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A review on Causes of Ecological change along Lake Victoria basin, Kenya

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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 in the Lake Victoria basin, a review of underlying causes (drivers and forces) is presented. This review discusses key theoretical underpinnings for the manifold linkages existing between selected pressures and drivers of land-use changes around the basin. This paper analyses ecosystems level cases of the causes of land use and cover changes in the basin, to determine any Spatio-temporal or institutional patterns and dynamics. A suite of recurrent core variables has been identified to influence land use and cover changes in the basin. Drivers are sometimes referred to as indirect or underlying drivers or driving forces. Key drivers include demographics; consumption and production patterns; scientific and technological innovation; economic demand, markets, and trade; distribution patterns; institutional and social-political frameworks, and value systems. Key pressures include emissions of substances that may take the form of pollutants or waste; external inputs such as fertilizers, chemicals, and irrigation; land use; resource extraction; and modification and movement of organisms. Human interventions may be directed towards causing the desired ecosystem change such as land use, or they may be intentional or unintentional by-products of other human activities, for example, pollution. The ecosystem is directly or indirectly affected by the social and economic sectors, contributing to change (either negative or positive) in human well-being and in the capacity/ability to cope with ecosystem changes. Impacts, be they on human well-being, the social and economic sectors or ecosystem services, are highly dependent on the characteristics of the drivers and, therefore, vary markedly between developing and developed regions.

Keywords: Causes, ecological changes, freshwater ecology, Lake Victoria, Kenya

Introduction

Imagine a basin in which ecosystem change threatens people's health, physical security, material needs and social cohesion. This is a basin beset by increasingly intense and frequent climatic change. Some people experience extensive flooding, while others endure intense droughts. Species extinction occurs at rates never before witnessed. Safe water is increasingly limited, hindering economic activity. Land degradation endangers the lives of millions of people. This has been the case in the lake basins of developing countries.

Rapid human population growth in developing countries concomitant with development pressure and an enormous increase in the number of wastes produced are placing tremendous demands on the aquatic ecosystems (Kalff, 2002). This trend, coupled with freshwater scarcity in most countries, including Kenya (Postel, 1992), continues to strain available resources. Streams and rivers continue to bear the consequences of pollution emanating from point and non-point sources. As a result, these delicate ecosystems are increasingly being subjected to perturbations that result in severe habitat degradation, impairment of water quality and loss of biodiversity (Vorosmarty *et al.*, 2000; Jackson *et al.*, 2001; GEF, 2007).

Hydromorphological degradation, which is an assortment of different man-made impact types (e.g. catchment and floodplain land-use, removal of riparian forest, bank modification, flow regulation) acting at different spatial scales (Feld and Hering, 2007), is rapidly emerging as the greatest stressor of streams and rivers in most parts of the world (Raven *et al.*, 1998). Glaring effects of hydro morphological degradation on riverine biota has been suggested for various river types in Europe and U.S.A. (Barbour *et al.*, 1999; Snyder *et al.*, 2003)) and Kenya (Ndaruga *et al.*, 2004; Kibichii *et al.*, 2007).

In Kenya, especially in the Lake Victoria Basin, many land-use practices are causing widespread degradation of the water-soil ecosystems. In most of the watersheds, hydro morphological impacts include agricultural practices without environmental safety measures (Raburu 2003; GEF, 2007, Okungu and Opango, 2005). In River Nzoia watershed agricultural development is on the rise (GEF, 2007) and this has been implicated on the rise of nutrient enrichment, pesticide contamination, erosion, and sedimentation in rivers and streams (Osano *et al.*, 2003; Okungu and Opango, 2005). In the Moiben sub-watershed of the larger Nzoia, the situation has witnessed an unprecedented increase in the use of fertilizers and manure in farming. Animal wastes from feeding lots also contribute excess nutrients, which are absorbed into the soil from where they are released slowly to streams and rivers. This has the potential of causing ammonia toxicity, elevated nitrate levels in groundwater, eutrophication affecting oxygen supply for aquatic life, and microbial problems that impact water use and consumption.

