S.E. Nicholson, B. Some and co-authors
Florida State University, AGRHYMET, Meterological Service of Burkina Faso Email: sen@met.fsu.edu

The overall goal of our TRMM project is to use gauge data from a dense station network over to validate TRMM rainfall estimates, other satellite estimates and blended products. This poster concerns the validation of level 3B-43 data (1o x 1o) on a monthly time scale for the year 1998 for West Africa. These efforts involved a workshop, held at FSU, in which scientists representing the meteorological services of 11 West Africa countries participated. They each brought monthly data for 1998 for all stations available in their countries. At a later time, daily data for 1998 and monthly data for 1999 will be utilized to continue validation efforts. At a later time, validation will extend to the entire continent, with high resolution validation carried out for an area of East Africa and an area of southern Africa.

Some 1026 stations with gauge data were utilized. A comparison was made between the gauge data and the TRMM-adjusted GPI, the GPCP blended data, the infrared-based GPI and the SSM/I microwave estimates. The comparisons consider mean fields, latitudinal transects and scatter plots of monthly rainfall for both 1o x 1o and 2.5o x 2.5o grids. Using the criterion of five gauges per grid for adequate rainfall estimates, 63 1o x 1o and

39 2.5o x 2.5o grid boxes could be utilized. Some of the latter contained over 90 gauges and most contained between 10 and 50 gauges, so that an excellent spatial averaged could be produced.

The mean fields derived from the dense gauge network, the GPCC gauge-only analysis and the GPCP are remarkably similar. The error, with reference to the rainfall field based on the denser network, is about 4% for either GPCC or GPCP. Agreement is relatively good even in individual years. The error associated with these data sets is about 4 % to 9 % and appears to be largely random, as the bias is generally less than .32 mm/day. In contrast, there are large systematic errors in the satellite-only analyses of GPI and SSM/I, on the order of 50 % to 60 % for the rain field as a whole and as large as a factor of two in many locations. This underscores the continued need for extensive gauge networks in order to adequately describe the large-scale precipitation field over Africa.

21 - AfricaArray

Andy Nyblade
Dept. of Geosciences, Penn State University, University Park, PA 16802 Email: andy@geosc.psu.edu

Paul Dirks
School of Geosciences, The University of the Witwatersrand, Johannesburg, South Africa Email: dirksp@geoscience.wits.ac.za

AfricaArray is a long-term (20 years) initiative to promote, in the full spirit of NEPAD (New Partnership for Africa's Development), coupled training and research programs for building and maintaining a scientific workforce for Africa's natural resource sector. Africa's natural resource sector (petroleum, minerals and water, in particular) is a major driving force for economic development. Africa is a primary source of strategic and base metals for the world market. Petroleum production from sub-Saharan African countries alone may provide 25% of U.S. oil imports by 2015. Water resources are needed for supporting sustainable livelihoods throughout the continent and in some countries geothermal reservoirs provide an important energy source. The name "AfricaArray" refers to an array of shared training programs, an array of shared scientific observatories, scientists across the continent working on an array of shared projects and above all, a shared vision that Africa will retain capacity in an array of scientific fields vital to the development of its natural resource sector. Initially, AfricaArray will focus on geophysics to:

- maintain and develop further geophysical training programs in Africa, in response to industry, government and university needs.
- promote geophysical research in Africa and establish an Africa-to-Africa research support system.
- obtain geophysical data, through a network of shared observatories, to effectively study scientific targets of economic and societal interest, as well as fundamental geological processes shaping the African continent.

Geophysics education and research has been selected as the initial focus for AfricaArray because geophysicists are in high demand in the strategically important fields of oil and gas exploration, mineral exploration, geothermal energy development, water resource development and earthquake hazard mitigation (including mine tremors). The discipline of geophysics is a cornerstone of many petroleum and mineral exploration programs. In fact, few oil and mineral discoveries are made without the use of advanced geophysical data sets to identify exploration targets, for example seismic reflection and airborne geophysical surveys. Geophysical exploration methods are also commonly used in prospecting for groundwater and geothermal reservoirs.

As demand increases for African geophysicists, especially in oil producing countries, what little capacity there is in Africa for geophysics training is disappearing fast, even though interest from students is high. Specialized fields like geophysics within African universities are particularly vulnerable in times of financial rationalization and competition for a skilled workforce. A recent survey of select mining and oil companies indicates that as many as 20 new geophysics graduates are needed every year by industry in Africa; additional geophysics graduates are needed in government agencies, particularly to work in water resource development and in academic institutions. There is insufficient capacity within Africa to provide high quality geophysics training for this number of students.

22 - Moving Conservation AHEAD (Animal Health for the Environment and Development): Progress at the Intersection of Program and Policy

Steven A. Osofsky, DVM, Michael D. Kock, BVetMed, MRCVS, MPVM, William Karesh, DVM and Robert A. Cook, VMD, MPA
Wildlife Health Sciences, Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, NY 10460 USA

David H. M. Cumming, PhD
Tropical Resource Ecology Programme, Dept. Biological Sciences, University of Zimbabwe, P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe

Richard Kock, MA Vet, MB MRCVS
African Union/Inter African Bureau for Animal Resources (OAU-IBAR) Pan African Programme for the Control of Epizootics, P.O. Box 30786, Nairobi, Kenya

A highly interactive forum was organized at which invited Southern and East African and other experts shared their vision for conservation and development success at the wildlife / livestock interface with IUCN World Parks Congress attendees and invited representatives from bilateral and multilateral development agencies and other interested parties. African governmental and nongovernmental experts from Botswana, Kenya, Malawi, Mozambique, Namibia, South Africa, Tanzania, Uganda, Zambia and Zimbabwe participated Our goal was to foster a sharing of ideas among African practitioners and development professionals that will lead to concrete and creative initiatives that address conservation and development challenges related to health at the livestock/wildlife/human interface. The focus was,

appropriately, on ongoing efforts and future needs in and around the region's flagship protected areas and conservancies and their buffer zones- the places where tensions and challenges at the livestock/wildlife interface are often greatest.

Discussions and planning focused on several themes of critical importance to the future of animal agriculture, wildlife and, of course, people: competition over grazing and water resources, disease mitigation, local and global food security, zoonoses and other potential sources of conflict related to the overall challenges of land-use planning and the pervasive reality of resource constraints. We have since been working to develop the most promising collaborative concepts that emerged from this forum into a suite of projects, grounded in real landscapes but cognizant of the critical need for policy reform and based on the solid professional partnerships we believe are emanating from the AHEAD (Animal Health for the Environment And Development) enabling environment.

