Factors driving land use change: Effects on ecosystems services and human wellbeing in Lake Victoria basin

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ABSTRACT

To offer an increased understanding of the spatial patterns, temporal, social and physical predictors of the conversion and transformations of land use and land cover in Lake Victoria basin, an assessment of proximate and underlying forces is presented. This paper discusses key theoretical underpinnings for the manifold linkages existing between selected drivers and land use and cover change around the basin and their consequences on human wellbeing. Using a meta-analytical research design, the paper analyses ecosystems level cases of the causes of land use and cover change in the basin, in order to determine any spatio-temporal or institutional patterns and dynamics. A suite of recurrent core variables have been identified to influence land use and cover changes in the basin. The most prominent of these at the underlying category are climatic factors, economic factors, institutions, national and regional policies, population growth, and other remote influences. At the proximate level, these factors drive cropland expansion, overgrazing, infrastructure extension and rates of land degradation. These are supported by empirical evidence from the basin. This assessment is crucial for appropriate local and transboundary policy interventions, which have to be fine-tuned to the locale-specific dynamic patterns associated with the inherent land use and land cover changes.

Keywords: Ecosystems services, human wellbeing, Lake Victoria basin, land use and cover change, proximate causes, underlying drivers, Vulnerability

INTRODUCTION

Land-use change is a locally pervasive and globally significant ecological trend (Geist & McConnel, 2006). The current pace, magnitude and spatial reach of human alterations of the Earth's land surface are unprecedented. Among the most important are changes in land cover - biophysical attributes of the Earth's surface - as related to land use - human purpose or intent applied to these attributes. Land use and land cover change (LUCC) directly impacts biotic diversity worldwide, contributes to climate change, is the primary source of soil degradation, and, by altering ecosystem services, affects the ability of biological systems to support human needs. Such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations.

Lake Victoria basin ecosystem (both terrestrial and aquatic) provides a number of vital services for people and society, such as biodiversity, food, fibre, water resources, carbon sequestration, and recreation. The future capability of the basin to provide these services is heavily hinged on changes in socio-economic characteristics, land use, biodiversity, atmospheric composition and climate of the ecosystem. Most published land use change assessments do not address the associated vulnerability of the human–environment system. It is not possible, hitherto, to address the important multidisciplinary policy relevant questions such as: which are the main regions or

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sectors within the basin that are vulnerable to ecosystems change? How do the vulnerabilities of regions compare? Which driving forces precipitate land use change and how are human livelihood strategies and wellbeing threatened by the nexus of the drivers and land use change?

Ecosystems change takes many forms. The chief form of ecosystems alteration is land use change that has been highlighted as a key human-induced effect on ecosystems (Turner et al., 1997; Lambin et al., 2001; Lambin, Geist & Lepers, 2003). Land use has been changing since people first began to manage their environment, but the changes in Lake Victoria basin over the past 30 years have been especially noticeable necessitating a new approach for an integrated assessment of its causes and effects. This forms an integral component of any ecosystems audit of the basin. Socio-economic changes have led to the major development of settlements, creation of new economic sectors, improved technology leading to a changing role for agriculture and fishery and new ways of exploiting the ecosystems services provided by Lake Victoria and its river systems, the basins' enormous forest and land resources as well as its expansive wetlands. The inadvertent land use change directly influences the provision of ecosystem services (e.g. provision of food and timber, climate regulation, nutrient cycling, and cultural identity) (Daily, 1997; MA, 2005). This paper uses human and environmental vulnerability concept, as measured by the sustainable supply of ecosystem services, to assess human well-being under the influence of ecosystems change, as indicated by land use change. There are similarities between this approach and that used by Luers *et al.* (2003). The paper is a synthesis of the technical processes under the ecosystems assessment framework of Lake Victoria basin reported recently in "Lake Victoria basin Environment Outlook" report (UNEP, 2006).

THE STUDY AREA

Lake Victoria basin is located in the upper reaches of the Nile River basin and occupies an area of about 251 000 km^2 of which 69,000km^2 is the lake area (UNEP, 2006) and straddles six countries (Kenya, Uganda, Tanzania, Rwanda, Burundi and Democratic Republic of Congo). The basin contains Lake Victoria, which is the largest freshwater lake in Africa. The mean depth is about 40 m with a recorded maximum depth of 84 m and the volume of water stored is estimated at about 2,760 km^3. The lake is at an altitude of 1135 m above the sea level and lies on the equator at 0°30′N - 3°00′S and 31°39′W - 34°53′E. Knowledge about the history and associated ecological changes of the lake is relatively advanced (Johnson *et al.,* 2000). The average population density in the entire basin is about 165 persons/km^2. This is due to its favourable conditions for agriculture, fishing and other economic activities. The average population density on the Kenyan, Tanzanian and Ugandan sides of the basin is 297 persons/km^2, 97 persons/km^2 and 635 persons/km^2 respectively.

