Ecological gradients as a framework for analysis of land-use change in East Africa

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Abstract

This paper discusses the ecological gradient as an organizing framework to assist understanding the complex interactions between societal and ecological processes underlying land-use change in East Africa. Detailed case studies on the gradients of the slopes of Mt Kilimanjaro, Kenya show how land-use change is responsive to the dynamics of both local and external driving forces. The study has shown that the distinct ecological conditions at the extremities of gradients are associated with specific land uses which may be different within livelihood systems such as for wet and dry season grazing. Access to water for cultivation, domestic use, livestock and wildlife is critical in determining the nature and distribution of livelihood systems. Land-use systems interact across the different ecological zones of the gradients characterized by vigorous spatial, cultural and economic interactions. Sometime conflicts occur between or within land-use/livelihood systems. There is strong evidence that the areas of higher economic potential remain advantaged compared with areas lower on the gradient. The ecological characteristics have been found to influence human activities and distribution. Interactions between societies are important in terms of trade, social relations and access to resources.

Key words: ecological zones, gradient, Kilimanjaro, land-use, livelihoods

Introduction

Many livelihood systems in Africa are organized to take advantage of the resources afforded by diverse ecological conditions. In many cases, these may be represented as ecological gradients. Such gradients may be defined as encompassing a range of ecological conditions from higher rainfall (potential) to lower rainfall (potential) where land-use and livelihood systems interact across the zones. This definition limits the geographical extent of the gradient to the land use of wildlife and human livelihood systems in terms of their interactions across zones and/or between livelihood systems. They can be both 'vertical' as on mountain slopes and 'horizontal' as for example across ecological zones in the West African desert-sahel-sudan zones. The vertical gradients on mountains, caused by orographic rainfall and temperature differences, are more spatially condensed.

Interactions across gradients may occur within land-use or livelihood systems, for example, where wildlife and livestock herders use wetter areas in dry seasons/drought and drier areas in wet seasons such as the Maasai in East Africa (Bernard, Campbell & Thom, 1989; Spear & Waller, 1993) and the Touareg (Nicolaisen, 1963) and Peul/Fulani (Dupire, 1962; Boutrais, 1988) in West Africa. Similarly, there are examples of cultivation systems where farmers use hilltops, hillsides and valleys allowing production of a variety of crops and thus mitigating risks such as total crop failure. Examples include the precolonial Kikuyu in Kenya (Ruthenberg, 1980), the Chagga on Mt Kilimanjaro (Moore, 1977; Bart, Mbonile & Devenne, 2003), the Mafa in north Cameroon (Boutrais, 1973; Boulet, 1975) and the Kofyar in Nigeria (Netting, 1968). Cross-gradient interactions may also exist between livelihood systems. The most important of these interactions are at the junctions between zones – e.g. between savannas and the rain-fed crop systems where upland farmers have economic, social and ecological exchange relationships with lowland herders.

Gradients also display socio-economic characteristics that vary both within livelihood systems, and between

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them in terms of trade, social relations and access to resources. Power relations often determine the processes defining such characteristics and access to resources. For example, in precolonial times greater power rested with herders in the dry lands and less with adjacent farming groups. In most cases, this power relationship was reversed with colonial rule, except in areas that were distant from state authority. The objective of this study was therefore to examine how ecological gradient as an organizing framework can assist in understanding the complex interactions between societal and ecological processes underlying land-use change in East Africa.

Materials and methods

This linkage paper has been developed based on a series of working papers written by scientists who participated in Landuse Change Interactions Dynamics project (LUCID) which was implemented between 2000 and 2004 in East Africa. Studies conducted on slopes of mounts Kilimanjaro, Kenya and some parts of Uganda were selected as they exhibit characteristics of ecological gradients. This commonality allows for the processes of land-use change and implications for land degradation and conservation to be compared and contrasted using the gradient as a common organizing framework. Selected papers for reference are found through a project website namely http://www.lucideastafrica.org. The papers used for reference were based on extensive field work undertaken in Tanzania (Mount Kilimanjaro), Kenya (Mount Kenya) and Uganda (Sango Bay Area, around Lake Mburo National Park in Mbarara and Rubaale districts and Ntungamo and Kabale district) whereby different biophysical and socio-economic data were collected using different approaches. In Uganda, the case study areas are not contiguous but represent an ecological gradient in the sense that all have different ecological characteristics.

