Adaptation of Socio-Ecological Systems in sub-Saharan Africa to Global Environmental Change: ICSU ROA's Strategy.

ACHUO ENOW and SOSPETER MUHONGO
International Council for Science,
Regional Office for Africa
P. O. Box 13252 Hatfield, 0028 Pretoria
SOUTH AFRICA
http://www.icsu-africa.org

Abstract: - Poverty is recognized as the major constraint to Africa's development, as it impacts heavily on all other components of human well-being such as health, quality nutrition, education, access to clean water, proper sanitation, security and other social services. Therefore, any effort to improve the well-being of African people has to be directed, among others, towards poverty alleviation. More than 70 % of African populations earn their living from agriculture. Most of the remainder also depends on exploitation of natural resources through mining, hunting, fishing and harvesting of timber and non-timber forest products. Unfortunately these resources are under constant threat due to global climate change as well as human pressure on the environment. The International Council for Science, Regional Office for Africa (ICSU ROA) identified four key priority areas (Sustainable Energy, Health and Human Well-being, Natural and Human-induced Hazards and Disaster, and Global Change) that need to be addressed in order to promote the sustainable development and well-being of African people. Science plans have been prepared in each of these priority areas, in which the current status of the subject matter in Africa is reviewed, the challenges highlighted, and research and development projects needed to address the challenges are proposed. These priority areas are closely inter-related and many of the key challenges that need to be addressed are influenced by environmental factors and climate change.
This paper presents the key global environmental change challenges to socio-ecological systems in Africa within the context of ICSU ROA's priority areas and describes the research and development projects that need to be undertaken to address the challenges.

Key-Words: - **Climate change, Degradation, Ecosystem, Environment, Hazards and disasters, Human well-being, Vulnerability**

1 Introduction

Many African countries, especially in sub-Saharan Africa, are faced with huge social and economic hurdles that impede their development and hamper the well-being of their people. The high levels of poverty in these countries have their repercussion on the provision or affordability of basic necessities for life. Hence, the continent is plagued with hunger, and a heavy burden of major killer diseases, absence of clean water, inadequate shelter, poor sanitation, poor transport and communication facilities, insecurity due to armed conflicts, and lack of facilities for proper education. About 70 % of Africa's populations depend of Agriculture for their livelihoods (UNEP, 2007). Most of the remainder also depends on exploitation of natural resources through such activities as mining, hunting, fishing and harvesting of timber and non-timber forest products. Furthermore, it is estimated that about 80% of Africans, especially those in rural areas, depend essentially on herbal and other forms of traditional medicine for their health care (Homsy et al, 2004). Africa's biodiversity therefore represents a valuable asset for the well-being of its people. With increasing demographic pressure due to rapid population growth at an annual rate of 2 – 4 % (REF), the current trend of exploitation of natural resources poses a threat to their sustainability. The situation is exacerbated by global climate change which accelerates the processes of environmental degradation and increases the frequency and severity of hazards and disasters, including health hazards.
The major threats of global environmental change, especially in the African context include: ecosystem degradation and biodiversity loss, emergence of new diseases, failure of agricultural production systems, depletion and/or contamination of surface and ground water resources, and increased atmospheric pollution. Hence the key challenge to science, engineering, technology and policy, is to set up

mechanisms for slowing down these processes where possible, and to develop strategies for adaptation to the changes. Any such interventions require a sound understanding of the various global change phenomena and their interactions with each other.

Taking cognizance of the several global initiatives aimed at addressing the challenges of climate and environmental change, we focus our discussion on how these phenomena specifically affect socio-ecological systems in sub-Saharan Africa, and we propose some research and development priorities to address these challenges in the African context. The proposed projects are embodied in the science plans of ICSU ROA in four priority areas that affect the well-being of African people.

2 Challenges to Human Well-being in sub-Saharan Africa

Human well-being is determined by such factors as: income, health, food, clean water, clean air, energy, education, shelter, security, and access to social services, including transport and communication. In most sub-Saharan African countries, the provision of these vital ingredients of human well-being is hindered by poverty, which influences all the other factors. The majority of Africans derive their income by tapping from nature in various forms ranging from different aspects of food production to mineral exploitation and energy generation. The quest to sustain even bare levels of livelihood against emerging challenges (such as the increasing burden of HIV/AIDS) that require higher levels of family income implies greater pressure on nature's reservoir. Hence fish depletion in rivers and lakes, degradation of agricultural land, destruction of natural habitats for wild life, risky mining operations, etc. These human pressures on natural ecosystems are further exacerbated by hazards and disasters, the occurrence of which has been made worse by global climate change.

