LUCID's Land Use Change Analysis as an Approach for Investigating Biodiversity Loss and Land Degradation Project

Linkages between Changes in Land Use, Biodiversity and Land Degradation in the Loitokitok Area of Kenya

LUCID Working Paper Series Number: 49

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Linkages among Changes in Land Use, Biodiversity and Land Degradation in the Loitokitok Area of Kenya

The Land Use Change, Impacts and Dynamics Project
Working Paper Number: 49

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1 Executive Summary

This study attempts to link land-use change, biodiversity and land degradation for the Loitokitok area, just north of Kilimanjaro in Kenya. These are the highlights of our findings:

- **Land-use change.** The Loitokitok area has experienced rapid and extensive land use change over the past 30 years in response to a variety of economic, cultural, political, institutional and demographic processes. Expansion of agriculture down the slopes of Mt. Kilimanjaro dominates these changes in land use. Farmers expanded rainfed agriculture from the slopes of Mt. Kilimanjaro onto the piedmont on the lower slopes and also now grow irrigated crops around swamps and along rivers. The expansion of the area under crops has restricted the viability of herding activities around the base of the mountain, resulting in increased sedentarization and diversification of herding livelihoods into mixed herding-farming livelihoods. Wildlife populations, which had access to swamps ringing the base of Kilimanjaro in the 1970's now have no access to one of these swamps and only partial access to three others.

- **Subdivision of group ranches.** Over the past 25 years there has been considerable tension in the group ranches over the security of land tenure, especially for young people. This has created a demand for sub-division, a process that has now begun on many of these lands. We expect sub-division will increase the security of land rights, but will also reduce the viability of pastoralism and wildlife, by restricting movements.

- **Land use and gender.** Women supply more of the labour required in livestock production than the men. This evolution in care of livestock towards women, and in crop production towards both men and women, appears to be related to sedentarisation.

- **Land-use change and wildlife.** Between the 1970's and 1990's, most of the 17 rangelands districts of Kenya lost over 50% of their wildlife. However, wildlife in one district, Laikipia increased over this period, and in Kajiado, where the Loitokitok site is found, wildlife numbers have remained unchanged. The conversion of swamps to cropland over the last 20 years near Loitokitok and the growth of settlements and human populations is altering the distribution and probably the abundance of wildife in the Amboseli Basin. Wildlife no longer have access to important wetland areas that were the stepping stones in their movements between the Amboseli and Tsavo ecosystems.

- **Land-use change and plant diversity.** Trees and shrubs clearly were more sensitive to farming and grazing than either herbs or grasses. The pastoral lowlands supported 50% more species than wetter, farming zones and more than 55% of these were natives. Our results suggest that pastoral land use is more compatible with high native plant diversity compared with middle zone farms. However, once pastoral people settle and cultivate farms, weeds replace native plants quickly, just as they do as farmers cultivate more well-watered farms in the midlands. Mixed croplands can support more than twice as many species as mono-cropping.

- **Land-use and soils.** In most cases in Loitokitok, nutrient levels are generally adequate in uncultivated soils, unless there is significant natural erosion or heavy grazing. Phosphorus and soil organic matter only fall below fertility thresholds where organic matter is naturally low or where farmers use practices that mine soil nutrients. Particularly in the lowlands, the soils show a characteristic wide range in available P, from moderate to high. This reflects that strongly weathered soils of the non-dissected erosional plains and the weakly weathered soils of the plains, both on gneisses, have a low P-status. Soil organic matter is naturally high in the upper, wetter zones on the slopes of the mountain, but are low in the hotter and drier zones around the base of the mountain. Soil organic carbon (SOC) and phosphorus (P) are generally low in grain fields, irrigated fields, fallows, and sometimes in maize fields, pasture and bushlands. This is due to continuous cultivation in all zones and possibly grazing in the lowlands, and the high mineralisation rates of soil organic carbon caused by high temperatures and adequate moisture, the latter particularly in the lowlands.

- **Implications for land management.** All soils across the agro-ecological zones have inherently good soil fertility. They do not, however, receive adequate nutrient replenishment to compensate for continuous nutrient mining. This replenishment could come in the form of organic manures, inorganic fertilizers or biomass transfer through agro-forestry or short fallow. These practices, are within the means of people in the area as many already practise agroforestry, those producing horticultural and other cash crops obtain sufficient income to purchase inputs, while others combine livestock raising with cropping and have access to manure.

- **Implications of sub-division of group ranches.** Land tenure policy is having strong impacts on the livelihoods of herders and farmers, and will have consequences for land management practices, water availability, agricultural production, fuelwood production, and conflicts among different land users. Policy makers and land managers need to clearly understand both the positive (tenure security) and negative (possible land and water degradation, increasing conflicts) that privatisation of land will bring to these drylands. As has been shown in other parts of Kajiado District, land privatisation of land may make herders and farmers more vulnerable to drought because their safety net of mobility has been removed.

- To be better accepted, **wildlife management policy** will need to address both the sustainability of peoples' livelihood systems and that of wildlife populations.

2 Introduction

Human use of the land is at the center of some of the most complicated and pressing problems faced by land managers, land users and policy makers around the world today (e.g., De Fries et al. 2004, Platt and Rutherford 2004). Globally, concerns about the changes in land use / cover emerged due to realization that land surface processes influence climate and that changes in these processes impact on ecosystem goods and services that all live depends upon (Lambin et. al. 2003). Land-use is at the center of the trade-offs between human needs and the environment because changes in land use often enhance the share of primary production for human consumption but decrease the share available for other ecosystem functions. The impacts that have been of primary concern are the effects of land-use change on biological diversity, soil degradation, and the ability of biological systems to support human needs. Crop yields have declined, forcing people to cultivate more and more land to meet their needs. Grazing areas have become less and less productive resulting from over stocking of livestock. Conflicts over the use of land have increased due to increased demand for land by different sectors of the economy. Of particular concern are the conflicts among cultivators, livestock keepers, wildlife conservationists, individual land users and governments due to encroachment of human use into the protected areas (Western 1976, Wells and Brandon 1992, Hoare 1999, Campbell et al. 2003).