Results and discussion

Characteristics of east African gradients

The ecological gradients on the slopes of Mt Kilimanjaro in Tanzania and Kenya, and on Mt. Kenya represent important ecosystems that have unique resources and many opportunities for the development of their people. These can be illustrated by the southern gradient on Mt. Kilimanjaro which have five distinct ecological zones namely: the lowland zone, reaching an altitude of about 900–1000 m.a.s.l.; the cultivated belt (Coffee-banana belt, De Pauw, 1984) extending up to 1700–1900 m.a.s.l; the montane forest zone, which includes the half mile strip along the southern edge of the forest and the Kilimanjaro Forest Reserve extending to 3500–3700 m.a.s.1.; Heath land occurring in the alpine and sub-alpine zones at altitudes exceeding 3500 m.a.s.1., and the alpine desert (the summit) dominated by bare rock and ice (Mbonile, Salome & Cosmas, 2003). Rubaale in Uganda is the highest in terms of altitude (1500 m.a.s.1), Lake Mburo and its surrounding areas are located at an altitude of around 1250 m.a.s.1 while Sango Bay area is located at 1160 m.a.s.1.

In terms of agro-ecological potential, the lowland zone is characterized by variable rainfall and drought is recurrent. Until recently, extensive livestock keeping (mainly traditional cattle) by the Maasai people dominated this zone, which also provided the habitat for large and varied wildlife populations. Over the past 40 years, the lower slopes and adjacent plains in both Kenya and Tanzania have witnessed increased cultivation because of smallholder farmers moving down the gradient and significant investment in irrigation.

The middle zone of gradients is characterized by high population density and a high rainfall, with temperatures ranging between 25 and 30°C. In the coffee/banana belt, improved dairy cattle and also the traditional cattle are kept under zero grazing. The lower edge of this zone is climatically similar to the lowlands and people engage in cattle production and the growing of annual crops, mainly maize and beans for both food and income (Campbell *et al.*, 2003a,b).

A similar gradient, also characterized by a variety of livelihood systems is found on Mt Kenya (Bernard *et al.*, 1989). According to Gachimbi (2002a,b), Embu and Mbeere Districts, Kenya, on the eastern slopes of Mt Kenya represent a range of ecological conditions. Embu District has a good climate and fertile soils ideal for small-scale farming of annual and perennial crops, while Mbeere District is of marginal agricultural potential.

Rainfall fluctuations in East Africa have been occurring in well-established cycles of about 10 years. Some of the droughts that have been clearly remembered by several East African households have been the droughts of 1974, 1983 and the most recent one of 1994. These drought periods were punctuated by abnormal climatic conditions like those of El Nino in 1997 that turned out to be a

disaster rather than a blessing. Besides farmers and pastoralists, drought attracts wildlife and areas near wetlands are heavily eroded. On the other hand, spells of heavy rainfall lead to the destruction of already established biomass (Wangui, 2003; Mbonile *et al.*, 2003). According to Pomeroy *et al.* (2003), Rubaale receive around 850 mm of rain per year while Sango Bay area receives annual rainfall exceeding 1200 mm year^{-1}.

At a gradient level, on the two mountains species diversity and richness increases with decrease in altitude. This implies that the lowlands, including the scrubland and the shrub land, which were used as pastureland were much more diverse having a number of grass species and shrubs which were not encountered anywhere in the highlands. In Tanzania, the notable shrubs included *Commiphora africana, Boscia angustifolia, Croton pseudopluchellus, Grewia burtii, Solanum incanum, Hyptis suavelons* and *Ocimum suave.* Such species may serve to indicate overgrazing in the area and thus land degradation. Other palatable annual grasses for livestock on slopes of Mt Kilimanjaro include *Eragrostis superba, Pennisetum polystachion, Heteropogon contortus* and *Eragrostis aethiopica.* Thus, with a decrease in altitude, the lowlands were favourable for grazing activities and to some extent cultivation of cereal cash crops such as maize, rice and a number of vegetables (Misana *et al.*, 2003). A belt of cultivated grassland and cropland has replaced virtually the entire lower part of the montane forest belt. Much of what used to be scrub, bush and lowland forest have been converted to cropland or grassland. A similar pattern of vegetation is found on the slopes of Mt Kenya, and similar land uses have emerged on the lower and upper slopes of the mountain (Olson *et al.*, 2003). In Uganda, dry Acacia dominates the area surrounding Lake Mburo while grass savanna dominates Sango Bay area.