Annual rainfall in the lake area varies between 950 and 2450 mm. On the terrestrial part of the basin annual rainfall ranges from 450 to 950 mm. Wetlands occupy 40.8% of the basin, cropland 40.3% and grassland, savannah and shrubland 37%. Lake Victoria wetlands belong to the most productive systems in the region and are vital to the local and regional socio-economic development and biodiversity (Gichuki, 2003). Land resources in the Lake Victoria basin present the inhabitants and their development partners with monumental paradoxes including enormous natural resource wealth with potentially high endowment value yet majority of the people live

in abject poverty and being home to incredible land use diversity yet the ecosystems are fragile and easily degraded by unsustainable land use (Ochola, 2006). Despite this the sustainable management of the basin's resources depends on a full understanding of the human – ecosystems interaction (EAC, 2004).

Figure 1: Land cover map of Lake Victoria basin

METHODS AND CONCEPTUAL BASIS

The approach adopted in this classical case of ecosystem assessment by integrating the potential impacts on human wellbeing. This represents a move towards more transient assessments as a function of shifting environmental parameters (including land use change) and socio-economic trends. This paper adopts an approach to assessing the drivers of land use change and highlighting the impacts of human well-being through the vulnerability concept. Vulnerability has been defined by IPCC (2001) as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes". The definition is broad enough to include susceptibility, which is a function of exposure, sensitivity, and adaptive capacity. The vulnerability concept has been used in many studies (e.g. Schro¨ter *et al.*, 2005; Metzger *et al.*, 2006). This paper, as an integrated environmental assessment work summarises the key drivers of land use change and their relationship with human and ecosystems vulnerability in the basin and explains how various land use changes are coupled to changes in ecosystem service provision in the basin. Figure 2 shows the framework used for assessing land use change and its impacts on human wellbeing.

Figure 2: Framework for understanding the relationship between land use and land cover. Redrawn from Figure 8 in Turner *et al.* (1995)

To illuminate the integral components of social and environmental processes that trigger observable land use change, the political ecology conceptual framework was adopted to direct and prioritize the process of this assessment. The framework allows critical synthesis of interactions between society and environment and reflecting on socio-economic and environmental processes at different scales. According to Olson (1998), the framework helps to clarify the multifaceted nature of the driving forces of land use change. Land use change analysis demands comprehensive and flexible conceptual frameworks (Campbell, 1998; Ewel, 2001). Benhin (2006) has used it to review the relationship between agriculture and deforestation. The concept was coupled with the human wellbeing dimensions framework and livelihood perspectives (Birch-Thomson, Frederiksen & Sano (2001) to relate land use change in the basin to human and ecosystems vulnerability.

Human well-being can be broadly defined as human capabilities, i.e. the extent to which individuals have the ability to live the kinds of lives they have reason to value (MA, 2006). The environment provides a variety of services, which, contribute to human well-being. Some of these services are directly used by people and are either consumptive or non-consumptive uses of the environment (Dodds & Pippard, 2005). The ability and freedom to make choices of benefiting from ecosystems services is shaped by social, political and economic factors at multiple levels as well as environmental change (Sen 1999) and hence ability to cope with and respond effectively to environmental change such as land use and cover change– that is their

degree of vulnerability. MA (2003) considers human well-being as encompassing personal and environmental security, access to materials for a good life, good health, and good social relations, all of which are closely related to each other and underlie the ability to make choices and take actions (MA 2003).