In this paper we report a summary of linkages among changes in land use, biodiversity and land degradation on the northern side of Mt. Kilimanjaro in Kenya, based on research conducted for the nearly 30 years between 1976 and 2003 by members of the LUCID team. This summary was made possible by the Global Environmental Facility through UNEP, which took the bold step to support this synthesis, rather than collection of new data. We combine analysis of land-use change with ground measurements and assessments of biodiversity change and land degradation to give a robust analysis of the impacts of land-use change. We have adopted a multidisciplinary approach combining ground assessments, remote sensing analysis, and human perceptions analysis.

We start our synthesis of these linkages with background information on the trends in land-use change in the study area from 1970-2000. We then assess the impacts of these changes on wildlife, soils, plant species and water quality. We finish by establishing links between plant species diversity (a proxy for biodiversity) and soil fertility and erosion (a proxy for soil conditions).

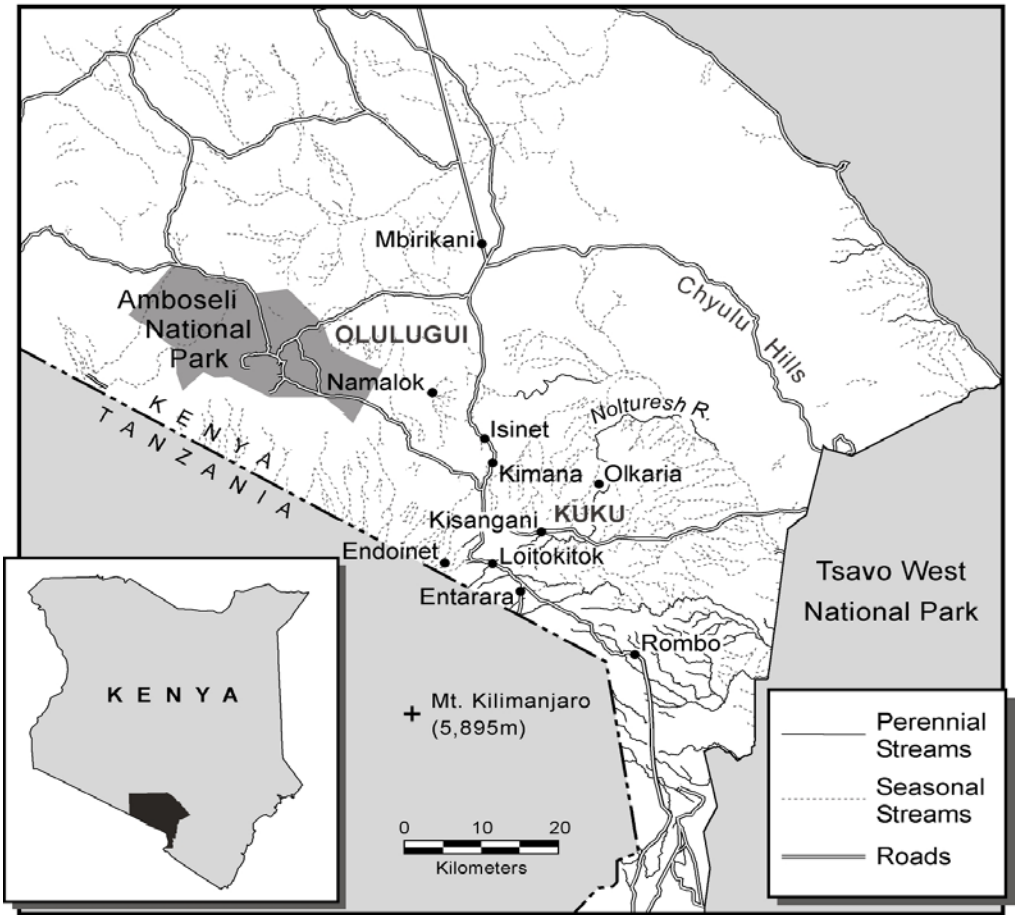
3 The Loitokitok Study Area and Methods

The study area is located in southeast Kajiado District, Kenya (Map 1). Here, rain falls twice a year in the classic bimodal pattern found around the equator in East Africa, with precipitation peaks in March-April and October-December. Lower elevations between Amboseli National Park and the Chyulu Hills receive less than 500mm and higher rainfall occurs on the Chyulu Hills and on the slopes of Mt. Kilimanjaro (Jaetzhold and Schmidt 1983). Total mean annual rainfall, over a distance of only 17 km, varies from about 400 to 1000 mm, a rise of 100 mm per 3 km traveled upslope. The rainfall is however inconsistent in time and space and drought is a recurrent problem in the area. During the present century droughts are recorded in 1933-35, 1943-46, 1948-49, 1952-53, 1960-61, 1972-76, 1983-84, and the early 1990s.

The site covers seven agro-ecological zones, spanning from the lower highlands to the lower midlands (Jaetzold and Schmidt 1983). Agricultural potential is highest on the slopes of Mt. Kilimanjaro due to reliable rainfall and fertile volcanic soils. The lowlands are of relatively low productivity, supporting a savanna bushland in which livestock herding and wildlife predominate. Altitude ranges from about 1900 m in the lower highlands (LH2) to about 900 m in the lower midlands (UM4) in the rangelands. The eight agro-ecological zones include:

1) LH2, the wheat/maize - pyrethrum zone, 2) LH3, the wheat (maize) – barley zone, 3) UM3, the marginal coffee zone, 4) UM4, the sunflower – maize zone, 5) UM5, the livestock sorghum zone, 6) LM4, the marginal cotton zone, 7) LM5, the livestock – millet zone, and 8) LM6, the ranching zone. This broad classification hides the presence of relatively small, localized areas that due to the existence of permanent water and fertile soil are potentially more productive than the surrounding rangelands. These areas include the swamps at Namalok, Isinet and Kimana, and the valleys of the perennial streams that originate on Mt. Kilimanjaro, such as at Rombo and the Nolturesh (Jaezthold and Schmidt 1983).