The properties of soils influence the choice of both cash crops and food crops grown along transects. For example, a detailed study conducted on the Tanzanian slopes of Mt Kilimanjaro indicates that most soils located on the upper and middle zone are inherently fertile as compared with soils located on the lower zones (Majule, 2003). Major factors attributing the difference include high soil fertility management levels in the Kihamba system whereby large amount of organic residues is added. On the other side, there are significant soil erosion control practices including trash grass and terraces. Soil fertility degradation is common in the lower zone as a result of poor management practices such as excessive application of artificial fertilizers in rented fields and transfer of biomass from the lowlands to the highlands (Misana *et al.*, 2003). Overgrazing is also a serious problem in the lower zone leading into soil erosion (Majule, 2003).

The survey conducted by Gachimbi (2002a) on the Kenyan slopes and Majule (2003) on the Tanzania slopes of Mt Kilimanjaro also demonstrated the natural fertility of volcanic soils, but warned of a decline of soil fertility is associated with land degradation and poor application of chemical fertilizers. Similar conclusions have been reached by studies of soils and soil management on Mt. Kenya (Gachimbi, 2002b).

The distribution of land uses and of wildlife species across the gradient often results in conflict when wildlife grazes crops or predates livestock. In Kenya, such conflict is long-standing though the specifics of such encounters have changed over time as a result of changing patterns of human–wildlife competition and conflict over an extended period of time. The differences over years lie in the complex processes of socio-economic change and their interplay with the environment. The driving forces are institutional and ecological, cultural, economic and political.

In the Loitokitok case study, for example, the interaction between people and wildlife differed from one area to another. The greatest number of conflicts with any species of wildlife is found in the swamps (Campbell *et al.*, 2003a,b). Over the past 75 years, the Maasai herders (original pastoral land managers) have relinquished to wildlife and farming their control over resources fundamental to their herding economy. Farming on the northern Kenyan slopes of Mt. Kilimanjaro began in the 1930s. Since the mid-1970s, land-use changes have occurred in the area between Amboseli and Tsavo West national parks. Cultivation has expanded at the expense of forest on Mt. Kilimanjaro, and riparian vegetation along rivers and around swamps in the lowlands. Also, the government is encouraging establishment of tourist facilities on group ranches adjacent to parks. Today, the land uses compete for access to resources particularly grazing land and water, and many people are now located where their economic and personal security are vulnerable to threats from wildlife. Decreasing wildlife populations have been observed with increase in human population (Worden *et al.*, 2003), as a result of habitat destruction. Escalating crop raiding conflicts resulting in erection of barriers and other protective measures that have contributed to disruption of wildlife as observed in Embu District, Kenya (Chira, 2003).

Dynamics of socio-economic characteristics of gradients

The patterns and processes of land-use across ecological gradients in Africa have changed dramatically over the past 150 years since the advent of colonial powers. There have been changes in the power relations that determined access to and control over the diverse resources of the gradients, and these have altered the sustainability and vulnerability of livelihood systems. These dynamics will be discussed in terms of themes that illustrate the principal driving forces of land-use change, power, land adjudication, demography and environmental conditions.

Historical evidence suggests that the mountain slopes of East Africa have been occupied for over 2000 years (Hamilton, 1982). The ancestors of the contemporary inhabitants probably move to these areas a part of the Bantu migrations, being attracted by fertile volcanic soils and reliable rainfall. The principal crops grown were sorghum and sweet potato, and many kept livestock, including cattle and goats. For example, the Chagga who have resided on the southern slopes of Mt. Kilimanjaro since the 1600s developed an intricate land-use system, the Kihamba or home gardens characterized by multi-purpose trees intercropped with food crops, mainly bananas, finger millet and beans, and the shamba land (small fields in-between the different vihamba) with food crops like maize, beans, yams, sweet potatoes, finger millet and grass for livestock (Anderson, 1982). This agroforestry farming system is supported by a sophisticated indigenous irrigation system. The farmers also own livestock, some being stall fed and applied manure from the livestock. The farmers of the uplands throughout East Africa traded with adjacent herding groups, such as the Maasai around Mt. Kilimanjaro and the Mbeere on the eastern slopes of Mt. Kenya. The Chagga also participated in the regional trade from the coast inland to Lake Victoria.