RESULTS AND DISCUSSIONS

Drivers of Land Use Change

Land use in Lake Victoria basin since 1970 has seen expansion of cropping into grazing lands; expansion of rain-fed agriculture into wetlands and along streams/rivers; intensification of existing agricultural land especially in the highlands, reduction of vegetation in protected areas; reduction in forestland; and increase in settled areas through sprawling informal urban centres especially along the beaches. These changes have occurred amid varied social, environmental and economic drivers. The MA (2005) defines a driver as any natural or human induced factor that directly or indirectly causes a change in an ecosystem. A *direct driver* unequivocally influences ecosystem processes. An *indirect driver* operates more diffusely, by altering one or more direct drivers. A multidisciplinary assessment is necessary for understanding the complexity of land-use change. The approach of Geist and Lambin (2002 & 2004) of classifying drivers of land use change into proximate and underlying cases is adopted. Land use change is best exemplified in deforestation and other conversion of land use types. Deforestation is explained by multiple factors and drivers acting synergistically rather than by single-factor causation. In Lake Victoria basin like other tropical ecosystems more than one third of the cases of deforestation are driven by the full interplay of economic, institutional, technological, cultural, and demographic variables (Geist & Lambin, 2004). Figure 3 illustrates the comprehensive link between the main causes of land use change that was adopted in this assessment.

Figure 3: Proximate and underlying causes of land use change (Adapted from Geist & Lambin, 2004)

Land use and cover change occurs through conversions and modifications. Land-cover conversions (i.e., the complete replacement of one cover type by another) are measured by a shift from one land-cover category to another, as is the case in agricultural expansion, deforestation, or change in urban extent while land-cover modifications are more subtle changes that affect the character of the land cover without changing its overall classification (Lambin *et al.*, 2003). The changes may be progressive (gradual) or episodic (as seen in drastic shifts brought about by extremes of climate such as El Ni˜no-driven droughts and natural disasters such as floods. The categories of ecosystems driving forces are: demographic, economic, socio-political, technological, and policy and institutional, cultural and other factors predisposing land to conversions and modifications. Drivers in all categories other than physical and biological are considered indirect. Important direct (physical and biological) drivers include changes in climate, plant nutrient use, land conversion, and diseases and invasive species.

Demographic changes in Lake Victoria basin have been fundamental. Population growth within the basin the basin has steadily outpaced continental averages by between 2.5 – 11.2% per decade. Population attributes of natural growth, migration, migration, distribution, life cycle features have been fertility rates known to explain human exploitation of environmental services (Angelsen, 1999) and hence land use

and cover changes witnessed hitherto in the basin (Angelsen *et al.* (1999). This has been especially true of the 100-km buffer ring around the lake (Figure 4).

Figure 4: Mapped population density for past four decades within 100-km buffer around Lake Victoria

The registered population growth within the 100-km buffer zone around Lake Victoria is significantly higher than that of the rest of Africa as a result of wealth of natural resources and economic benefits the basin offers. The low percentage of forest cover and high density of population around Lake Victoria may pose a serious threat to the lake's ecosystems. An increase in population prompts the movement of new settlement into regions with fragile ecosystems; land under other uses is encroached upon by people seeking to find new lands to cultivate; people are moving increasingly into what in the past were probably viewed as either pristine areas in need of protection to maintain biodiversity, or as areas marginal to agricultural production because of the fragility of their vegetative cover, soil structure, highly variable rainfall, or a mismatch between environmental conditions and land-use practices.

Figure 5: Population growth in Lake Victoria basin in comparison with Africa (a); the relationship between area of land use types and population density in the basin (b); and the spatial distribution of the land use types around the lake (c)

Socio-economic and *cultural* factors drive land use change in many ways through practices and ecosystems goods and service use that affects demand for energy and ecosystems products. The values, beliefs, and norms of inhabitants of the basin's dwellers though diver has far reaching ecosystems consequences. The land use choices of the Luo in Kenya, for instance, is culture bound (Ochola *et al.*, 2002). Culture also fosters diverse forms of learning about and adapting to ecosystem changes as seen in traditional consecration of sacred and protected sites by managing and protecting the cultural and spiritual values assigned to natural resources.

Although no direct empirical evidence exists to link land use conversions and modifications to the development and diffusion of *scientific knowledge and technologies*, it is clear that intensive exploitation of the lake basin's resources that influence land use change as well as state of ecological systems and human well-being is related to technological change. Expansion and productivity in agriculture, forestry, fisheries and other sectors are tied to technology (Ewert *et al.*, 2004). Given appropriate policy and institutional mechanisms, technology can drive use of the basin's land resources in ways that cut across political and agro-climatic boundaries while investment in national agricultural research, infrastructure, and urban growth also ways in.