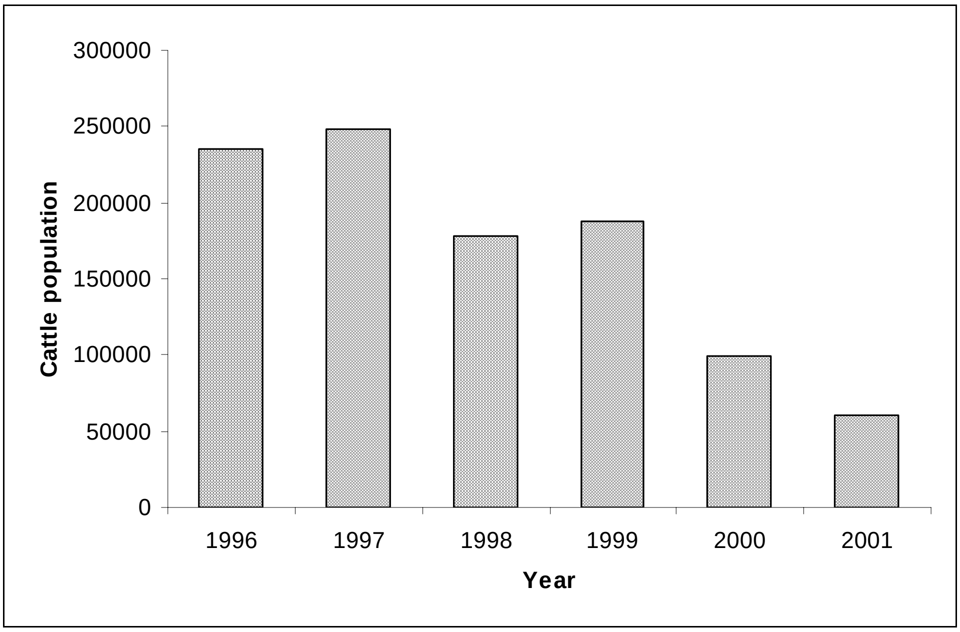
Map 1. Location of the study area just north of Kilimanjaro in southern Kenya.



Around Loitokitok town, soils are young and fertile (Jaetzold and Schmidt 1983), and developed on Tertiary basic igneous rocks (nitro-cambic cambisols and eutric cambisols). These rich soils spill like a mantle off the footslopes of Kilimanjaro, grading into soils of somewhat lower fertility towards Kuku and the Esoitpus River derived from igneous rocks (luvisols, phaeozoms). Soils of low fertility dominate the lakebed (lacustrine plains) in the lowlands in nearby Amboseli National Park and near Kimana swamp. These soils were derived from volcanic ash and other sources. See more detailed descriptions of the soils in the study site in (Gachimbi 2002).

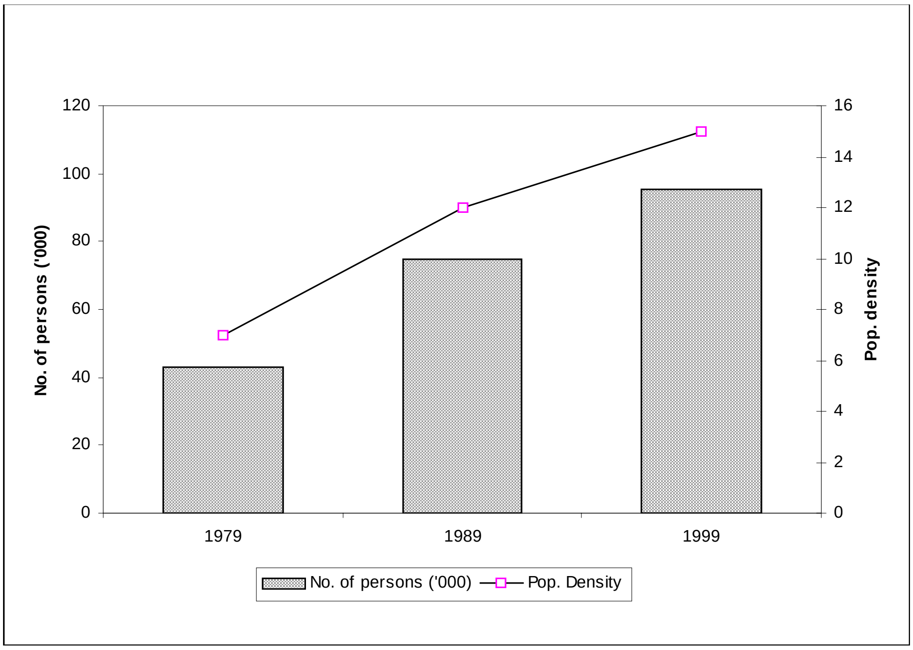
The area's rural economy is diverse. Subsistence production dominates, though horticultural production has expanded over the past two decades and the area has become one of Kenya's foremost producers of horticultural products (Krugmann 1996). Livestock herding by the Maasai is still widespread, and is subject to strong dynamics due to drought, exemplified by the livestock loss during the recent 1999-2000 drought (Figure 1). Wildlife-based tourism is the most important activity in terms of the national economy.

Figure 1. Cattle populations for Loitokitok Division, Kajiado District from 1996-2001. Source: District Agricultural Officer (DAO), Annual Reports 1996-2001.



Population growth in the District has been rapid since independence (Figure 2). The size of the human population more than doubled between 1979 and 1999 in Loitokitok Division, from 5 people per km^2 to 12 people per km^2. In the Loitokitok area it reflects natural increase as well as migration of large numbers from the congested central highlands to cultivate the fertile and relatively well-watered slopes of Mt. Kilimanjaro and other hills.

Figure 2. Human population numbers and density for Loitokitok Division, Kajiado district, Kenya from 1979-1999. Data source: GoK 1999.



The methods employed by the different studies that we summarise here can be found in the following working papers on the LUCID website (www.lucidea.org): (Gachimbi 2002, Campbell et al. 2003, Githaiga and Muchiru, Wangui 2003, Worden et al. 2003, Maitima et al. 2004). We collected information on: 1) plant diversity, soil fertility and erosion in different land use types and across agro-ecological zones, 2) wildlife diversity and abundance around swamps used by wildlife alone, livestock and wildlife together, and livestock and crops alone, 3) farmer and herder perceptions of changes in their environment, and 4) water quantity and quality in the swamps described above. A summary of the methods used to collect each set of information appears below at the beginning of the appropriate section; further information can be found on the several working papers on the LUCID website.