As we look around the world, impacts from interactions between livestock and wildlife (and habitat) are often profound. The issues at this interface represent an unfortunately all-too-often neglected sector of critical importance to the long-term ecological and sociopolitical security of protected areas and grazing lands worldwide. With its initial focus on Southern and East Africa and its diverse land-use mosaic, we believe the AHEAD initiative can help facilitate collaborative work with and among African partners to continue to bring sound science to bear on natural resource management decisions that directly affect the livelihoods and cultures of Africa's people, including those decisions that impact the future of Africa's protected areas and wildlife resources. As socioeconomic progress demands sustained improvements in health for humans, their domestic animals and the environment, we recognize the need to utilize a "one health" perspective- an approach that was the foundation of our discussions at the World Parks Congress and that has guided the follow-on work since.

Since the September 2003 program launch, AHEAD has helped catalyze the development of several innovative regional projects that focus on the health/conservation nexus. In addition, the importance of these issues was formally recognized by the IUCN World Parks Congress when it officially included 'Disease and Protected Area Management' as a key emerging issue in its "Emerging Issues" documentation, http://www.iucn.org/themes/wcpa/wpc2003/english/outputs/durban/eissues.htm, the first time ecosystem health issues have been addressed like this in the Congress' 40 year history.

23 - Ecological Research in Tanzania

Craig Packer

University of Minnesota Email: packer@cbs.umn.edu

Tanzania has a long tradition of wildlife research. Tanzania National Parks (TANAPA) established the Serengeti Research Institute in the mid-1960s so that management policies could be based on objective scientific data. Funding for the institute was provided by foundations in Europe and North America. In 1980, Tanzania Wildlife Research Institute (TAWIRI) was established as an autonomous parastatal organization that coordinated research over the entire country. Today, wildlife research is being conducted in most of Tanzania's national parks and many of its game reserves; the Tanzanian government provides a modest amount of funding, and partnerships with western donors are highly valued.

The most intensive wildlife research in Tanzania is still being conducted in the Serengeti, and the community of Serengeti researchers has recently integrated their separate research programs into the NSF-funded project on the "Biocomplexity of the greater Serengeti – humans in a biologically diverse ecosystem." The Biocomplexity project aims to investigate the dynamics of coupled natural and human systems through collaborative and multidisciplinary investigation using mathematical modeling and collated long-term data from the Serengeti Ecosystem. The purpose is to understand how an ecosystem can persist in a matrix of non-biological socio-economic interactions.

Besides heading the Biocomplexity project, I lead two other NSF projects, "Viral transmission dynamics in Serengeti carnivores" and "Long-term studies of African lions." The most important goals of the Disease Project are to 1) develop realistic multi-host models of disease transmission by measuring contact rates between domestic dogs and wild carnivores (as well as between different wild carnivore species) and 2) determine if domestic dogs serve as the reservoir host for rabies and distemper via a large-scale ring vaccination of domestic dogs around the Serengeti. The lion project provides the most detailed data on any single species in the Serengeti, and it is particularly valuable in terms of the lions' response to ecological perturbations.

24 - Developing South Africa's Environmental Observation Network (SAEON)

J. C. Pauw

South African Environmental Observation Network, National Research Foundation, Private Bag X 2600, Pretoria 0001 Email: johan@saeon.ac.za

The rationale for a SAEON evolved from the Long-Term Ecological Research (LTER) paradigm that strives to overcome the limitations of normal environmental research which is mostly done in too short time frames on too small areas and focusing on too few variables to provide reliable answers within the context of ecological time and large ecosystems. Our vision is to establish an observation and research network that provides the understanding, based on long-term information, needed to address large-scale environmental issues. We aim to create a framework that permits collection, transmission and interpretation of data on slow variables in distributed network of observatories. The new understanding brought about through SAEON will inform suitable policies and appropriate actions for dealing with the inevitability of environmental change and its consequences for the livelihoods of South Africans. The core research framework of the SAEON is directed at studying the stressors of ecosystems such as climate change, land-use and settlement changes, eutrophication of the biosphere and the responses of ecosystems to these stressors as measured in its biodiversity, productivity and nutrient fluxes. Societal changes with regards to population growth and health, macro-economic vectors, institutional structures and tech-

nological advances/assimilation and how these influence ecosystem biodiversity and hydrology will become important new directions in environmental research. The SAEON will inform national programmes and policies directed at securing the competitiveness of the environment and sustainable development. It will enhance the ability to meet the requirements of international conventions (e.g. FCCC). This will also empower the public to participate fully in assessing the consequences of local, regional and national environmental and developmental scenarios as facilitated through the SAEON's education and outreach programmes.

25 - Monitoring and Understanding Long-Term, Large-Scale Environmental Change Across Southern Africa

Johan Pauw
South African Environmental Observation Network, National Research Foundation, Private Bag X 2600, Pretoria 0001

Joh Henschel

Gogabeb Training and Research Centre, P.O. Box 953, Walvis Bay, Namibia Email: jhenschel@drfn.org.na

The Environmental Long-Term Observatories Network of Southern Africa (ELTOSA) is a regional LTER network of country Environmental Observatories Networks (EON) encompassing the natural environments and their socio-economic context. In the global context, Southern Africa represents a unique geographic location. There is a great diversity of habitats and people, including extremes represented in several deserts and rainforests, escarpments and mountains, woodland savannahs and inselbergs, perennial and ephemeral rivers, swamps, lagoons and lakes, warm coral reefs and cold upwelling currents and oceanic islands ranging from tropical to uninhabited subantarctic. The region includes four global biodiversity hotspots and contains many large and famous national parks, game reserves, or other kinds of wilderness areas, harbouring not only fauna and flora, but also entire ecosystems and human settlements. There is a need to monitor the same kinds of habitats and parameters at different sites in order to fully understand the spatial dimensions of ecosystems drivers and response mechanisms, or to replicate observations. While EON monitors spatial shifts in species, vegetation types and productivity, it will be important to relate these to the dominant issues of climate change, water sources, use and needs, as well as land tenure, land transformation and land use. Rural people in Southern Africa depend on natural resources - many are poor and in dire need of improved livelihood security. They are subject to the vagaries of an already harsh environment and the shortage of resources and education that they have to cope with render then even more vulnerable to extreme events caused by climate change. The main challenges facing EON in Southern Africa are of the institutional kind. There is a need to maintain local leadership with regards to foreign funded long-term environmental research programmes.