A review of the current status and trend of these phenomena in sub-Saharan Africa has revealed a number of challenges that need to be addressed.

2.1 Threats of Climate Change to Biological Production Systems

Africa has registered an average increase in atmospheric temperature of about 0.7ºC during the 20th century (UNEP 2006). This warming of the atmosphere affects the physiology of plants and animals, and consequently impacts on yields. Micro-variations in atmospheric temperature can also affect specific ecosystems and food chains. A small alteration in the food chain in a micro-ecosystem can have enormous consequences on the economic activities and livelihood of the local communities. For example, an increase in atmospheric temperature has warmed up surface waters in the east African Rift valley lakes and this has reduced algae growth in the lakes due to reduced mixing of surface waters of the lakes with the deep nutrient-rich waters. The reduced algae population also means less food in the entire food web, and a consequent decrease in fish population in the lakes (Fields, 2005). The ultimate impact of this phenomenon on fishing activity and livelihood of the inhabitants of the lake region and the repercussions on the broader socio-economic scale cannot be underestimated. The drop in fishing catch imposes a shift in economic activity to farming on marginal lands. This leads to increased deforestation, erosion and degradation of such lands. The whole chain of events leads to a continuous cycle of continued environmental degradation and exposure to more risks of disasters, as illustrated in Fig. 1.

Global warming also affects the biological cycles of pests and disease vectors of plants and animals of agricultural importance. While, this may have a beneficial effect through the suppression or weakening of deleterious organisms, the risk of a change in feeding habits of other organisms as a measure of survival in the changing environment poses a potential nightmare. Prediction of such changes and designing appropriate measures to accommodate them constitutes a major challenge.

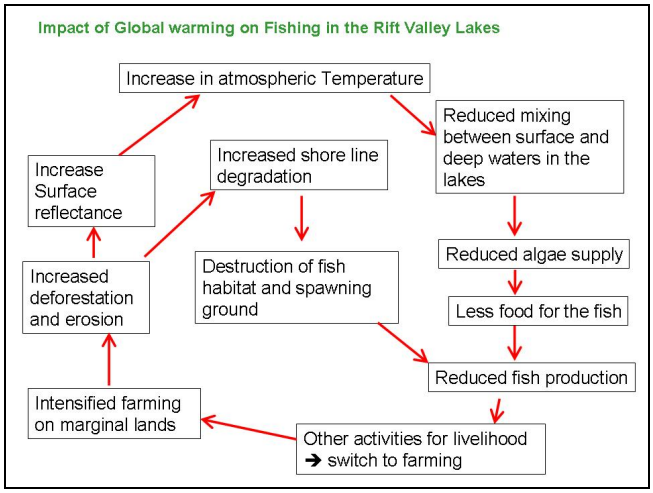

Fig 1. Impact of global warming on livelihoods and the environment around the East African Rift valley lakes

Global climate change has resulted in alterations of rainfall patterns. Agriculture in Africa, especially in rural areas, is essentially rain-fed. Irregular and unpredictable rains pose a major challenge to peasant farmers, as they can no longer rely in the seasonal patterns that they know. Unexpected dry spells in the middle of a cropping cycle are becoming more and more common, resulting in crop failure, and thus increasing the severity of hunger and poverty. Another consequence of the altered rainfall patterns is the occurrence of more frequent droughts of longer duration on one extreme, and more frequent and severe floods on the other. These phenomena lead to crop failure and crop damage, respectively, and ultimately to land degradation, hence, a decline in agricultural production.

2.2 Human Health Challenges

Modifications of microclimates due to global environmental change tend to favour the emergence and proliferation of human diseases and vectors, thus leading to disease outbreaks in new areas, while intensifying their transmission in endemic areas (Patz et al, 2000). The emergence of new human diseases in environments previously free of such diseases can be catastrophic, often attaining epidemic proportions, as the people in such environments have not developed any immunity to such diseases and are therefore very vulnerable. For example, outbreaks of epidemic malaria in the highlands of eastern Africa, southern Africa and in some semi-arid regions of Africa have become very common in recent years and these are associated with climatic hazards such as the El Nino phenomenon (Boko et al, 2007). Other diseases associated with this hazardous climatic condition are Rift Valley fever and cholera. It is presumed that the emergence of highland malaria in the Mt. Kenya region resulted from climate change-driven anomalies in rainfall and temperature, which resulted in favourable conditions for breeding of the malaria vector.