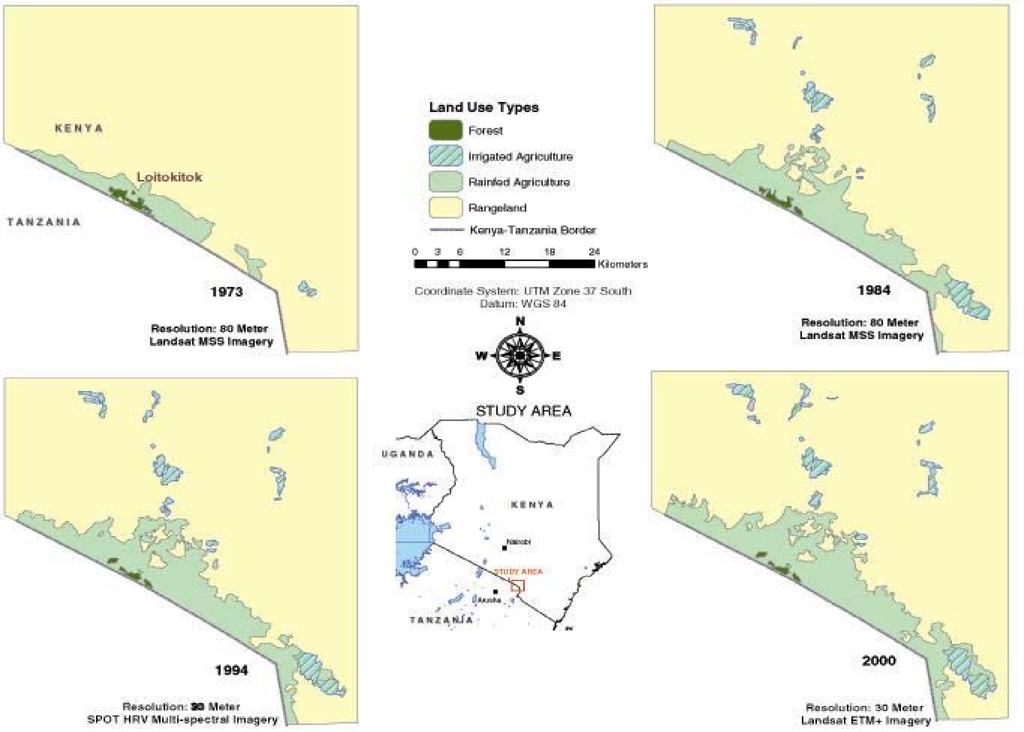
4 Land-Use Change, 1970-2000

David Campbell, David Lusch, Tom Smucker, and Edna Wangui completed a study of changes in land-use in the Loitokitok area from 1970-2000 as part of the LUCID project. They found that this area has experienced rapid and extensive land use change over the past 30 years in response to a variety of economic, cultural, political, institutional and demographic processes (Campbell et al. 2000, Campbell et al. 2003). Expansion of agriculture down the slopes of Mt. Kilimanjaro dominates these changes in land use. Farmers expanded rainfed agriculture from the slopes of Mt. Kilimanjaro onto the piedmont on the lower slopes and also now grow irrigated crops around swamps and along rivers. The expansion of the area under crops has restricted the viability of herding activities around the base of the mountain, resulting in increased sedentarization and diversification of herding livelihoods into mixed herding-farming livelihoods. Wildlife populations, which had access to swamps ringing the base of Kilimanjaro in the 1970's now have no access to 1 of these swamps and only partial access to 3 others.

The forest area on the upper slopes of Mount Kilimanjaro adjacent to the national forest in Tanzania, declined 2.3 percent from an estimated 646 hectares in 1973 to 417 hectares in 2000. Over that time period, the area of rainfed agriculture expanded 177 percent and that of irrigated agriculture 45.2 percent. The principal changes are associated with the availability of water for crop production.

The period of most rapid expansion of both irrigated and rainfed cultivation was between 1973 and 1984. The general pattern of agricultural expansion between 1973 and 1984 (Map 2) follows a concentric pattern conforming to the slopes of Mt. Kilimanjaro (Jaetzhold and Schmidt 1983). An uneven expansion extended farther down slope around the town of Loitokitok and along the main road from the town to Nairobi. These slopes receive over 800 mm of rainfall annually and a number of perennial streams flow down them to the plains. They offered considerable opportunities for cultivation and by the mid-1980s almost the entire area between the Tanzania border and the semi-arid plains has been cleared and planted, by immigrant farmers, mostly from Central and Eastern Provinces, and by Maasai themselves. Land adjacent to permanent water sources, e.g., at Kimana, Rombo and around swamps at Namalok and Isinet had also been cleared for cultivation. The second focus of the expansion of cultivation is that around swamps and around rivers, taking advantage of opportunities for irrigated crop production.

Map 2. Land use in 1973, 1984, 1994 and 2000 at the Loitokitok site, Kenya.



5 Contemporary Processes of Sub-Division of Group Ranches

Paul Ntiati designed a study to describe some of the important socio-economic and ecological implications of the contemporary process of subdivision of group ranches resulting in a change from communal to individual land tenure in the Loitokitok Division of Kajiado District, Kenya (Ntiati 2002). Mr. Ntiati conducted group interviews, meetings with key informants, and discussions with community leaders and development agencies involved in land tenure issues.

The land tenure reform programme implemented in Kajiado District started in 1961 with the demarcation of commercial ranches and group ranches. Its objective was to set the stage for development of what was assessed to be the best sustainable production system in the semi arid and arid rangelands of Kenya, and Kajiado District in particular.

Over the past 25 years there has been considerable tension in the group ranches over the security of land tenure, especially for young people. This has created a demand for sub-division, a process that has now begun on many of these lands. Subdivision is likely to affect all land uses in the area. These include the Maasai pastoral system and the wildlife that depend on availability of large landscapes that allow both livestock and wildlife to access resources that are widely distributed in both time and space. This is happening in a context in which tourist activities as well as agriculture have expanded on the slopes of Mt. Kilimanjaro along rivers and swamps. It is therefore important to understand the sub-division process, how it is controlled and its implication on land uses and livelihood systems.

Land tenure changes in Kajiado District and Loitokitok sub-district in particular have been mostly externally driven, they have undermined the value of traditional natural resource management. The intentions were good -- the need to secure land for Maasai was also clear -- but it was the lack of real support for their implementation and the assumption that the financial, legal and institutional mechanisms needed were in place for the group ranches to work. These have failed to provide positive results and have led to the failure of the group ranch system.

Group ranches were formed under the Land (Group Representative) Act of 1968. This an Act of Parliament to provide for the incorporation of representatives of groups who have been recorded as owners as owners of land under the Land Adjudication Act, and for the purpose connected collective pastoral management and resource use. This arrangement can continue to be maintained until the members decide to dissolve the group ranch (The Land Group Representative Act -Cap 287). The group ranch can be dissolved upon a written application to the registrar signed by a majority of the group representative pursuant to a resolution passed by a sixty percent of the group present in person or proxy at a special general meeting convened for that purpose. The affairs of the group shall be wound up in such manner as the registrar may approve.