A number of processes contributed to change in the nature and distribution of livelihood systems since the colonial period. These included a disruption of precolonial power and authority structures, economic development, population growth, land alienation and land consolidation in high potential lands. These processes created a land shortage in many high potential areas leading to out-migration of farmers. They moved to lower potential areas including to areas adjacent to existing settlement, to high potential 'islands' in dry lands such as river valleys and swamps, and to the lower slopes of mountains.

The most important impact of colonialism on cross-gradient interaction emanated from the loss of military and political power by herding groups, and the transfer of authority, under indirect rule, to farming societies. As herders lost power and their dominance of access to water in dry seasons and during droughts, farmers expanded into the wetter margins of the rangelands, including into river valleys and swamps formerly controlled by herders (Campbell, 1981).

The colonial policy favoured farming relative to nomadic, extensive livestock production. Political power shifted from herders to farmers, and the latter become more integrated with the state in terms of political and institutional power, access to infrastructure and markets, and the processing and marketing of their commodities. The British in Kenya chose to restrict access to the lucrative cash crop and commercial livestock sectors to settlers in the 'White Highlands'. The colonial authorities imposed taxes on the indigenous population and Kenyan smallholders in the central highlands, including Mt. Kenya. To obtain cash for taxes, farmers were encouraged to produce grains for sale in the expanding administrative and market towns, as well as for subsistence. The British imposed a system of chiefs who were responsible for collecting taxes and assuring labour for terracing of the slopes to improve soil conservation. Colonial investment in the highlands, particularly in and close to administrative headquarters such as Embu town, included extension services, roads, schools and medical facilities.

In Tanganyika, the Germans saw great potential in the production systems on the slopes of Mt. Kilimanjaro. They established coffee estates, and Moshi developed as a market and administrative centre linked by rail to the coast. After World War I, the British assumed authority and they encouraged the Chagga to grow coffee and vegetables for sale in Moshi and the coastal towns. The home gardens intensified, and an increase of population led to a decline in access to swidden lands. The expansion of coffee production led to the conversion of the grazing areas in the uplands, which necessitated stall-feeding (Soini, 2002). Among the Chagga, some of the small fields (shambas) where food crops were grown and Dracaena groves, areas set aside for burials and sacrifices were also converted to home gardens. In contrast to the situation in Kenya, the livelihood systems on the mountain slopes were integrated into the colonial economy. Increased wealth led the Chagga to create producer cooperatives and to invest in roads, education and medical facilities.

The change in the distribution of livelihood systems affected wildlife migrations and distribution. In the East Africa wildlife conservation policy, a systems of parks and reserves was established which affected lowland livelihood systems' access to resources. In some areas, this was also true of upland systems where upland parks were demarcated such as on Mt. Kilimanjaro in Tanzania and Mt. Kenya and the Aberdares in Kenya. A significant outcome of conservation policy was that issues of compatibility, competition and/or conflict arose between wildlife and adjacent livelihood systems (Campbell *et al.*, 2000).

Land adjudication policy

Land ownership and user rights are critical issues in determining access to humid areas that support rainfed cropping and to water along rivers and around swamps. The colonial authorities implemented policies that had a significant impact upon African society. The process of demarcating land as national parks and reserves for the conservation of wildlife was one facet of colonial land policy. A second was to allocate land to settlers, as with the coffee and sisal estates in Tanzania, and the 'White Highlands' in Kenya. In the central highlands of Kenya, it contributed to severe disruption of established land-use systems. This included land consolidation that reduced valley-hill crop diversification across the gradient, thus increasing the risks associated with drought and crop diseases. These policies of appropriation of land from the indigenous systems, and land consolidation were resented by the African population and provided the impetus for the Mau Mau revolt against the British.

Since the mid-1950s on Mt. Kenya, the British and subsequently the independent government have enforced land adjudication programmes that transferred land tenure from communal land organized by clans to private farm land organized by individual families. The focus was initially upon the high potential agricultural lands, including the rain fed slopes of Mt. Kenya. Land adjudication has stimulated a land market with the potential for redistribution of rights of access. Land became a commodity and replaced cattle as the measure of wealth. The policy was later applied to the drier lower slopes of the gradient and is now being applied to the rangelands.