26 - Dynamics of Poverty and Soil Degradation on Smallholder Farms in Central and Western Kenya

A.N. Pell, J.M. Kinyangi, S.O. Ngoze, D.R. Brown, C.B. Barrett, L.E. Blume, J.G. Gamara, C.J. Lehmann, P.P. Marenya, H.A. Markewich and A.O. S.J. Riha
Cornell University, Ithaca, NY, Email: ap19@cornell.edu

D.M. Mbugua
Cornell University, Ithaca, NY; Kenyan Agricultural Research Institute, Nairobi, Keny;, World Agroforestry Centre, Nairobi, Kenya

Odenyo
Cornell University, Ithaca, NY; World Agroforestry Centre, Nairobi, Kenya

L.V. Verchot and J. Wangila
World Agroforestry Centre, Nairobi, Kenya

Small changes in the natural resource base may have important consequences for poor smallholder farmers in the highlands of central and western Kenya. Likewise, modest changes in human activities may alter ecosystem functioning in these frequently degraded environments. Our project's goal is to capture the dialog between farmers and their environment in order to measure, understand and model the interlinked biophysical and socioeconomic processes characteristic of small crop-livestock farms in Kenya. We have collected data from 239 farms in two sites in central and western Kenya on soil chemistry and biology, crop and livestock production, socioeconomic conditions, land use and on-farm and off-farm labor allocation and investment patterns. To determine the effects of cultivation on soil fertility, soil samples have been collected from a chronosequence in an area where plots have been cultivated from 1 to more than 100 years. Total soil carbon and the aggregate light and free light fractions of soil organic matter decrease with time of cultivation while the organo-mineral fraction increases. Considerable effort has been expended to link social and biophysical aspects of the agro-ecosystem in a dynamic model in order to explore the relationships between farmers' perceptions of their options and biophysical and economic processes. Our prototype bioeconomic model includes modules for soil fertility and herd dynamics, cash resources and labor flows as well as crop and livestock production and the use of livestock manure as a soil amendment, reproducing the typical dynamics of the human and natural resource system. This simple model demonstrates the fertility and income dynamics common in the study area, where even minimal soil nutrient amendments (such as might be obtained by intercropping beans with maize and leaving residues on the field to be grazed by small animals during the dry season) can generate persistent gains in soil health and farmer well-being.

27 - Sources and Impacts of Atmospheric Aerosols over Southern Africa

S. J. Piketh, L. B. Otter and K. E. Ross
Climatology Research Group, University of the Witwatersrand, Johannesburg South Africa
Email: stuart@crg.bpb.wits.ac.za

The International Panel of Climate change report highlighted the effects that climate change will have on developing countries, especially Africa (IPCC, 2001). Although significant advances have been made in understanding human induced climatic changes, many scientific questions remain unanswered. At the forefront of these issues presently, is the role that aerosols play in the climate radiation balance (IPCC, 2001). Atmospheric transports from major source regions, such as the industrialized South African Highveld, distribute aerosols across the region enhancing the spatial range of their climatic effects which are known to be significant at a regional scale.

The Climatology Research Group's main research thrust is understanding the sources and impacts of atmospheric aerosols over the southern African subcontinent. Sources of aerosols include industrial emissions, biomass burning (natural and domestic), aeolian dust, biogenic and emissions from the adjacent oceans. The group has several research projects that involve measuring or calculating emissions of aerosols or their gaseous precursors. An attempt has also been made to evaluate the impacts of atmospheric aerosols on the radiation budget, cloud microphysical processes and the natural systems to which aerosols are deposited from the atmosphere. Research project titles over the past five years include the following:

1. Quantifying the emissions of gaseous aerosol precursors (isoprene and monoterpenes) from the biosphere.

2. Quantifying the emissions from domestic biomass burning in eleven countries in southern Africa.

3. Evaluating the impacts pf industrial emissions on cloud condensation nuclei (CCN) and cloud microphysical processes.

4. Estimating the impact of the deposition atmospheric aerosols to terrestrial and marine ecosystems.

This poster will present interesting components of the research activities of the Climatology Research Group.

28 - Landscape Interactions Between Pastoral People and Wildlife in East Africa: Competition, Synergies or Both?

Robin S.F. Reid, Mohammed Y. Said, Joseph Ogutu, Shem Kifugo, Andrew Muchiru and Sandra van Dijk
International Livestock Research Institute, Nairobi, Kenya, Email: r.reid@cgiar.org

N. Thompson Hobbs, Jeff Worden and Shauna Burnsilver
NREL, Colorado State University, Fort Collins, Colorado

Helen Gichohi
African Wildlife Foundation, Nairobi, Kenya

Our global objectives are to better understand the causes, processes and consequences of change in land use in pastoral ecosystems and what these mean for the future of these ecosystems and peoples . Our NSF-funded research questions in East Africa are as follows: 1) What are the patterns and processes of fragmentation in pastoral lands across a range of different environmental, political and economic systems? 2) What are the effects of landscape fragmentation on herbivores, ecosystems, enterprises and people? 3) More specifically, how does settlement by pastoralists modify the responses of wild herbivores to heterogeneity in grassland landscapes? Why do these influences occur? Do interspecific interactions, notably competition, facilitation, or predation, explain the effect of people on wildlife? We work principally in five ecosystems in northern Tanzania and southern Kenya: Longido, Tarangire/Simanjiro, Amboseli, Kitengela and Mara/Serengeti. We use household surveys, in-depth family interviews, livestock herd following, remote sensing analysis (air photos, Landsat TM, Modis), wildlife counts and vegetation surveys to quantify these interactions. We find three principal processes of social change that cause fragmentation in these systems: sedentarisation, intensification and diversification. In Kenya, land privatization is also strongly altering where people live, how they use the land and how they interact with wildlife. Pastoral and non-pastoral people settle first in the wetter pastoral lands and around key resources like swamps and riverine areas and reduce the spatial extent of their herding practices. At the regional scale, these social and other changes are causing strong declines in wildlife populations in much of the pastoral lands of Kenya and probably parts of northern Tanzania; but there may also be some positive interactions at the local level. In the Mara ecosystem of Kenya, our preliminary results suggest potential synergies between people and wildlife, as some species of wildlife preferentially cluster neither near nor far from pastoral settlements. We suggest that there are a suite of local-scale processes, including harassment, competition and/or facilitation of forage nutrient flows, protection from predators, that both repel and attract wildlife to pastoral settlements. We are attempting to develop robust models, at several scales, that explain why and how pastoral people and wildlife interact and use these models to suggest ways to better manage these integrated ecosystems into the future.

29 - Global Positioning System (GPS) Constraints on Arabia-Africa-Eurasia Plate Interactions and Inter-plate Deformations: Developing a Physical Basis for Earthquake Hazard Assessment

Robert Reilinger, Simon McClusky and Philippe Vernant

Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02142 USA Email: reilinge@erl.mit.edu

Woladai Ghebreab and Biniam Haileab

Department of Earth Sciences, University of Asmara, Asmara, Eritrea.

Greater Mediterranean GPS Consortium

We present the most recent results of an international program to use the GPS to map motions of the Earth's surface throughout the zone of interaction of the African, Arabian and Eurasian plates. Most of the GPS data for SSA comes from a global network of continuously recording GPS stations operated by independent institutions and archived with the International GPS Service (http://igscb.jpl.nasa.gov/). Our Consortium has focused on the major plate boundaries, including the complex deformation occurring in the Arabia-Eurasia collision zone (eastern Turkey, Zagros Fold and Thrust belt and Caucasus), the Africa-Eurasia interactions in the Mediterranean region (Atlas Mountain system, Calabrian, Hellenic and Cyprus arcs), the Arabia-Africa plate boundary (Dead Sea fault, Sinai block and Red Sea rift). GPS provides quantitative information on the rates and styles of deformation thereby providing new constraints on dynamic models for plate motions and interactions. This information in turn provides an improved physical basis for evaluating earthquake and volcanic hazards in the region.