Lake Victoria basin ecosystem (both terrestrial and aquatic) provides several vital services for people and society, such as biodiversity, food, fiber, 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 sectors within the basin that are vulnerable to ecosystem change? How do the vulnerabilities of regions compare? Which driving forces precipitate land-use change and how are human livelihood strategies and well-being threatened by the nexus of the drivers and land-use change?

The Lake Victoria Basin environment in general and land use, in particular, has been experiencing changes resulting from anthropogenic activities as well as natural processes (Ogutu *et al.,* 2005). Many wetlands systems have suffered in the past from unsympathetic intensive developments, which have led to their destruction or degradation with the loss of wetland habitat and the 'services' it provides (Denny, 1995). Research findings indicate that the wetlands are increasingly being polluted and placed under stress (Kairu, 2001). There has been unrestricted cultivation and livestock keeping as major forces behind the invasion of wetlands. The recent climatic and hydrological changes in Lake Victoria have led to water scarcity on the lake ecosystem thus creating a large tract of land near the lake shoreline, extending all around the lake basin. These changes have led to either positive and/or negative impacts on the land resources as well as local livelihoods (Ogutu *et al.,* 2005; Odada *et al.*, 2009).

Land use activities occurring within a watershed such as urbanization, agriculture, mining, deforestation, road construction, and impoundments often severely alter aquatic habitat morphology and water quality of individual catchment areas (Gichuki, 2003; Ogutu *et al.,* 2005). These activities impact the physical, chemical, and biological processes that occur within a stream and wetland ecosystem. Among the causes of streams' habitat degradation include excessive nutrients, lack of diverse habitat complexity, sedimentation occurrence, and turbidity.

Drivers and Pressures

Ecological changes along the lake basin are induced by various drivers and pressures. Drivers such as demographic changes, economic demand, and trade, science and technology, as well as institutional and socio-political frameworks induce pressures that, in turn, influence the state of the ecosystem with impacts on the environment itself, and on society and economic activity. 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. Most pressures on ecosystems result from, for example, changes in emissions (atmosphere), land use, water and resource extraction (biodiversity). These drivers and pressures have changed, often at an increasing rate for the last two decades in the Lake Victoria basin.

The greatest direct human pressure on the climate system arises from the emission of greenhouse gases, chief of which is CO2, mainly originating from fossil fuel consumption. Since the dawn of the industrial age, the concentrations of these gases have been steadily increasing in the atmosphere.

The unprecedented recent rise has resulted in a current level of 380 parts per million, much higher than the pre-industrial (18th century) level of 280 ppm. Since 1987, annual global emissions of CO2 from fossil fuel combustion have risen by about one-third, and the present per capita emissions clearly illustrate large differences among regions.

There has also been a sharp rise in the amount of methane, another major greenhouse gas, with an atmospheric level 150 percent above that of the 19th century (Siegenthaler et. al., 2005, Spahni et. al., 2005). Examination of ice cores has revealed that levels of CO2 and methane are now far outside their ranges of natural variability over the preceding 500 000 years (Siegenthale et. al., 2005).

There are other atmospheric pollutants that affect the planet's heat balance. They include industrial gases, such as sulfur hexafluoride, hydrofluorocarbons, and perfluorocarbons; several ozone-depleting gases that are regulated under the Montreal Protocol; tropospheric ozone; nitrous oxide; particulates; and sulfur- and carbon-based aerosols from burning fossil fuels and biomass. Elemental carbon aerosols (soot or "black carbon") contribute to global warming by absorbing short-wave radiation, while also contributing to local air pollution. Removing such pollutants will be beneficial both concerning climate change and health effects. Sulfur-based aerosol pollutants, on the other hand, cool the planet through their influence on the formation of clouds, and by scattering incoming sunlight, and are thus currently "shielding" the planet from the full warming effect of greenhouse gas emissions (IPCC 2007). In the future, the policy measures needed to reduce public health problems and local environmental impacts associated with sulfur-based pollutants will weaken this unintended but fortunate shielding.