Under the Land (Group Representative) Act (1968) group ranches were adjudicated with the principal objectives being to:

- Increase the productivity of pastoral land by increasing off-take
- Pre-empt landlessness among the Maasai due to allocation of individual ranches to some pastoralists
- Improve the earning capacity of pastoralists
- Reduce environmental degradation from overgrazing on communal lands.

The concept of group ranches was, at first, generally popular among the Maasai pastoralists as it provided security and safeguard against land alienation by non-Maasai people, and annexation as national parks or government forests. But, the failure of the group ranch system to deliver the objectives of improved livelihoods and security of tenure has led to their ongoing dissolution and subsequent subdivision. Sub-division is now inevitable. Subdivision of group ranches becomes a central question as Munei put it that '*It is now clear from the major problems of livestock development in Kajiado District are no longer about management of group ranches but those of coping with the breakdown of group ranches. In particular, the sub-division of group ranches, further subdivision of resultant parcels by owners and the eventual sale of land are emerging as more urgent problems'* (Munei 1991:2).

All group ranches in the study area, except for Eselenkei and Kuku' A group ranches are under the process of subdivision. The procedures used in sub-division of the group ranches are characterised by lack of a defined process and therefore are ad-hoc in nature. The process is similar in all the group ranches and land subdivision guidelines are lacking.

Subdivision of group ranches will have implications for herding but its impact may not be realised in the first 5-years after subdivision. However, even so before the official sub-division has commenced, illegal subdivision is already going on especially in arable areas either for rain-fed or irrigated agriculture. More and more land is being converted for farming and less and less is available for livestock and wildlife.

For example in Rombo Group Ranch 50% of the 38,000 ha group ranch land has already been sub-divided informally. The rest of the ranch is a bare and highly degraded area. More than 70% of the 18,000 cattle in Rombo Group Ranch are entering Tsavo West National Park year in year out. During the study, in month of September 2001, livestock were already grazing 15km inside Tsavo West National Park. Irrigation is expanding but water will not be adequate to meet the current demand. There are already conflicts between herders and farmers because no water is flowing down stream.

Subdivision of group ranches and subsequent fencing is going to interfere with the wet and dry season traditional grazing regimes for both livestock and wildlife. The study area being dry rangeland lying in agro-ecological zones IV and V is prone to poor rainfall. These dry lands are likely to be affected by subdivision since movement of livestock will be restricted by fencing and boundary limitation. More areas are likely to be degraded. Figure 6 shows areas of less than 30% grass cover as was observed by the author during the study period of July - October 2001.

6 Land-Use Change and Gender Division of Labour

Edna Wangui, who received her PhD as part of the LUCID project, completed a study on the relationship between gender division of labour in crop and livestock production and changing land use/cover patterns along the Mt. Kilimanjaro ecological gradient, Kenya. The study sought to answer the following research questions:

(1) What is the historical division of labour and how was it related to land use?
(2) How has the division of labour changed over the past seventy years?
(3) How and why does the division of labour vary by agro-ecological zone?
(4) How does ethnicity influence gender division of labour?
(5) Why has the division of labour changed?
(6) How is the gendered division of labour negotiated in the context of the changing land use systems?

Dr. Wangui used a combination of household interviews, key informant interviews focus group discussions and participant observation were used to collect data on gendered division of labour and land-use for methods and other details, see (for methods and other details, see Wangui 2003). Data were collected over a period of ten months beginning March 2001. The study found that local changes in land use and gender roles are influenced by an interaction of social, ecological, economic and political forces, acting at a variety of scales from local to global. Structural adjustment programmes, the national land reform and ecological forces influence land use decisions made by farmers in Oloitokitok Division. Land use decisions in turn have implications for gender roles. This study found that land use alone is not enough to explain the changing gender roles that are observed in the division. Social forces such as interaction with other communities, the changing value of formal education, conversion to Christianity, and the changing structure of dwelling units have all contributed to change the roles that women and men have in the households.

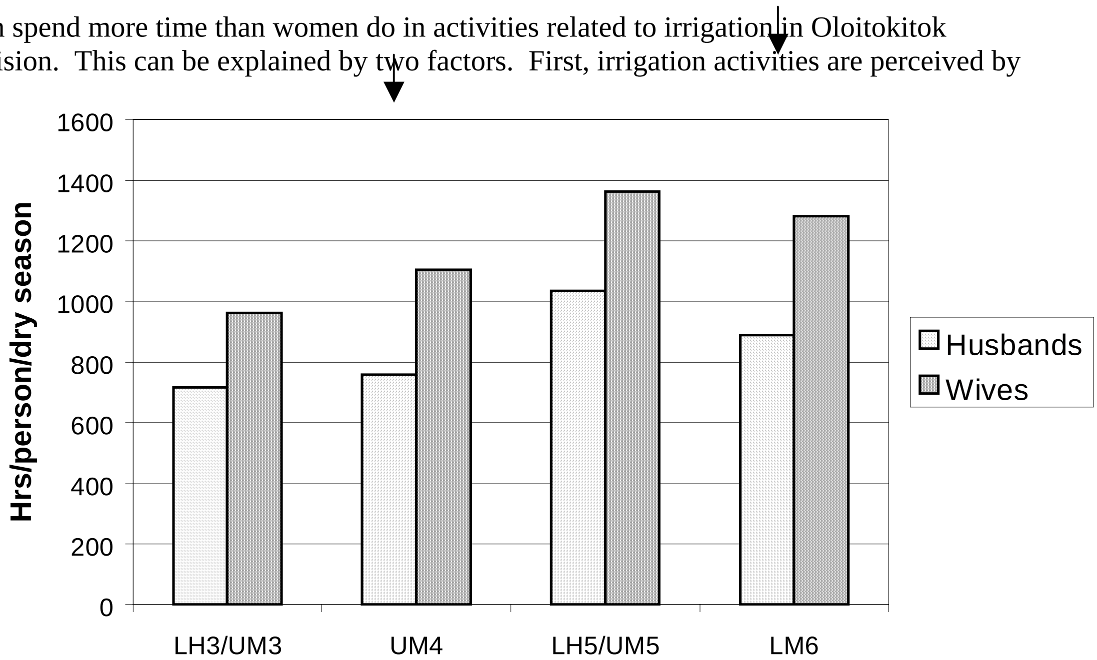
The study found spatial patterns in the way men and women use the land, that have persisted since in the 1930s. In the 1930s, range grazing was the dominant activity in almost all Oloitokitok households. Range grazing was predominantly done by the men. During this time, women took care of the sick and young livestock that were left at the homestead when the rest of the livestock went to graze on the range. Currently, range grazing is slowly being replaced by zero-grazing, and grazing close to the homestead, particularly in areas with higher rainfall. These methods of grazing are primarily confined to areas within or close to the homestead. Over time, the dominant locality of the livestock has been transferred from the range to areas closer or within the domestic locale, and consequently from the care of the men into the care of the women.