The basin's *climate* system has changed since the holocene era (Johnson, Kelts & Odada, 2000) and continues to vary spatially and temporally, in part due to human activities, and is projected to continue to change and influence ecosystems change (Odada *et al.*, 2004). Recent climatic trends for the lake basin have shown 10–40 percent decreases in precipitation since 1960 (REF), and the potential for further decreases in precipitation and increased air temperatures (Hulme *et al.*, 2001) has raised concerns about the ecological and social impact of potential climate change and variation. Liu *et al.* (2004) and Tschakert *et al.* (2004) have used models to show that

decreasing precipitation and increasing air temperature are expected to cause decreases in plant carbon, soil carbon, system carbon, and plant production, all of which are instrumental in land cover dynamics. The full range of factors identified to have separately or interactively driven change in land use patterns in the basin for the past 30 years are illustrated in Table 1.

Table 1: Key driving forces of land use change in Lake Victoria basin (Synchronized with Olson *et al.* (2004)).

Human Wellbeing Impacts

Land use changes such as forest conversions to agriculture or urban use, decrease ecosystems services. The products and services provided by forests (such as timber, water, wildlife, carbon storage, aesthetic beauty, etc.) are lost. The liquidation of forest assets has a profound impact on communities that rely on the forest for food and economic development. Land use conversion affects both the amount and spatial pattern of forest habitat, which in turn can affect the ecological function and future development of remaining forest lands. Fragmentation of land into small ownership parcels which is common in the basin also complicates management and cooperation at local levels. In addition to its ecological and management effects, such tenure changes resulting from land conversion can lead to social conflict. The human well being approach of (MA, 2003; 2005; 2006) is adopted in assessing land use change impacts of local livelihoods in the basin.

Recent modifications in land-use, overexploitation of the resource base and demographic changes could lead to degradation of the ecosystem integrity. Ecosystem effects could include latitudinal and altitudinal shifts in plant and animal species as well as loss of biodiversity due to water scarcity. The ecosystems alterations occurring in the basin, typified by land use and cover changes, as a result of the drivers discussed earlier are threatening the realization of the ecosystems goods and services provision in the form of source of food, energy, drinking and irrigation water, transport, and as a repository for human, agricultural, and industrial waste. With one of the highest population growth rates in the region, the lake basin ecosystem is undergoing tremendous stress. The ecological disasters of the lake are classical examples of how humans abuse aquatic environment (Odada *et al.,* 2004). The nutrient loading (from largely intensive land use) of the aquatic ecosystem was blamed on the sharp and uncontrolled increase in water hyacinth (Plate 1) in the last decade, which in turn adversely affected lake navigation and blocked sunlight from reaching the water's surface layer.

Plate 1: Land cover changes between 1995 and 2001 occasioned by invasion and subsequent control of water hyacinth water weed. Notice difference in parts marked by the arrows.

There is evidence that ecosystems changes in the basin are tied to deterioration in physical and biological, scientific, socio-economic, health and safety, equity and humanitarian, anthropological, sustainable development, sectoral (fisheries, forestry, agronomy, livestock), and other human wellbeing aspects of the region. In this regard, the regional case study could serve as a prototype for other regional hotspots and flashpoints audits. This was the goal of Lake Victoria Basin Ecosystems assessment report (UNEP, 2006) upon which this paper is based. The vulnerability of the environment and human wellbeing in the basin can be traced to changes in the ecosystem fuelled by land use and cover change. Water erosion is extensive in many

parts of the Lake Victoria Basin, with approximately 45% of the land prone to such erosion. Increased siltation of the lake and increased risk of flooding in estuaries are the direct effects of soil erosion and other degradation forces in the basin. The near annual flash floods on the Lake Victoria plains have been linked to such forces emanating from point and non-point processes (Gichuki, 2003). The land use changes in the basin are directly or indirectly linked to human well-being in the basin as measured by the following indicators:

- Life Expectancy;
- Infant Mortality;
- Extent of vector-borne diseases;
- Respiratory disease related to air quality;
- Poverty;
- Land area covered by forest;
- Area protected to maintain biological diversity;
- Proportion of population with access to improved water and sanitation;
- Unemployment rate;
- Population with access to health care; and
- Gender Empowerment;

The impacts are known to be historical (Verschuren, 2002). The eutrophication of Lake Victoria is clearly linked to land-use changes and rapid population growth in the lake catchments, with impacts clearly affecting the lake from about 1930. The infestation of Lake Victoria by water hyacinth in the 1990s disrupted transportation and fishing, clogged municipal water pipes, and created a habitat for disease-causing insects. The urgent need to rapidly transform land use in the Lake Victoria Basin is underscored by the fact that the region's anticipated population growth will not only reduce the availability of land per capita, but will accelerate the rate of its degradation. Dwindling land resources in the basin present its inhabitants and their development partners with monumental paradoxes, from the mounting freshwater demands of some 30 million people, to growing industrialisation and urbanisation, increasing agricultural pollution, the loss of freshwater biodiversity, and the overexploitation of fishery resources.