30 - Determinants of Woody Cover in African Savannas: Is Tree-Grass Coexistence Disturbance Dependant?

Mahesh Sankaran, Niall Hanan and Jayashree Ratnam
Colorado State University, Fort Collins, CO, Email: mahesh@nrel.colostate.edu

Robert Scholes
CSIR, Pretoria, South Africa

Despite decades of research, the origin, nature and dynamics of savannas are not fully understood. In particular, mechanisms permitting trees and grasses to coexist and factors determining the relative proportions of each life-form across different savanna types are complex. Resource availability (water, nutrients), fire and herbivory are all thought to exert important regulatory influences on savanna structure, but perceptions differ on which mechanisms are most important under which conditions. In part, the lack of consensus arises because most studies have been small-scale and site specific: it is likely that different processes are active to different degrees in different savannas of the world. Here, we report results from a continental scale analysis of structure in African savannas (~850 sites) aimed at investigating the relative importance of and interactions between, the different factors across broad environmental gradients. Our results suggest that savannas switch from being water-limited 'stable' systems to disturbance-mediated 'unstable' systems across a gradient of increasing rainfall. Between 200 mm and 650 mm mean annual precipitation (MAP), water availability limits tree cover and permits grasses to persist in the system. In this range of rainfall, fire and grazing, although capable of modifying tree-grass ratios, are not necessary for tree-grass coexistence. Thus arid and semiarid African savannas (<650 mm MAP) can be considered stable systems where fire and herbivory, though of great importance in determining actual woody cover and density, are not essential for tree-grass coexistence. Above 650 mm MAP, water availability appears sufficient to support tree canopy closure such that grasses can be out-competed. Savanna systems in this range of rainfall are unstable systems where disturbances such as fire, grazing and browsing are required for tree-grass co-existence.

31 - Biogeochemistry of Semi-arid Savannas and Plantation Forests in Southern Africa

Mary. C. Scholes
School of Animal, Plant and Environmental Sciences, Private Bag 3, University of the Witwatersrand, Johannesburg, South Africa Email: mary@gecko.biol.wits.ac.za.

Ecosystem evolution in Africa has been determined by a complex set of changing interactions between herbivores, fire, man, climate and soils. Water availability determines ecosystem function by controlling the duration of the period for which processes such as primary production and nutrient mineralization can occur. The difference between ecosystem function under the same climate is largely determined by the presence of herbivores and other forms of land use and management practices. Two ecosystems in South Africa, savannas and plantation forestry, form the focus of this research programme. The research group consists of postdocs, MSc and PhD students. The studies focus on the biogeochemistry of the systems with emphasis on nitrogen, carbon and phosphorus.

Savannas: The Kruger National Park is a large wildlife conservation area, with stratified rainfall and soil nutrient patterns. The western half consists mainly of low nutrient, granite-based soils with higher nutrient, basaltic soils in the east and rainfall decreasing from south to north. Spatial heterogeneity of the fertile and infertile areas influences the size of the elemental pools and the transfer of elements between the terrestrial and atmospheric components. Within these stratifications, foraging patches were compared by determining the percentage tuft utilization and number of faecal deposits at the extremes of a utilization gradient. Sodic sites and termite mounds are preferred foraging areas, with high site productivity contributing substantially to the nutritional status of the herbivores. Enhanced moisture status of the sodic sites leads to nitrous oxide emissions, with nitric oxide emissions dominating the drier upland site. Understanding the factors that determine herbivore distribution will provide insights into how ecosystems have co-evolved with large herbivores and thereby improve our abilities to manage these systems.

Plantations: Southern Africa is covered by less than 1% of indigenous forests but the demand for wood and wood products is high. Extensive areas of high altitude grasslands have been planted with Eucalyptus and Pinus species since the 1960s. The forestry industry needs to grow timber in a sustainable manner at a competitive price; it also needs to comply with many national and international regulations linked to sustainable development. Some of the major findings include: nitrogen deposition is high, up to 40kgN ha-1 yr-1 : there is no conclusive data to support yield decline with rotation: soil total carbon and light fraction carbon levels are being used as indicators of sustainability: the development of an index for nitrogen mineralization has proved to be useful for inclusion as a predicative indicator of yield.

32 - Climate Research over the Greater Horn of Africa (GHA)

Fredrick Semazzi, Rich-

ard Anyah, Jared Bowden and Robert Mera
North Carolina State University, Climate Modeling Research Laboratory Email: fred_semazzi@ncsu.edu

Over the past decade, the Climate Modeling Laboratory at North Carolina State University (NCSU), in collaboration with the University of Nairobi, Kenya and the IGAD Climate Prediction and Applications Center (ICPAC), have spearheaded a number of climate research initiatives for the GHA sub-region. While the primary aim is to contribute to the development of a state-of-the-art seasonal climate prediction system for the region, the broader goals are to improve understanding, characterization and prediction of climate variability over the region on sub-seasonal, inter-annual and longer time scales. The ongoing work covers four major research areas: (i) Diagnostics based on observations and output from global climate models (GCMs). This comprises use of empirical techniques to diagnose and build predictor-predictand relationships between GHA climate and the global circulation systems and/or teleconnections such as global sea surface temperature anomalies, (2) global climate modeling, which involves GCM ensemble simulations and sensitivity experiments to study seasonal to inter-annual variability of the regional climate, (3) dynamical downscaling of GCMs using regional climate models (RCMs) and (4) development of end-user interface, via decision theory modeling.

Through rigorous empirical analysis we have demonstrated that there is a very succinct decadal trend in the regional climate over the latter decades during the last century that eluded previous studies. This trend is characterized by increasing temperatures over most of the sub-region (probably a footprint of global warming). The trend is also associated with a dipole pattern of rainfall anomalies; drier/wetter conditions over areas south/north of the equator. This is, consistent with the accelerated retreat of the snow over Mt. Kilimanjaro that falls within the drier corridor.

Our GCM ensemble simulations also demonstrate the potential of using such models to understand the variability and even make projections of the GHA climate associated with large-scale (global) climate circulation anomalies such as El Niño. This potential predictability of El Niño related climate anomalies over the GHA is particularly important given the current capability of GCMs to predict such events with lead times of up to 12 months.

In order to understand the modulating effects of the complex terrain and land surface heterogeneities on the sub-regional climate, the information resolvable by the GCMs is unsatisfactory for many applications. To this end, our dynamical downscaling efforts have culminated into the successful customization (modification) of NCAR regional climate model (RegCM3) for simulating the GHA climate. In addition, we have developed a fully coupled RegCM3-3D lake modeling system for Lake Victoria basin. It is evident from our results that for the lake basin (catchment scale) applications, the traditional modeling approach in which the lake hydrodynamics are neglected and only the lake thermodynamics are incorporated through simplified thermal diffusion formulation is not entirely satisfactory. However, the biggest constraint to many of our modeling initiatives over the GHA is inadequate validation data, especially at the catchment scale.