Integration into a cash economy and increasing focus on cash crop farming has changed the gendered spatial patterns of marketing. In pre-colonial times, women were engaged in long distance travel for trade purposes (Spear and Waller 1993). Exchange was through barter trade as the monetary system was not yet in place. Women would trade livestock products for crop products to supplement their diet. Currently men are the ones primarily engaged in long distance trade travel than the women are. While men travel as far as Mombasa to sell crop produce, women only travel to markets within the division to sell their crops. Crops sold by men are usually grown specifically for cash, while crops sold by women constitutes the surplus of the food crops they produce. Men primarily sell cattle, sheep and goats at livestock markets within the division. Women on the other hand can only sell poultry, as these are the only livestock that they have complete control over. Poultry sales are rare, and they primarily happen within the homestead.

Women supply more of the labour required in livestock production than the men. This evolution in care of livestock towards women, and in crop production towards both men and women, appears to be related to sedentarisation. Sedentarisation in Oloitokitok has occurred as access to former communal grazing land has declined, and as incomes have rapidly diversified towards rainfed and irrigated cropping. These changes in lifestyles towards sedentarisation are similar to that found by others working among the Rendille of northern Kenya (Fratkin and Smith 1994, Nduma et al. 2001). Among the Rendille, sedentarisation presented new economic opportunities for women, through the sale of agricultural produce, milk and labour in neighbouring towns. As Maasai communities adjacent to the Maasai Mara National Reserve settle, they diversify income towards farming, wildlife tourism and large scale cereal cultivation (Thompson and Homewood 2002). Similar patterns were found in pastoral communities in southern Ethiopia (Little et al. 2001).

Figure 3. Time spent on livestock production in each agro-ecological zone[1] (arrows indicate significant differences). Source: Author's fieldwork.

Men spend more time than women do in activities related to irrigation in Oloitokitok Division. This can be explained by two factors. First, irrigation activities are perceived by



the men to be too difficult for women, and the men therefore chose to perform them. Secondly, crops grown on irrigated lowlands are mostly grown for cash. The tendency in Oloitokitok Division is for men to control property that have high use and exchange value. Men have therefore relegated the care of livestock to women as livestock have declined in exchange value, and focused on cash cropping for its higher exchange value.

In this study, men were found to spend significantly more time in field preparation than women did. This study found no significant difference between the time that men and women spend on weeding. These differences in findings could be related to the lower male out-migration in the study area.

[1] Data on time allocation in livestock production represents hours spent by each individual during the long dry season (4 months)

Conflicts that occur over the control of the female labour are not about the labour, but more about resources produced by the female labour. When resources generated from household female labour are used for the benefit of the entire household, no conflict arises. Conflict arises when men, who control resource distribution in the households, misappropriate resources generated by the household's collective labour.

7 Implications of Land-use Change for Diversity of Wildlife and Plants

These trends in land use are altering the soil, water, and vegetation characteristics of the the Loitokitok area. As soil, water, and vegetation interact within ecological systems, so do they within human-ecological systems. It is important therefore to identify the impact of land-use change on both the individual components (soil, water and vegetation) and upon the interaction between these components. Further, it is important to investigate possible from these altered conditions and interactions in the soil/water/vegetation system feedback to the human-ecological system – to cultivation, herding, and wildlife.