CONCLUSIONS

Land use change will continue to have far reaching influences on important ecosystem services in Lake Victoria basin. Vulnerability to land use change differs across regions of the basin and sectors representing ecosystem services due mainly to differences in economic versus environmentally oriented development across the basin. The paper reveals that, although the magnitude, sign, and spatial patterns of land use and cover change may be an artifact of the particular theoretical framework and model of analysis, there is potential in understanding the inadvertent consequences of human activities on the land which have feedback loops on human wellbeing. Moreover, the study offers a methodology for evaluating how key drivers of land use change namely climate changes and variation, demographic changes, technology and agricultural expansion among others may alter the multiple services offered by ecosystems to human beings in the basin and beyond.

This paper illustrates some of the potential feedbacks that might have resulted from land use change driver interactions in the basin, occasioned mainly by anthropogenic forces such as agricultural activities. Although the findings of this assessment are

logical, there are however numerous uncertainties that may preclude the generalization of the assertions made in this paper. A significant omission in this assessment has been the representation of specific forms of cultivated land and specific interaction between land use change and biophysical systems such as carbon sequestration. Future improvements on this work should include better representation of cultivated systems, including various crop types and their productivity and suitability and effects of atmospheric chemistry as it resonates with land cover change. Also to be included in the advancements are modelling of the changes in suitability arising from changes in ecosystems properties. These could also define a more complete uncertainty analysis to test for the robustness of the results of the current assessment of factors precipitating land use change in the basin. Nevertheless, our study is illustrative and outlines an important issue for future research consideration. It addresses an important question: While the inhabitants of the basin exploit the natural resources from its environment through land use practices, are they inadvertently undermining the very ecosystem services that offer them those resources in the first place.

Acknowledgements

The work presented in this paper was carried out as part of the UNEP-DEWA funded First Ecosystems Assessment of Lake Victoria basin (Job No: DEWA/0799/NA). We thank all experts who contributed through technical background papers, insights and data at various stages. The assessment process was led the Pan-African START Secretariat (PASS) with additional funding by the US National Science Foundation / US Climate Change Science Program (USNSF/USCCSP).

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1 TABLES

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3 Table 1: Key driving forces of land use change in Lake Victoria basin (Synchronized with
4 Olson *et al.* (2004)).

Demography - Population growth and density - Urbanization - Migration and distribution - Birth and death rates (health, fertility, household socio-economics, education & culture) *Socio-cultural factors* - Land based cultural practices and values - Inheritance arrangements - Changing land distribution and wealth - Land use conflicts - Traditional livelihood strategy - Gender relations - Fluidity of land tenure systems *Economic changes* - Local, regional and international trade changes - Growing demand for individual crops/ecosystems products - Emergence of new economic sectors/livelihood *Policies and governance* - Land policies (property rites, protected area, settlement schemes) - Agricultural policies affecting parastatals, cooperatives, plantations, agricultural support and marketing - Industrial and value policies - Investment in education, health, infrastructure - International environmental protocol and agreements - Governance (resource distribution, local NRM, corruption, etc) *Regional Characteristics* - Relative wealth and ecosystems asset value and availability - Land availability - Transboundary ecosystems factors - Regional governance *Technological change* - Agricultural and NRM technology availability and use - Irrigation development - Research, science and technology for land use developments	*Agricultural expansion* - Expansion of cropping into grazing lands - Expansion of rain-fed agriculture into wetlands and along streams/rivers - Intensification of existing agricultural - Reduction of vegetation in protected areas - Reduction in forestland; and increase in settled areas through sprawling informal urban centres especially along the beaches *Forest exploitation* - Commercial wood extraction - Fuel wood and charcoal burning - Other forest products *Infrastructural development* - Transport (road construction) - Markets - Settlements - Public service (water, electrical grids) - Private company development *Climate change and variation* - Rainfall distribution and variation - Temperature rise *Other predisposing factors* - Environmental factors e.g. land characteristics – soil quality, topography) - Biophysical factors (fires, droughts, floods) - Social triggers (conflicts, social disorder, displacement, policy shifts, economic shocks)