33 - Forest Cover Change and its Implications to the Conservation of Forest Resources: Case Study of the Beira Corridor

A. Sitoe, B. Guedes, J. Argola, F. Tchaúque, A. Muhate and J. Monteiro

Department of Forestry, Eduardo Mondlane University, P.O. Box 257, Maputo, Mozambique Email: sittus@zebra.uem.mz

The Beira Corridor is a concept of a railway, a highway and an oil pipeline crossing four districts with several villages and towns in a distance of about 200 Km. Ecologically, the area covers several vegetation types, from mangroves to mountain forests intercalated by grasslands and different types of savanna and forests. This represents the variation of altitude ranging from sea level to about 1000 m.a.s.l. High population pressure and poverty, among other aspects result in degradation of forest resources resulting in and an A study aiming at the understanding of the forest cover conversion rates, biomass distribution and the main causes leading to forest cover change. Landsat TM images were used to estimate forest cover change between 1990 and 1999. Destructive methods were used to evaluate woody biomass in different forest types. Ground truthing were accompanied by a questionnaire to identify the major causes of forest conversion. Dependence on wood biomass for energy, slash agriculture for subsistence and uncontrolled use of fire for hunting, result in high forest conversion rates threatening the biodiversity of plant and animal species, although species were not identified at this stage. Forest conversion rate (among different vegetation cover types) was estimated at 25% per year and a deforestation (conversion from forest to non-forest) was estimated at 1.2% per year for the study period. Estimated wood biomass varied from 17 ton.ha-1 to 64 ton.ha-1. Although deforestation rate is relatively low, changes from dense forests to more open forest types may lead to local extinction of plant and animal species, with negative consequences to the local communities depending on these resources. Further studies, including the identification of species and the establishment of a transect for long term observation are suggested. Social and economic studies are also suggested.

34 - BioNET-INTERNATIONAL: the Global Network Taxonomy for Taxonomy

Richard Smith and Lucie Rogo
BioNET-INTERNATIONAL Email: l.rogo@bionet-intl.org

BioNET-INTERNATIONAL is a donor funded, non-profit, non-governmental initiative with sub-regional inter-governmental organizations in the form of Technical Cooperation Networks. The Global Network is comprised of sub-regional Technical Cooperation Networks of developing country institutions supported by a consortium of expert institutions and a Technical Secretariat.

The sub-regional networks are technical cooperation networks based on the UNDP model and are known as Lo-

cally Owned and Operated Partnerships (LOOPs). They are permanent structures formed by intergovernmental agreement. Ten LOOPs are operational. The networks were establish to assist developing countries to overcome the taxonomic impediment by becoming self-reliant in taxonomy i.e. self-reliant in the skills, infrastructure and technologies needed to discover, identify, classify and to understand the relationships of all organisms on this planet. In addition, these networks were also established to assist developing countries to recognize and know the organisms that constitute and threaten their biodiversity, not for taxonomy's own sake, but rather to support national programmes for sustainable agricultural development, and conservation and sustainable use of the components of the environment.

Each regional network decides its own priority activities. These typically include training, rehabilitation of taxonomic resources, effective communication within and between networks, ensuring access to new technologies and guaranteeing the sustainability of the networks.

Outputs include: new taxonomic capacity and services at the local, national and regional levels; new foci of taxonomic expertise; new access to, and new reference collections, records, information; and self reliance via local ownership of taxonomic services.

In Africa, four LOOPs have been established. These are:

EAFRINET-this network includes institutions in Eastern Africa countries;

SAFRINET- this is the Southern African network and is operated under the auspices of SACCAR and endorsed by all SADC countries;

WAFRINET- this network includes institutions in countries in West Africa;

and

NAFRINET- this network includes institutions of countries in North Africa.

Development of partnerships between United States of American institutions and institutions in sub-Saharan Africa within these networks could encourage effective collaboration in research and promote capacity building in the sub-Saharan region.

Core funding for BioNET's global secretariat has come from the Swiss Agency for Development and Cooperation while LOOP work programmes have been undertaken with a number of technical and funding partners who will be identified in the poster presentation.

35 - The University of Virginia 'People, Culture and Environment of Southern Africa' Summer Study Abroad Program – An Example of a Collaborative International Educational Program

R. J. Swap, L. Estes, H. Sabea and C. Terni
University of Virginia, USA Email: swapper@virginia.edu

H. Annegarn
University of Johannesburg, South Africa

C. Ford and W. Twine
University of the Witwatersrand – Johannesburg Rural Facility, South Africa

V. Netshandamu and P. Omara-Ojungu
University of Venda, South Africa

K. Vaz and N. Ribeiro
University of Eduardo Mondlane, Mozambique

F. Eckardt
University of Botswana, Botswana

We describe an interdisciplinary course (Environmental Science and Anthropology) for the non-specialist undergraduate students in which students have the unique opportunity to gain insight into the role the environment plays in shaping the people and culture of southern Africa. The program builds upon more than 12 years of relationships between UVA faculty and their southern African colleagues. UVA students will interact with students and faculty from multiple institutional partners in the Southern Africa Virginia Networks and Associations (SAVANA) consortium of institutions of higher learning. Students from the USA are joined by their counterparts from universities within the consortium in the classroom, in the field and in discussions.

The program involves an intensive blend of in-class lectures (mornings) and field trips (afternoons) with daily debriefing discussions (evenings). The full days provide a comprehensive interdisciplinary introduction to the people, culture and environment of southern Africa. The UVA-SAVANA relationship offers students a chance to meet operators of game reserves, experience village life and research firsthand and to interact with local people in a way that is meaningful both for students and their hosts. The program involves students spending time at seven different locations: Johannesburg, Gauteng Province, South Africa (University of the Witwatersrand); Thohoyondou, Limpopo Province, South Africa (University of Venda); Maputo/Massengir/XaiXai, Mozambique (University of Eduardo Mondlane); and Acornhoek, Limpopo Province, South Africa (University of the Witwatersrand – Rural Facility).

The class size is kept to 12 to 15 students from the University of Virginia and about 6 African students from the Southern African Virginia Networks and Associations (SAVANA) consortium. This pairing with SAVANA students provides a unique, 'round-the clock' learning experience for both U.S. and southern African students.Program participants have come from a variety of undergraduate majors and student backgrounds. Among course alumni are majors in: Anthropology, African American Affairs, Architecture, Biology, English, Environmental Thought and Practice, Environmental Science, History, International Relations, Political Science, Psychology, Sociology and Women's Studies. Many program participants are also active members of the University community at home, serving in student government and on the executive boards of student organizations. Participants from the 2003 South African Summer Study Abroad program created and maintain the University Giving Tree (UGT) group here on Grounds. Former

participants have gone on to join Peace Corps, Teach for America, Americorps as well as to volunteer in South Africa and domestically.