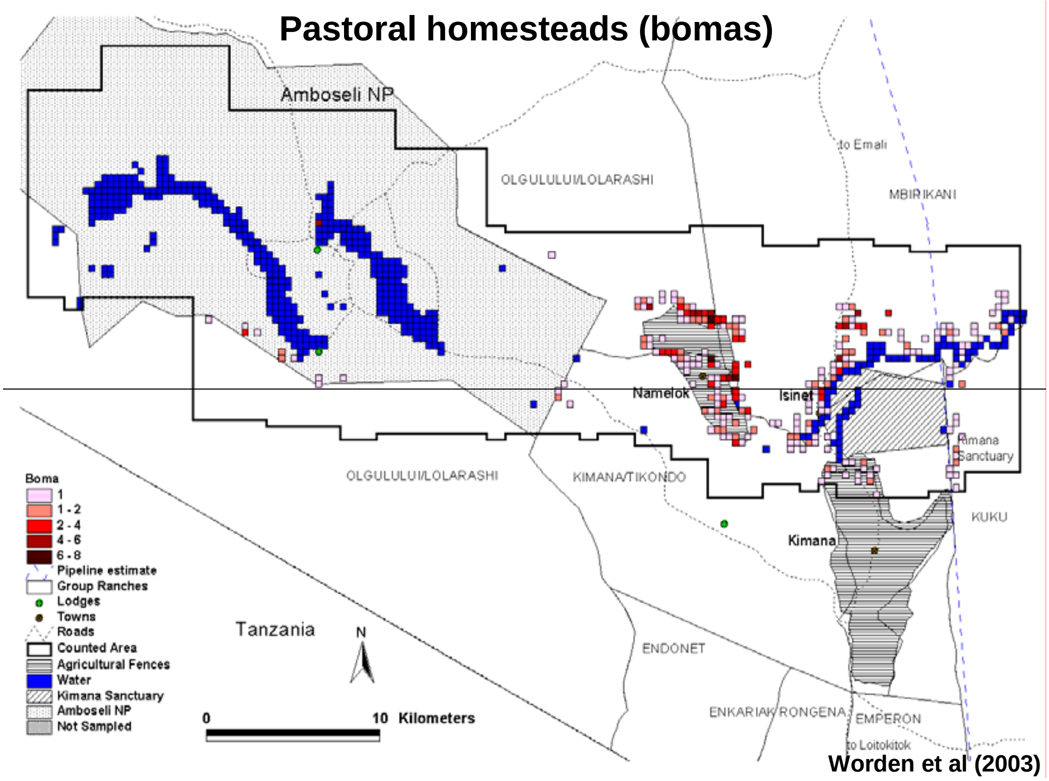
7.1 Impacts of land use on wildlife

Between the 1970's and 1990's, most of the 17 rangelands districts of Kenya lost over 50% of their wildlife (Said 2003). In the Mara ecosystem of Narok, 70% of the wildlife disappeared during this period (Ottichilo et al., Serneels and Lambin 2001). The reasons for these losses are the expansion of subsistence and commercial agriculture in wetter areas and the expansion settlements and fencing, changes in burning practices, drought and increased poaching in wet and dry areas (Dublin 1995, Ottichilo et al.).

However, wildlife in one district, Laikipia increased over this period, and in Kajiado, where the Loitokitok site is found, wildlife numbers have remained unchanged. Even so, our field observations led us to ask if the land-use changes in the swamps at the base of Mt. Kilimanjaro are affecting resident wildlife. Wildlife, like people and livestock, aggregate around these swamps, particularly in the dry season (Western 1976). We counted (from ultralight) and mapped wildlife in and around these swamps to assess the impacts of three land use systems on wildlife: wildlife-only use in the swamps of Amboseli National Park, cultivation in Namelok swamp, and mixed livestock/wildlife use in Kimani swamp (Worden et al. 2003). Namelok swamp is currently ringed by a fence and pastoral families cluster their settlements within this fence and also at the north end of Kimani swamp (center and right hand swamps in Figure 3).

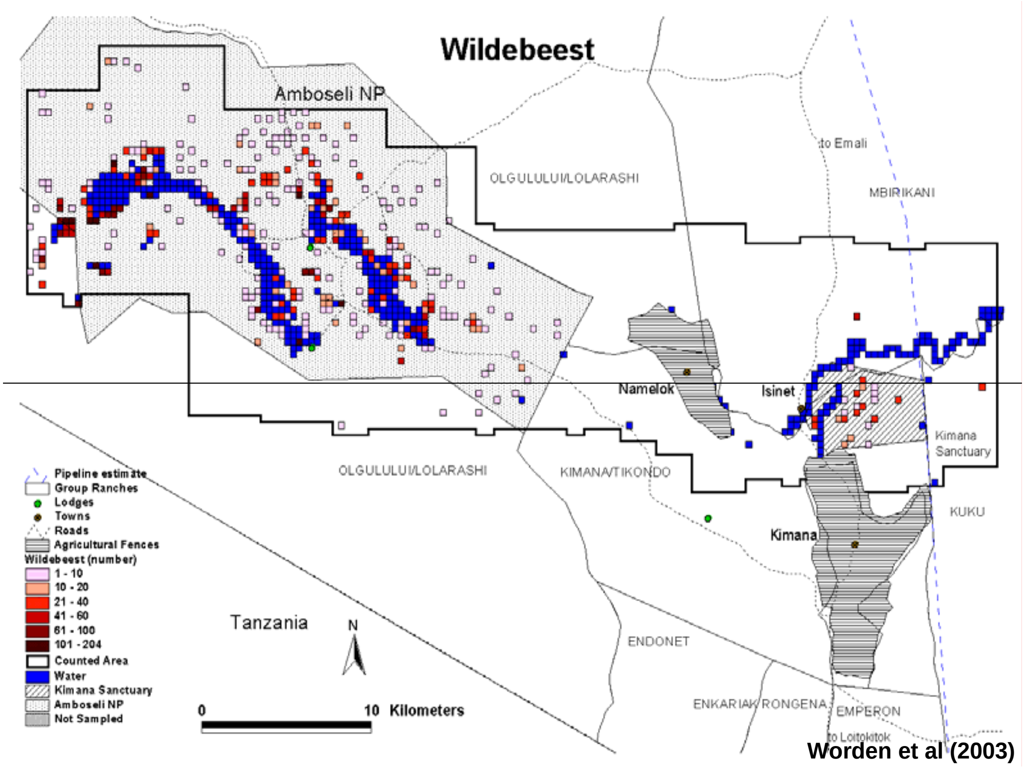
We found most species of wildlife near water during this daytime count. However, fencing and cultivation of Namalok swamp effectively excluded all wildlife from this important swamp itself, which used to be a 'stepping stone' for wildlife between this ecosystem and the Tsavo ecosystem to the east (Figure 4). The conversion and subsequent fencing of the swamp has resulted in the local extinction of buffalo and hippo, and the virtual collapse of elephant, zebra, and wildebeest populations outside the fence also. All of these species show extreme preference for areas close to water and their declines suggest a significant response to conversion and excision of the swamp habitat. By contrast, gerenuk and giraffe, water independent species, were less affected by the loss of the swamp and may in fact benefit from an increase in woody plant species that has been observed with sedentarization and intensification of pastoral populations (e.g., Western 1989, Tobler et al. 2003) and the loss of ecosystem engineers such as elephants and rhino (van Wjingaarden 1985, Owen-Smith 1988, 1989, Western and Gichohi 1993). It is also interesting to note that while Namelok is the most human dominated of the swamps surveyed, it does not have the highest livestock biomass density. While this may be an expected pattern in peri-urban and urban environments, the low livestock density relative to that found in Kimana corroborates the hypothesis that the intensification of human land-use in the swamps has negative implications for both livestock and wildlife. However, wildlife were abundant in Kimana swamp, that is used by both livestock and wildlife, and is adjacent to the Kimana Wildlife Sanctuary that provides protection to wildlife. This implies that co-existence between domestic livestock and wildlife is still possible in this ecosystem under a facilitative land use system.

Figure 4. Distribution of pastoral homesteads (red dots) around three swamps (blue except gray cropland in centre swamp at Namelok) at the base of Mt. Kilimanjaro at the Loitokitok site, Kenya. Dark grey indicates areas surrounded by fencing.