The Earth's surface temperature has increased by approximately 0.74°C since 1906, and there is very high confidence among scientists that the globally averaged net effect of human activities since 1750 has been one of warming (IPCC 2007). The warming of the last few decades is exceptionally rapid in comparison to the changes in climate during the past two millennia. Likely, the present temperature has not been exceeded during this period. Earlier discrepancies between surface temperature measurements and satellite measurements have been largely resolved (Mears and Wentz 2005). Model calculations including both natural and anthropogenic drivers give quite good agreement with the observed changes since the beginning of the industrial age. Most of the warming over the last century has occurred in recent decades, and this more rapid warming cannot be accounted for by changes in solar radiation or any other effects related to the sun that have been examined (IPCC 2007). The climate system possesses intrinsic positive and negative feedback mechanisms that are generally beyond society's control. The net effect of warming is strong positive feedback (IPCC 2001b), with several processes within the Earth's complex climate system acting to accelerate warming once it starts. The magnitude of such feedbacks is the subject of intense study.

Human intervention has put a lot of pressure on the Lake Victoria basin, land use in the Lake Victoria basin since 1970 has seen the 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 center especially along beaches (UNEP, 2006a). These changes have occurred amid varied social, environmental, and economic drivers.

A multidisciplinary assessment is necessary for understanding the complexity of land-use change. The approach of Geist & Lambin (2004) of classifying drivers of land-use change into proximate and underlying cases is adopted. Land-use change is best exemplified in deforestation and another conversion of land-use types. In the Lake Victoria basin like other tropical ecosystems, more than one-third of the causes of deforestation is driven by the full interplay of economic, institutional, technological, cultural, and demographic variables (Geist & Lambin, 2004).

Land use and cover change occur 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 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 factors

Demographic changes in the Lake Victoria basin have been fundamental. Population growth within the basin has steadily outpaced continental averages by between 2.5% 11.2% per decade. Population attributes of natural growth, 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.

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 the 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 vegetation cover, soil structure, highly variable rainfall, or a mismatch between environmental conditions and land-use practices. Forced and economic migrations influence demographic changes and settlement patterns, particularly at the regional level.

Socio-economics and cultural factors

Economic growth and unsustainable consumption patterns represent a growing pressure on the environment, though this pressure is often distributed unequally. Dasgupta (2002) argues that economic growth is unsustainable in poor countries, partly because it is sustainable in wealthy countries.

Socio-economic and cultural factors drive land-use change in many ways through practices and ecosystems goods and service users that affect demand for energy and ecosystems products. The values, beliefs, and norms of inhabitants of the basin's dwellers through diverse have far-reaching ecosystem consequences. The land-use choices of the Luo in Kenya, for instance, are culture-bound (Ochola et. al., 2000). 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 the lake basin's resources that influence land-use change as well as state of ecological systems and human wellbeing is related to technological change. Expansion and productivity in agriculture, forestry, fisheries, and other sectors are tied to technology (Ewert *et al.*, 2004).

The basin's climate system has changed since the Holocene era (Johnson *et al.*, 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). Cline (2007) elucidates climate change impacts on global and country-level agricultural land use identifying the inter-linkages also relevant for understanding climate change impacts on ecosystems level changes. Recent climatic trends for the lake basin have shown 10–40% decreases in precipitation

since 1960 (UNEP, 2006a), 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.

Increased economic development has resulted in the growth of trade. Trade has continued to grow over the past 20 years, as a result of lower transport and communication costs, trade liberalization, and multilateral trade agreements, such as the North American Free Trade Agreement. Between 1990 and 2003, trade in goods increased from 32.5 to 41.5 percent of world GDP.

As with globalization, a two-way relationship exists between the ecosystem and trade. Transport has increased as a result of increasing flows of goods and production networks. Transport is now one of the most dynamic sectors in a modern economy and has strong environmental impacts (Button and Nijkamp 2004). Trade itself can exert pressure on the environment. Increases in international grain prices may increase the profitability of agriculture, and result in the expansion of farming into forested areas in Lake Victoria catchment areas. In the presence of market or intervention failures, international trade may also exacerbate environmental problems indirectly. For example, production subsidies in the fishing sector can promote overfishing (OECD 1994). Natural disasters, in turn, can have an impact on trade at the national level, when exports fall as a result of physical damage.