The out break of such epidemics greatly affects agricultural and other livelihood activities directly through a reduction of available labour force, but also indirectly by diverting limited financial resources from other investments to health care.

Land cover change, mainly driven by human activity but made worse by climate change, affects species diversity, including disease vectors. Deforestation, for example, increases the local temperature and this has been shown to increase the rate of malaria transmission in the highlands of western Kenya (Munga et al, 2006; Pascual et al, 2006). Besides this impact on disease transmission, land cover change also implies loss of some valuable species, some of which are of medicinal importance. This situation is particularly critical in sub-Saharan Africa where more than 80 % of the population depends on herbal and other forms of traditional medicine (WHO 2002).

Another major human-induced environmental health hazard is that of air pollution particularly from aerosols, biomass burning and gas flaring. Added to this is the pollution of both surface and ground water with chemical leaks and leachates from industrial plants, mines and agricultural fields, as well as from poor disposal of sewage and other wastes.

2.3 Impact of Global Climate Change on Hazards and Disasters

Africa is plagued by different types of natural and human-induced hazards and disasters such as floods, droughts, cyclones and hurricanes, earthquakes, volcanic eruptions, landslides, tsunamis, wildfires, pest plagues, and air and water pollution. These events cause extensive losses to livelihoods and property, and claim many lives. Local populations in many of these disaster–prone areas have learned to live with them over the years. However, due to global environmental change (particularly climate change), the frequency of these events has increased in recent years, and the limited capacity to predict their occurrence poses a huge challenge to the resilience of socio-economic systems in affected areas. Changes in temperature and rainfall regimes have increased the frequency and duration of droughts as well as the frequency and severity of floods. Landslides, erosion and mud flows have been intensified by increasing loss of land cover due to both climate change and demographic pressure. The resulting land degradation from these disasters further increases vulnerability to subsequent events. The major challenge faced in Africa in this respect is the need to clearly understand the dynamics of these hazards and disasters and to improve the capacity to predict them and to develop appropriate strategies for mitigation.

3 Proposed Flagship Projects

In the face of the challenges highlighted above, among several others, the ICSU Regional Office for Africa has prepared science plans in which priority research and development projects have been proposed. Some of these projects are beyond the scope of this paper; therefore we limit our

discussion to those projects that are directly relevant to global environmental change. The science plans in ICSU ROA's four priority areas in which these projects are described in detail, are now being published in separate documents and they are available on www.icsu-africa-org.

3.1 Land Degradation, Biodiversity Loss and Human Well-being in Africa.

The importance of this project area lies in the fact that Africa is endowed with an extensive and variable biodiversity on which its population depends for livelihood and health care. The specific research projects will be designed to study the bio-diversity of lived environments in general (fresh water, marine and land). Attention will be focused on: improvement of observation systems; elaboration of the ESSP global land project in Africa; future options for land-use; establishing links between biodiversity, ecosystem function and services, and human well-being; projections on patterns and trends in ecosystem dynamics, including possible alterations in food chains as well as trends in evolution of plant, animal and human pathogens and their vectors; development of strategies for conservation and sustainable use of biodiversity-based natural resources in Africa and in its surrounding oceans; and the development of sustainable alternative livelihood options.

3.2 Rainfall in Africa

Rainfall is considered to be the biggest climate question in Africa because tropical and subtropical rainfall processes are currently poorly studied and modelled. The major concern is that of adaptation to current rainfall variability as this may provide the key to climate change adaptation. Specific activities in this project area will include: improved rainfall measurement, quality assurance and archiving of data; development of techniques and procedures to increase the confidence in medium-term forecasts to reduce vulnerability in the longer-term; obtaining an accurate statistical picture of size and intensities of rainfall events; establishing a causal relationship between rainfall and sea surface temperature; and the influence of aerosols and emissions from biomass burning.