36 - Sustainable Watershed Management in Uganda: Opportunities and Challenges

M. M. Tenywa, M. J. G. Majaliwa, E. J. Wasige and A. Lufafa
Makerere University, Department of Soil Science, P. O Box 7062, Kampala-Uganda E-mail: soilscience@agric.mak.ac.ug

M. K. Magunda
Kawanda Agricultural Research Institute, P.O. Box 7065 Kampala-Uganda

R. Lal
The Ohio State University, School of Natural Resources 2021 Coffey Rd. Columbus OH, USA

J. Gowing
University of Newcastle upon Tyne, Centre for Land Use and Water Resources, NEI 7RU Newcastle upon Tyne, UK

P. L. Woomer
Sustainable Agriculture Centre for Research and Development (SACRED) in Africa, P.O. Box 2275, Bungoma, Kenya

Sub-Saharan Africa is facing declining land productivity, interalia as a result of poor land management coupled with climate variability. An over view of the efforts towards sustainable watershed management in three basins (Lake Victoria-sub-humid, Lake Kyoga-semi-arid and Mt. Elgon-humid) in Uganda is presented. Watersheds related issues investigated in the last 10 years were aimed at improving decision making processes through understanding of soil moisture deficits in the semi-arid areas, nature and magnitude of degradation in the sub-humid areas and management of watersheds that cross political boundaries in the decentralized humid districts. A combination of experimentation and modeling approach has been used. Results of the water balance from semi-arid lands revealed the major rainwater loss pathway as ET (91.2%). For the sub-humid areas the GIS-based USLE studies showed that soil loss rates are generally above the threshold of 5 t ha-1 being highest in annual cropping systems and originating from designated "hotspots" identified using AGNPS model. For the humid areas, a sub-county watershed index (SCWI) was developed to guide management of watersheds that cross-political boundaries. Given resources, plans are underway to scale up these studies across the basins using a modeling approach and develop a Decision Support System for sustainable natural resource management.

37 - Building Central Africa's Capacity in the Understanding and Monitoring of Forest Dynamics

D. W. Thomas, R. Condit and E. C. Losos
Center for Tropical Forest Science, Smithsonian Tropical Research Institute Email: duncanwt@aol.com

B. Bishaw and D. Hibbs
Department of Forest Science, Oregon State University

G. B. Chuyong
Department of Life Science, University of Buea, Cameroon

C. Ewango and D. Kenfack
Department of Botany, Missouri Botanical Garden

T. Hart and J. R. Makana
Wildlife Conservation Society, Kinshasa, D.R.Congo

The Center for Tropical Forest Science coordinates a global network of long-term research sites, two of which are located in tropical Africa: the Korup Forest Dynamics Plot in Cameroon and the Ituri Forest Dynamics Plots in the Democratic Republic of Congo. Each plot program has a number of collaborating institutions and many scientists, both African and foreign. All plots in the network are linked by common field methodology and this translates into shared methods of data analysis, comparable results and highly replicable approaches for using forest dynamics in sustainable forest management. The plots are all permanent, of large size (up to 50 hectares) and are censused regularly for all trees 1.0 cm diameter and above. The CTFS approach is a very effective vehicle for training and capacity-building in central Africa, since it involves long-term association between institutions and scientists, to conduct successive plot censuses and data analyses and implement ancillary research programs.

Network activities that contribute to training and capacity-building include intensive training in data analysis and statistics and in formulating and answering questions about forest growth and diversity that are relevant to sustainable forest management. Workshops for Africa have focused on the analysis of forest plot data, on field methods for data collection and on botanical inventory methods, as well as conferences to present research findings. As layers of information are added at each plot, the sophistication of the research that can be accomplished and of the hypotheses that can be tested increases. African scientists are encourage through grants and technical support to design and implement their own research, often in collaboration with scientists from other sites.

38 - Fire - A Key Factor in the Ecology and Management of African Grasslands and Savannas

W. S. W. Trollope and L. A. Trollope
Department Livestock and Pasture Science, Isebe Lemfuyo Namadlelo, University Fort Hare, Private Bag x1314, Alice, 5700 South Africa Email: winfire@procomp.co.za, wtrollope@ufh.ac.za

Fire is regarded as a natural ecological factor of the environment in Africa that has been occurring since time immemorial in the savanna and grassland areas of the continent. The capacity of Africa to support fire stems from the fact that

it is highly prone to lightning storms and has an ideal fire climate comprising dry and wet periods. It also has the most extensive area of tropical savanna in the worldwhich is characterised by a grassy understorey that becomes extremely inflammable during the dry season. The use of fire in the management of vegetation for both domestic livestock systems and in wildlife management is widely recognised. Research on the effects of fire has been conducted throughout the grassland and savanna areas of Africa since the early period of the twentieth century and focused on the effects of season and frequency of burning on the forage production potential of the grass sward and the ratio of bush to grass in African savannas. However, in 1971 a conference was convened in the United States of America by the Tall Timbers Research Station at Tallahassee in Florida on the theme of "Fire in Africa." This congress was attended by fire ecologists from throughout Africa and the major benefit that accrued from attending this meeting was the realization that in Africa the study of fire behaviour and its effects on the ecosystem, as described by type and intensity of fire, had been largely ignored in all the fire research that had been conducted up until that time. This led to the further recognition that the effects of fire must include the effects of all the components of the fire regime on the ecosystem viz., the type and intensity of fire and the season and frequency of burning. As a consequence a research program was initiated in South Africa in 1972 and later extended to East Africa in 1992, to characterise the behaviour of fires burning in savanna and grassland vegetation and determine the effect of type and intensity of fire on the vegetation. This research program has successfully developed a greater understanding into the effects of type and intensity of fire in African grasslands and savannas. This in turn has led to the development of more effective and practical guidelines for the fire regimes to be used in controlled burning for domestic livestock and wildlife management systems in the grassland and savanna areas. Research on the fire ecology of grasslands and savannas continues to enjoy scientific attention in Africa and currently there are active research programs being conducted in the Eastern Cape Province, KwaZulu-Natal Province and the Kruger National Park in South Africa and the Ngorongoro Crater in Tanzania.

39 - Making Digital Science Productive and Meaningful in the Developing World

Paul F. Uhlir, Julie M. Esanu and Amy Franklin
Office of International Scientific and Technical Information Programs, The National Academies Email: puhlir@nas.edu

The digital revolution is fundamentally transforming not only the conduct of scientific research, but virtually all spheres of human endeavor worldwide. The extent and rapidity of this change offers unprecedented opportunities for creating, managing, disseminating and using scientific and technical (SandT) data and information. It also raises new challenges that need to be confronted. Many opportunities arise in the evolving "information societies" and "knowledge economies," whether through data-intensive research and applications, in the conversion of data into higher levels of information and knowledge, or by making vast amounts of factual and scholarly information available for a broad spectrum of end users. The inherent challenges are in effectively managing these information resources for optimal access and use and for developing rational rules and structures for that process.