Increased energy consumption has also been realized due to economic development. The country is facing twin threats: inadequate and insecure supplies of energy at affordable prices, and environmental damage due to overconsumption of energy (IEA 2006a). The demand for energy keeps growing, placing an ever-increasing burden on natural resources and the environment. Global increases in carbon dioxide emissions are primarily due to fossil fuel use (IPCC 2007), the fuels that met 82 percent of the world's energy demand in 2004. Traditional biomass (firewood and dung) remains an important energy source in developing countries, where 2.1 billion people rely on it for heating and cooking (IEA 2006a). The use of cleaner energy sources, such as solar and wind power, remains minimal overall. The need to curb growth in energy demand, increase fuel supply diversity and mitigate climate destabilizing emissions is more urgent than ever (IEA 2006a).

Technological innovation

Advances in agriculture, energy, medicine, and manufacturing have offered hope for continued human development and a cleaner environment. New farming technologies and practices related

to water use, fertilizer, and plant breeding have transformed agriculture, increasing food production and addressing undernutrition and chronic famine in some regions. Since 1970, food consumption is increasing in all regions and is expected to continue to increase as a result of economic development and population growth. Concerns have been raised over the ability to meet future demand: 11 percent of the world's land is already used for agriculture, and in many places, little room exists for agricultural expansion due to land or water shortages. Biotechnology, including genetic modification, as well as nanotechnology, has the potential to increase production in agriculture and contribute to advances in human health (UNDP 2004) but remains subject to much controversy over effects on health and the environment. Earlier lessons from new technologies show the importance of applying the precautionary approach (CIEL 1991) because unintended effects of technological advances can lead to the degradation of ecosystem services. For example, eutrophication of freshwater systems and hypoxia in coastal marine ecosystems result from the excess application of inorganic fertilizers. Advances in fishing technologies have contributed significantly to the depletion of marine fish stocks.

Communications and cultural patterns have also been revolutionized in the last 20 years, with the exponential growth of the Internet and telecommunications. Worldwide, mobile phone subscribers increased from 2 per 1 000 people in 1990 to 220 per 1 000 in 2003 and worldwide Internet use increased from 1 in 1 000 in 1990 to 114 per 1 000 in 2003 (GEO Data Portal, from ITU 2005). Many developed countries lead the way in the number of Internet users, hosts, and secure servers, prompting some to claim that there is a digital divide between different regions of the world.

Policy and Institutional factors

At the regional level, countries have expanded or established institutions to enhance cooperation such as the African Union (AU). Regions became more visible in global deliberations, through, for example, the emphasis on regional preparatory meetings for the World Summit on Sustainable Development.

The national level remains central in governance, despite discussions in the context of globalization and regionalization. Some countries are adopting innovative governance systems and there has been a trend towards both political and fiscal decentralization of governance to sub-national levels. This does not necessarily mean that local authorities have been empowered. It has been argued that decentralization without devolution of power can be a way to strengthen the presence of the central authority (Stohr 2001).

Local governments have also engaged much more widely in international cooperation in various areas, and their role has been strengthened at the global level through the establishment in 2000 of the UN Advisory Committee of Local Authorities (UNACLA) and the World Urban Forum in 2002, as well as the founding of the United Cities and Local Governments Organization in 2004.

Unfortunately, policy-making and institutional reforms remain anchored in the less complex, more manageable environmental challenges of the 1970s, and have not kept pace with the emergence of these persistent environmental problems.

An inventory of environmental policy goals and targets, a review of experience in managing cross-cutting issues, an assessment of the adequacy of multilateral environmental agreements (MEAs), underpin this review. Evidence shows that there is an urgent need to address the types of environmental problems that may have irreversible consequences, which may make local, regional, or even global environments progressively uninhabitable.

Conclusions

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. 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 impact of services offered by ecosystems to human beings in the basin and beyond.

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