The gradient on the northern slope of Mt. Kilimanjaro in Kenya has experienced land adjudication programmes since the mid-1950s. Initially, land on the wetter slopes was allocated as individual ranches and that in the lowlands as group ranches. The individual ranches were quickly subdivided into small farms. Some of these were farmed by Maasai who had married wives from farming groups such as Kikuyu, Kamba and Chagga. Others were sold to immigrant farmers who had experienced land shortage elsewhere in Kenya, such as on the slopes of Mt. Kenya. (Campbell, 1999). Over time, with population growth in the area and with continuing immigration, farming spread down the gradient into the drier slopes, and eventually extended to irrigated riparian areas along rivers and around swamps in the group ranches. Those farming in these areas did not have formal rights to land, and many settled as sharecroppers with Maasai members of group ranches or farmed as day labourers. Population growth, ambiguity as to land rights among younger members of group ranches, the increase in farming and the lucrative returns to irrigation, have culminated in contemporary demands for subdivision of the group ranches. The implications of a subsequent land market for the herding and wildlife-based economies of the area are uncertain (Ntiati, 2002).

Land adjudication is a response to economic development and to the perception that it is a necessary precondition for sustainable land management. It is also driven by population growth and migration. Each of these has a specific relationship with the land potential exhibited across the gradient. The upper reaches have greater economic potential, a higher land value, population densities are elevated and in the absence of conservation measures, the potential for land degradation is high. The lower slopes, in contrast, have less remunerative production systems and lower population densities. Recent trends in down-gradient migration are resulting in an intensification of land use, with an associated potential for land degradation.

Population dynamics

The pattern and intensity of land use across the gradients is reflected in demographic characteristics. The slopes of both mountains where the rainfall is more than 1000 mm per year have high population density exceeding 600 people per km^2 in some districts like Embu, in Kenya and Moshi Rural in Tanzania. On the other hand, in the lowlands and on the leeward slopes of these mountains where the rainfall is below 500 mm pa the population densities have been low until very recently when farmers settled to form clusters of dense population especially in well watered areas (Campbell, 1999; Olson *et al.*, 2003).

Population densities on the Tanzanian slopes of Mt. Kilimanjaro have changed dramatically during the last 60 years and illustrate patterns of change similar to those of the slopes of Mt. Kenya (Maro, 1975; Mbonile, 1999). The population increased from about 267,700 in 1948 to about 840,000 in 1988 and to 1,053,204 in 2002. There is also a high in-migration to local urban areas. However, this high population growth is slightly reduced by the heavy out-migration of population to other regions in Tanzania as well as abroad (Mbonile, 1999). Three major reasons explain these rapid changes of population dynamics in Tanzania. First, the introduction of traditional irrigation systems enabled the farmers to grow crops throughout the year and increased the productivity of staple foods like bananas. Second, there was a change in the cropping system with the introduction of coffee as cash crop, combined with improved health care and hygiene. The cash enabled the population to buy foods from other places and support the high population density. Third, the increase of population mobility between the lowlands and the highlands increased the area that could be cultivated. In addition, people are tapping resources like grass and crop residues, transporting them to the highlands where they enrich the soil by making compost manure and feeding them to livestock that in turn produce manure.

Conclusion

The study has shown that the distinct ecological conditions at the extremities of gradients are associated with specific land uses. Land-use systems interact across the different ecological zones of the gradients, and thus a gradient is characterized by vigorous spatial, cultural and economic interactions, sometimes conflicts between or within land use/livelihood systems. The level of exchange, competition and conflict across the gradient is determined by the relative power of different livelihood systems – ethnic, military, political, economic and technological to control access to key resources. The major land-use changes have been the expansion of cultivation down the slopes and the replacement of natural vegetation by cultivated land. In the uplands, there has been encroachment on the forest for agriculture and in some areas exotic trees have replaced the indigenous trees. In the low lands, including the plains, agriculture has expanded into areas formerly used for watering animals, grazing and wildlife conservation. This study has illustrated the importance of gradients to livelihood systems in East Africa. The ecological characteristics have influenced their activities and distribution. There are important interactions between them in terms of trade, social relations and access to resources. These interactions have changed over time as power relations between groups have altered access to resources, and as external economic and political processes have shaped options available to different livelihood systems. These changes have had an impact on the sustainability of the resource base across the gradient and future patterns of land use will reflect the ability of the resources to support them.

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Conflicts of interest

All authors declare no conflicts of interests.

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