5

FIGURES

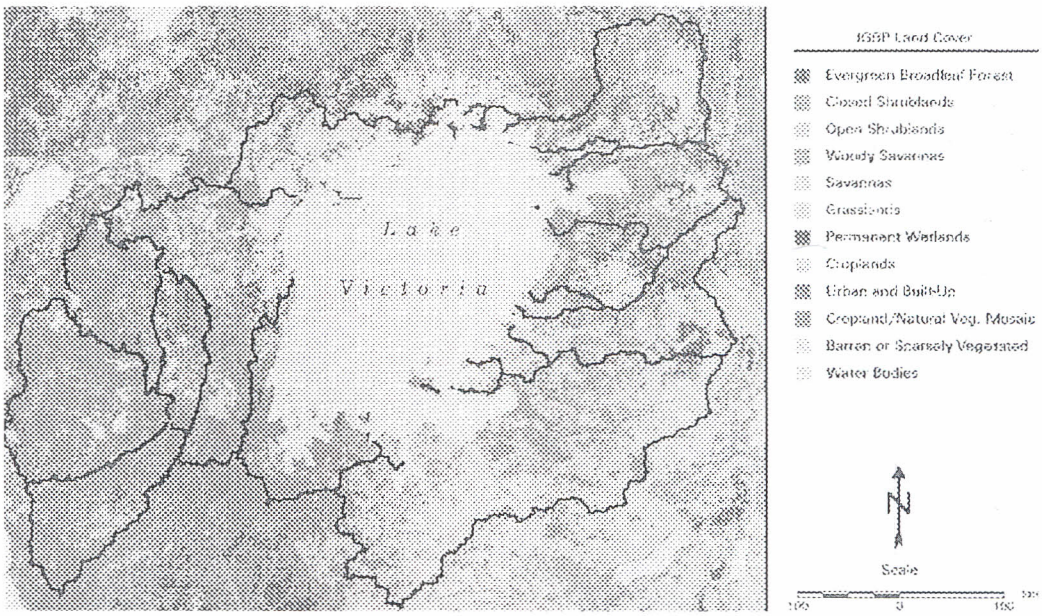

Figure 1: Land cover map of Lake Victoria basin

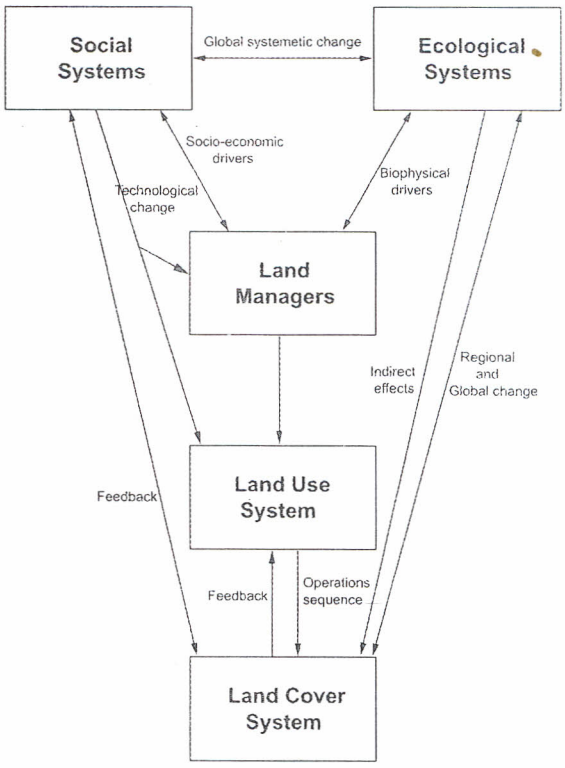

Figure 2: Framework for understanding the relationship between land use and land cover. Redrawn from Figure 8 in Turner *et al.* (1995)