Not surprisingly, developing countries face the highest hurdles and in many respects have the greatest information management and access requirements. Factual databases and the scientific literature provide important research, socio-economic and policy tools for these countries, just as they do in more economically developed nations. Digital (SandT) data and information and the underlying ICT infrastructure form an essential resource for capacity building in science and education and for successfully addressing pressing social problems, supporting sustainable development of commerce and industry and promoting good governance. The greater the access to digital resources, the greater the potential uses and value that can be derived from them.

Without the means to effectively develop, preserve, access and use foundational databases and the scientific literature, as well as other key elements of the modern ICT infrastructure, developing countries are almost certain to fall further behind in their quest to reap the benefits of the digital revolution. Although in many cases this is happening today, it is not an inevitable outcome. The possibilities to leapfrog into state-of-the-art information infrastructure and management practices are not necessarily as remote as they may seem. This is particularly true for those countries that have a strong educational foundation and stable governance. Positive examples and success stories continue to multiply. Yet there are insufficient activities focusing on these problems at both the national and international levels. Working to resolve the many different challenges in this arena today will produce significant intellectual capital—with great return on investment—for future generations.

Toward these ends, the National Academies' Office of International Scientific and Technical Information Programs is focused on improving the management, accessibility and use of SandT data and information by the research community worldwide. Particular emphasis is placed on the situation in developing countries and on promoting appropriate national and international policy measures in support of these objectives. The attention to developing countries is not simply a matter of altruism, but equally one of self-interest, since science is inherently an international endeavor. This poster will summarize our portfolio of developing country activities in the digital information arena.

40 - Ecoinformatics Training: Toward Data Sharing and Collaborative Research

Kristin Vanderbilt
Sevilleta LTER, University of New Mexico, Albuquerque, NM 87131 Email: vanderbi@sevilleta.unm.edu

Ecological research encompasses a range of themes including biodiversity, global change and sustainability that require data be obtained and synthesized across larger temporal and spatial scales than traditional plot-based ecological studies. One way ecologists are beginning to address questions at this scale is through collaborative international research programs. This kind of collaboration requires not only communication of verbal and writ-

ten correspondence but communication of data and methodologies across spatial, disciplinary and cultural distance as well.

Good data management procedures and protocols will be essential to developing and testing hypotheses at the international network level. Data management in large-scale projects provides the quality assurance, documentation and accessibility that make data communication and exchange possible. Data management also provides long-term value to the data by assuring that archived data can be retrieved and understood by investigators in the future. Training programs in effective data management facilitate better research and increases productivity through the development of practical solutions and adoption of standards.

The Long Term Ecological Research (LTER) Data Management group has accumulated over two decades of experience in managing ecological data and has established protocols and standards in this area. Members of this group have facilitated information management training sessions for several international audiences, including a group of scientists and technicians from ELTOSA who met in Mozambique in 2002. These training workshops have emphasized the basic components of an information management system, which include detailed data documentation (metadata), quality assurance and quality control, data archival and mechanisms for the discovery and retrieval of archived data. Training workshops such as these help scientists without an information management background to acquire the basic skills necessary to establish a system for documenting, storing and making their data available to other researchers in order to foster collaborative research.

41 - Impacts of Land Cover Change along the Tanzania Coast: A Case Study ofGeographic Information for Sustainable Development

Y.Q. (Yeqiao) Wang, Gregory Bonynge, Jarunee Nugranad and Michael Traber
Department of Natural Resources Science, University of Rhode Island, Kingston, RI 02881, USA Email: yqwang@uri.edu

Vedast Makota
National Environment Management Council, P.O. Box, 63154, Dar es Salaam, Tanzania

Amani Ngusaru
Institute of Marine Sciences, University of Dar es Salaam, P.O. Box 668, Zanzibar, Tanzania

James Tobey
Coastal Resource Center, University of Rhode Island Bay Campus, Narragansett, RI 02882, USA

Tanzania coastal line is a representative section of Eastern African coast. It extends 840 km from Kenyan to Mozambique and is biologically and physically varied. Tanzania coastal area is experiencing rapid land-use and land-cover change (LULCC) as the result of population growth, urban development and intensified agriculture and mariculture. Spatial information on LULCC is in great demand for coastal management. In this project remotely sensed images from 1990s Landsat Thematic Mapper (TM) and 2000 Landsat-7 Enhanced Thematic Mapper Plus (ETM+) sensors and geographic information system (GIS) technologies are applied to discern LULCC in coastal districts of Tanzania. Results of change detection show that areas of urban land increased dramatically. Areas of mangrove forests declined modestly, but field verification shows severe deterioration of their conditions near urban areas. While the areas of dense woodland decreased, the areas of open woodland and the areas of woodland interspersed with agriculture increased. This study answered key management questions; built capacity for use of science and spatial information in management; and identified priority locations for coastal planning and conservation. There is an increasing need for the use of science-based decisions for policy making in Tanzania. Coastal and natural resource managers in particular have recognized the value of this type of information for resource management and sustainable development. This reflects the level of attention given to scientific and technological issues in general on the part of coastal management professionals. The integrative quality of geographic information that links social, economic and environmental data opens new opportunities for collaboration among natural scientists, social scientists and decision-makers at all levels. The intersection of resource use, land-cover change, poverty and environmental management, with their attendant social and economic consequences, are at the forefront of coastal and marine management in Tanzania. Successful implementation of recent national priorities addressing poverty alleviation and integrated coastal management require objective scientific information to assist with developing policy priorities, understanding cause and effect linkages between human activities and ecosystem changes, formulating management strategies and devising conservation measures. The results from this study demonstrate and encourage on the use of geospatial technologies and information in environmental and natural resources monitoring. It also provides comprehensive scientific data for further studies of environmental impacts of human-induced LULCC on the near-shore coastal ecosystems of the Eastern Africa.

42 - Africa and the Global Carbon Cycle: Field Networks and Model Studies of African Carbon Exchange

Christopher A. Williams, Niall Hanan and A. Scott Denning
Colorado State University, Fort Collins, CO, Email: caw@nrel.colostate.edu

Joseph Berry
Carnegie Institution of Washington, Stanford, CA

Robert Scholes
CSIR, Pretoria, South Africa

Jason Neff
University of Colorado, Boulder

Jeffrey Privette
NASA-GSFC, Greenbelt, MD

Two new initiatives seek to improve our understanding of carbon exchange and land surface atmosphere interactions in African ecosystems at time scales encompassing hourly to multi-annual and space scales from sub-landscape to continental.

The Afriflux project seeks to develop a network of scientists and students interested in ecosystem-atmosphere exchange of carbon dioxide, water and other trace gases in African ecosystems. Afriflux will enhance our understanding of African ecosystems, the determinants of productivity and biogeochemical cycles, the supply of ecosystem goods and services and the interactions between African vegetation and regional and global climate. Several eddy flux sites are established in Africa and more are planned and the network is designed to solidify collaboration and synthesis among these groups. The major emphases of the network include workshops focusing on joint data analysis, graduate student exchanges and capacity building that will enhance long-term collaboration and integration of understanding among and between the diverse African landscapes.