3.3 Resilience of Food Supply Systems

With the absolute dependence of Agricultural production systems on environmental conditions, some generic issues that need critical attention include: the impact of global environmental change on food insecurity in Africa; the consequences of various adaptation options on the existing environmental and social conditions; design of the emerging African green revolution for sustainable modernisation of agriculture and rural transformation; trade-offs between land for food production and for "energy" (competing claims); and crop and cropping system diversification options. Specific research projects in Agriculture will examine the potential for sustainable livestock production (tolerance to disease and to drought, high yielding, zero grazing) and on developing improved crop varieties for pest and drought resistance, high yield, and reduced biological cycles to cope with shortened rainy periods as desertification progresses.

3.4 Vulnerability and Resilience to Hazards and Disasters

Hydro-meteorological events are of more common occurrence in Africa than other types of hazards and disasters, and they are the most influenced by climate change and variability. Therefore the projects on vulnerability and resilience will focus essentially on these types of hazards, and particularly on drought and flooding. The projects will address generic issues relevant to the mitigation of hazards and disasters. These include: risk analysis techniques and disaster management strategies appropriate to different risk profiles; development of early warning systems and preparedness against hazards and disasters; development of adapted technologies in areas prone to specific types of hazards (for example, the adaptation of architectural designs to reduce the impact of floods, tornadoes, or earthquakes); efficient communication strategies for timely warning on the occurrence of an event; resilience of socio-ecological systems; causal relationship between environmental degradation (for example, deforestation, desertification) and hazards and disasters; assessment and development of methodologies (for example, decision-support tools); and compilation of vulnerability maps.

We propose to specifically link research on geo-hazards to the activities of the UN-proclaimed International Year of Planet Earth (IYPE). Attention will be focused on: earth observation systems; seismic events, particularly the Rift valley earth quakes and landslides; tsunamis, volcanic activities, including gas explosions in crater lakes; pollution resulting from exploitation of mineral resources; and environmental impact assessment of structures such

dams, and of the collapse of structures due to mining activity.

3.5 Integrated Modelling of Multiple Disasters

Despite the regular occurrence of hazards and disasters, there is little understanding of their real economic impact, especially when several devastating events occur together. The purpose of integrated modelling is to: enable precise evaluation of the vulnerability to compounded hazards and disasters, and to establish an index describing vulnerability to compounded events; make accurate assessments of losses due to hazards and disasters; minimize costs of hazards; assess vulnerability associated with urbanization; and provide a tool to enable the prediction of the effects of climate change on hazards and disasters, especially floods and droughts. Studies on the effect of climate change will include an inventory on climate change data, understanding climate dynamics, the impact of extreme events on ecosystem services, economic implications of climate change and variability at a regional scale, and building adaptive capacity for resilience to climate-driven hazards.

3.6 Water Resources

Water availability is linked to climate change and biodiversity loss, and it impacts on food security. Therefore the issue of water resources needs to be considered beyond a resource assessment, and should be extended to exploring the social and technology domains, including issues of governance. The burning questions that need to be addressed include: assessment of groundwater recharge, pollution and threats; the protection of water resources, water quality and aquatic ecosystems; consequences of water resource variability on food security; treatment and safe re-use of domestic and industrial waste waters; strengthening of sector monitoring and information management; and improving water management and use.

3.7 Atmospheric Pollution

Projects on issues of air pollution will focus on: the development of experimental and observational protocols for African conditions; institution of introductory courses in atmospheric chemistry and physics, laboratory analysis, modelling and weather monitoring; and case studies involving integrated measurement and modelling of a few urban centres.

3.8 Ocean Basin linkages

The uniqueness of the ocean circulation around Africa and their impact on the continental ecosystems are of particular interest, especially as the dynamics in these water bodies are greatly affected by climate change. Specific issues of interest include: the impact of Climate Change on thermohaline circulation; understanding the Indo-Atlantic inter-ocean exchanges; coupling of land-sea-atmospheric processes in models; expanding global observation systems; and linkages to Large Marine Ecosystem studies.

4 Conclusion

Socio-ecological systems in Africa remain very vulnerable to the increasing trends in climate change and environmental degradation. The project proposals presented here are meant to complement, rather than duplicate on-going initiatives aimed at promoting adaptation of African communities to global environmental change. The successful implementation of these projects will result in better scientific knowledge and understanding of the concepts discussed, and will provide adequate scientific evidence and skills to guide development policies. Effective implementation of these projects will require substantial mobilization of human and financial resources and research facilities for training, research, and community education (outreach), as well as extensive regional and international collaboration, partnerships, and networking.

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