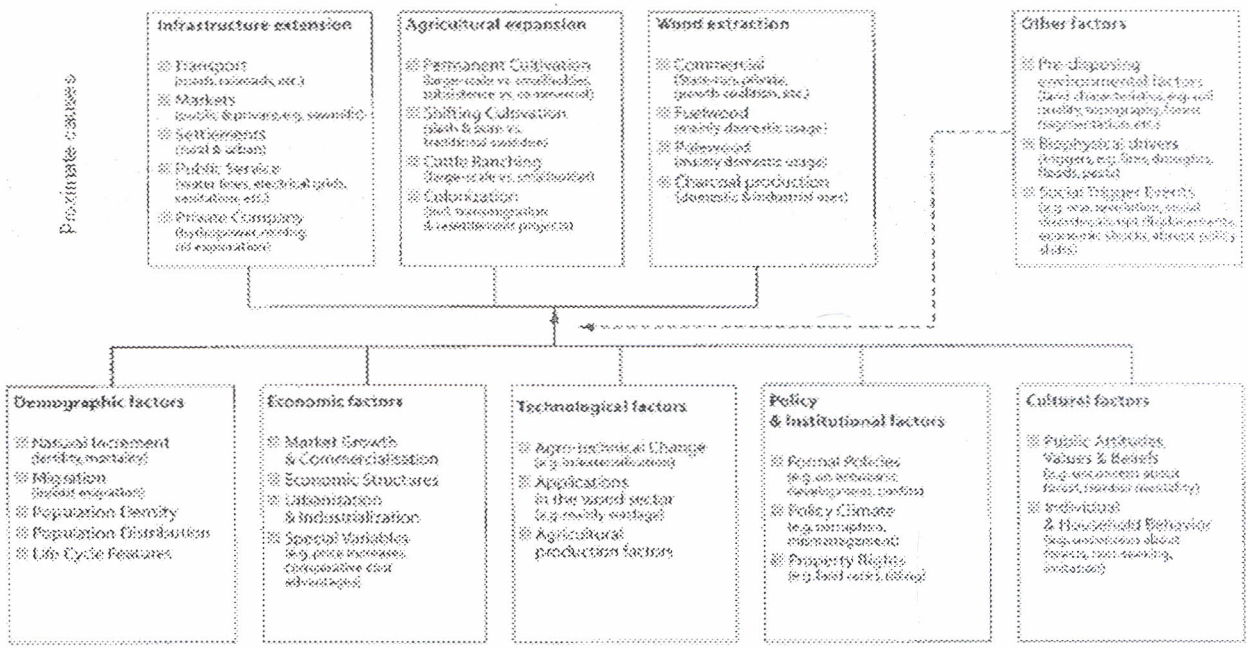

Figure 3: Proximate and underlying causes of land use change (Adapted from Geist & Lambin, 2004)

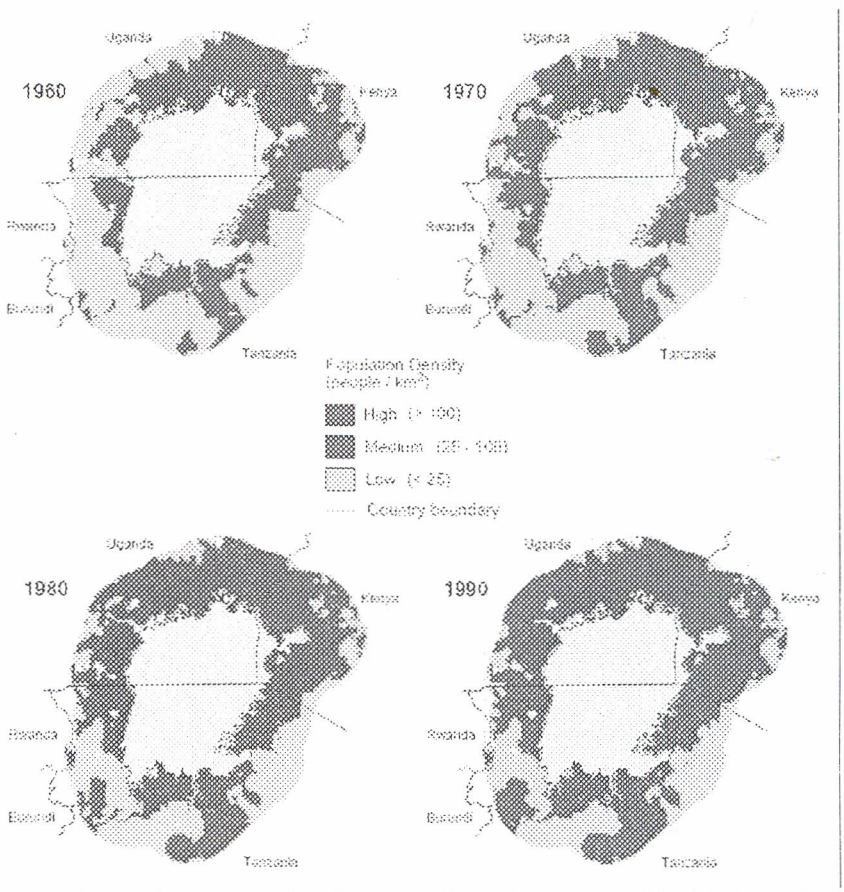

Figure 4: Mapped population density for past four decades within 100-km buffer around Lake Victoria