The African Carbon Exchange project (ACE) is designed to improve our understanding of regional and global carbon dynamics through an inter-annual study focused on Africa. ACE will utilize an array of techniques to understand how climate variability and human activities affect continental-scale carbon cycle and atmospheric carbon dioxide concentrations. We are using a combination of methods to provide more tightly constrained estimates of the spatial and temporal variation in carbon uptake and release from the region. The project builds on data and understanding from intensive field sites in the region (the Afriflux network) and will add targeted measurements for the purposes of this work. Satellite data will be used to estimate the spatial and temporal variation in vegetation activity at weekly to multi-annual time-scales across the continent. These data are being used to parameterize terrestrial carbon balance models that predict spatially and temporally continuous fields of net carbon, water and stable isotope exchange. In parallel with this "forward modeling" we plan inverse analysis of [CO2] and stable isotope concentrations, using the existing flask measurement network augmented by new high precision [CO2] measurements. The novel combination of forward and inverse estimates of African carbon exchange will lead to improved estimates of the spatial and temporal dynamics of carbon and water exchange in Africa and lead to an improved understanding of the impacts of climate, climate variability and land use on carbon exchange and the contributions of Africa to the global carbon cycle.

43 - Impact of Agricultural Techniques on Wetland Processes - Uganda, Africa: Treatment Reliability and Hydraulic Strategies

Chad Yaindl, Rachael Oleski, Roger Ruggles, David Brandes and Arthur D. Kney
Lafayette College

Lammeck Kajubi
Makerere University

Over the past ten years Lake Victoria in Africa, the second largest freshwater lake in the world has begun to show signs of stress due to anthropogenic influence documented by indicators such as biochemical oxygen demand (BOD) and various nutrients (i.e., nitrogen and phosphorous). The increased concentrations of the nutrients may help to explain the increased growth of water hyacinth (Eichhornia crassipes). In addition, metals such as lead and cadmium have been reported at levels of concern in Lake Victoria.

To address these issues of increasing pollutants in and around Lake Victoria a cooperative study between Makerere University, Uganda, Africa and Lafayette College, Easton PA, USA, has been established through a National Science Foundation (NSF) program - International Opportunities for Scientists and Engineers Program (IOSEP). The overall study consists of four components:

1. A study of transition through a historical assessment of land use utilizing remotely sensed images

2. Rapid monitoring of the wetland-lake interface on Lake Victoria

3. Comprehensive chemical, hydrologic and sedimentation assessment of selected Kampala and Jinja, Uganda wetlands.

4. Wetland construction research examining innovative agricultural techniques, treatment reliability and hydrologic strategies.

This particular study, the impact of agricultural techniques on wetland processes, addresses components 3 and 4 of the overall IOSEP study. Based on observations made by our Makerere/Lafayette team over the summer of 2003 it appears that many of the inland wetlands adjoining the towns of Kampala and Jinja, Uganda are being increasingly used for agricultural purposes. Because of this practice it is hypothesized that this valuable natural pretreatment infrastructure (i.e., wetlands) is being affected in such a way that the primary wetland buffers along the shores of Lake Victoria are unable to handle the typical pollutant loads as in the past, thus leading to increased loading of the lake. It remains unclear as to how the alteration of these inland wetlands is affecting the overall treatment of runoff entering Lake Victoria.

Over the summer of 2004 a team of faculty and students from both Makerere began to study the affect agricultural practice has on inland wetlands. Influent and effluent samples were taken from undisturbed and disturbed wetlands of similar size, age and influent characteristics anywhere from 2 to 4 times over the summer. Sampling parameters include chemical oxygen demand (COD), nitrogen (as N), phosphorous (as P), pH, conductivity and turbidity. Results were analyzed and recommendations for further study were developed. Recommendations include considerations of integrating agricultural practices that address hydraulic strategies and treatment reliability.

44 - An Integrative Approach to Understanding Biodiversity in Madagascar

Anne D. Yoder and Carol Hanley
Yale University Email: anne.yoder@yale.edu

Achille Raselimanana
WWF Madagasar

Steven M. Goodman
Field Museum of Natural History, WWF Madagascar and Université d'Antananarivo

Madagascar has been designated as one of the most critical geographic priorities for conservation action, retaining less than 10% of the natural habitats that existed before human colonization. It is critical that information be obtained as quickly as possible to document the biota that occurs in the remaining and highly threatened forested areas of Madagascar, to gain an understanding of the evolutionary processes and associated distributional patterns that have shaped this diversity and to use this information to help set conservation priorities. Together with a host of Malagasy and American students and collaborators, we are taking an approach to biodiversity documentation and investigation that integrates field and lab activities. Typically, our studies begin with biological inventory in the field, followed by detailed morphological and natural history investigations. Genetic samples are then processed to test the predictions derived from the field investigations. Genetic analyses are performed to verify the status of new and previously-described species and to identify the historical biogeographic forces that influence their distribution in time and space. We will highlight studies from a number of vertebrate taxa including mouse lemurs, trident bats, carnivorans and plated lizards. These studies have revealed remarkable levels of species richness, patterns of geographic microendemism and unexpected biogeographic structuring of species and populations that in some cases contradict expectations based on climate and ecology. All studies are conducted as collaborations among American and Malagasy scholars. As part of these activities, the Yoder Lab has operated a summer training program for the past 5 years in phylogenetic and conservation genetic methods for Malagasy students. Goodman has coordinated the Ecology Training Program (ETP) of WWF-Madagascar for over a decade. The basic objectives of the ETP are: 1) train Malagasy scientists in order to advance biological, ecological and conservation policy-making, 2) provide academic and research opportunities for promising Malagasy students and researchers, 3) facilitate communication and exchange in the fields of biology and ecology amongst Malagasy students and researchers and 4) furnish logistical, financial and supervisory support to Malagasy students in fields related to conservation in collaboration with local universities. All participants in our integrative program aim to apply the biological insights and analytical methods towards setting and implementing conservation priorities in Madagascar.

Credits:

The workshop for Enhancing Collaborative Research on the Environment in Sub-Saharan Africa was coordinated by David C. Hartnett and Fredrick H. M. Semazzi; NSF Office of International Science and Engineering (OISE) of the National Science Foundation funded the workshop under Grant#OISE-0444295; Elizabeth Lyons was the cognizant officer for the NSF grant and provided invaluable guidance in the organization of the workshop and preparation of this report; Jennifer Cash, Lynn Coryell, Harmony Dalgleish, Scott Cover, Beth Graf, Vickie Merritt, and Ann Norcross provided diligent secretarial, administrative and logistics support; Vicky Earp was responsible for the outstanding graphic design work; Special credit is due to the institutions, agencies, and scientists from a wide range of disciplines, who played critical roles by participating in the workshop, and providing their time and expertise to write, comment and review the report.

200 copies of this public document were printed at a cost of $2.80 each