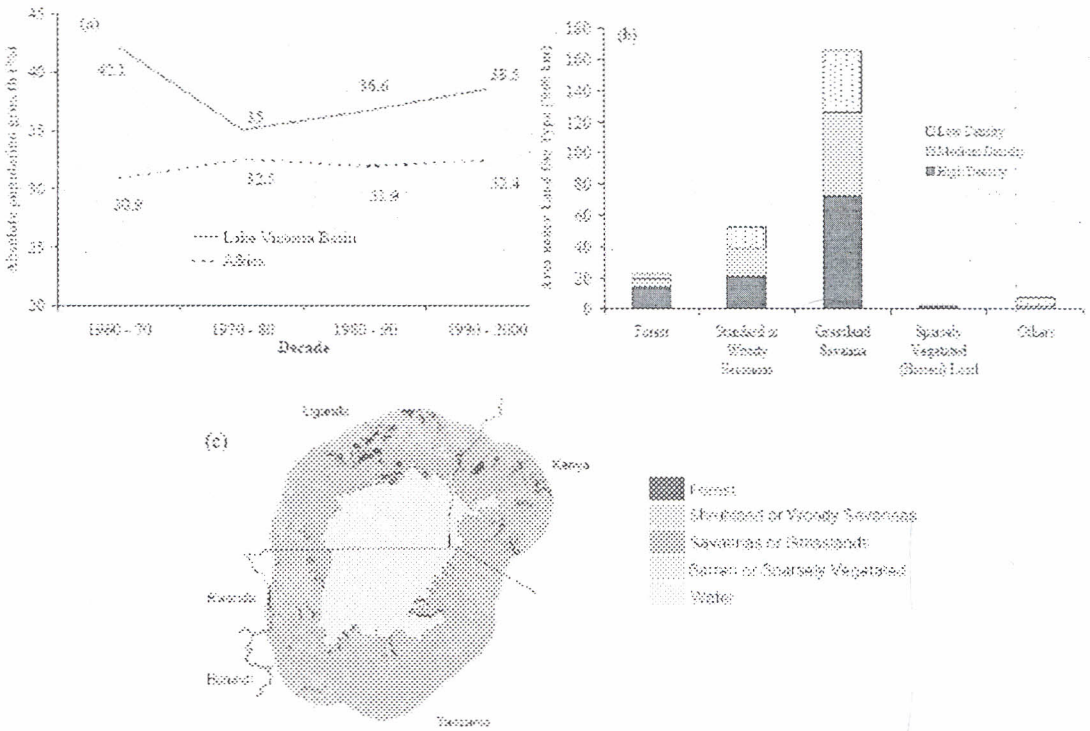

Figure 5: Population growth in Lake Victoria basin in comparison with Africa (a); the relationship between area of land use types and population density in the basin (b); and the spatial distribution of the land use types around the lake (c)

PLATES

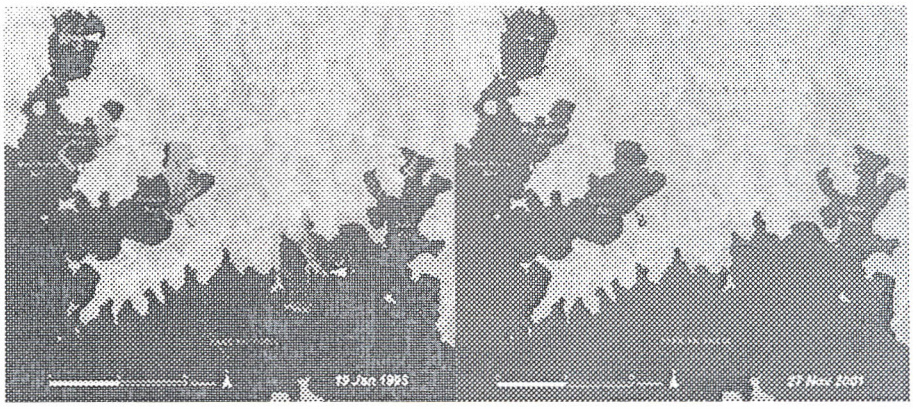

Plate 1: Land cover changes between 1995 and 2001 occasioned by invasion and subsequent control of water hyacinth water weed. Notice difference in parts marked by the arrows.