Some wildlife appeared to avoid livestock, while others were unaffected by livestock. In general wildlife herds were most abundant and diverse farther from livestock. However, the distribution of gerenuk, Grant's and impala show little relationship to that of livestock. Wildebeest and especially buffalo and zebra, on the other hand, appear to be actively avoiding livestock. Elephant, giraffe and warthog (and possibly eland, ostrich, and waterbuck) occur at intermediate distances from livestock. Wildebeest appear to only avoid livestock in Kimana where the permanent presence of settlements and domestic animals may result in direct competition for forage. Zebra, on the other hand, appear to avoid livestock in Amboseli and to a lesser degree Namelok, but occupy intermediate distances in Kimana. Thus, conservation of biodiversity will be most successful if it accounts for these particular responses of wildlife species to livestock.

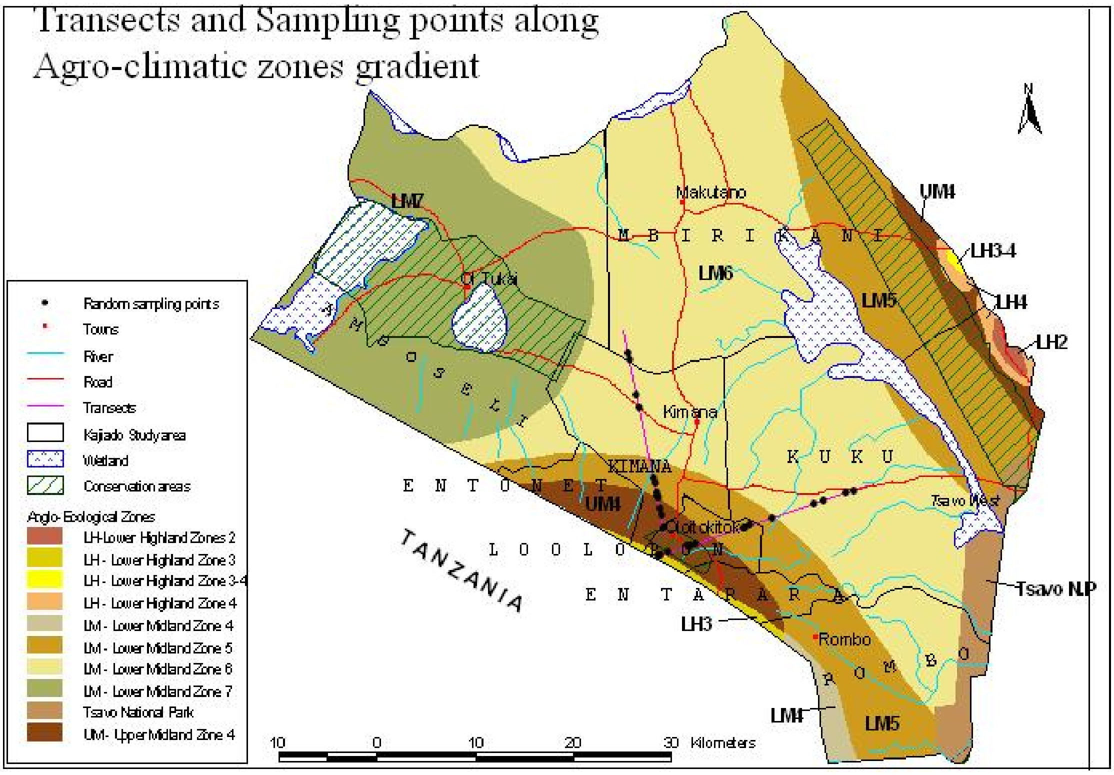
Figure 5. Distribution of wildebeest (red dots) around swamps in the Loitokitok area. Dark grey indicates areas surrounded by fencing.



7.2 Impacts of land use on the diversity and abundance of plant species

Simon Mugatha, Stephen Mathai, Joseph Maitima and Robin Reid completed a study of the effects of land-use change on plant diversity along an ecological gradient from the dry rangelands to the lower highlands on Kilimanjaro. These We measured the diversity and abundance of plant species (and soils, see the next section) on two transects radiating in two perpendicular directions from Loitokitok town, downslope from the lower highlands into the dry rangelands below (Map 3). Along each of these two transects, we established four, 1-km long sub-transects running perpendicular and across the slope within each of the four agro-ecological zones. On each of these sub-transects, we established 2 sampling sites in each of the common land use / cover types available. For example, in the lower highland zone, we only found annual and perennial croplands, so these were the only two land cover / use types sampled in this agro-ecological zone. Vegetation was sampled in quadrats in each lan-use type. The land-use types sampled included: forest, woodland, bushland, grassland, pasture, fallow, perennial crop, annual crop and settlement. We do not present the lower highland results in what follows because the zone was small, as were the number of samples.

Map 3. Location of the two sampling transects and sampling points that cross several agro-ecological zones, starting in Loitokitok town and heading downslope into the dry rangelands ringing the base of Mt. Kilimanjaro.



Comparing between the middle and lower zones, there were more species in the lowest and driest zone, where agro-pastoral people principally graze livestock (Table 1). All land use/land cover types in the low drylands supported 25-600% more species than the middle zone and 50% of these were native species (Table 2). Woodlands and bushlands were particularly rich with species here. Furthermore, only here did we find threatened, endangered, rare or endemic species (about 2% of the flora, Table 3). Surprisingly, grasslands here were remarkably species poor. Cultivated fields in the swamps contained many plant species, but about 75% of these were weeds. Our results suggest that pastoral land use is more compatible with high native plant diversity compared with middle zone farms. However, once pastoral people and immigrant farmers settle and cultivate farms around swamps and along rivers, weeds replace native plants quickly, just as they do as farmers cultivate more well-watered farms in the midlands.

In the midland zone, we found that annual mixed croplands supported more species and had more plant cover than any other type of land–use type, but 91% of these were weeds and 1-5% of these were invasive species. In this zone, less used forest, bushlands and woodlands had fewer species, but only about 40% of these were weeds. Unexpectedly, in both zones, there was more plant cover in cultivated fields than in the less used types of land cover.

Table 1. Effects of land-use type on total plant species numbers and total plant % cover by agro-ecological zone at the Loitokitok site, Kenya. Data indicated with a dash means that this land-use type did not appear on our transects in this zone. Note that cropping in the lower zone (drylands) was only in the swamps.

	Middle zone (UM4)		Lower zone (LM5/LM6)	
Land-use/land cover type	**Total spp #**	**Total % cover**[2]	**Total spp #**	**Total % cover**[2]
Forest	32	12.1	-	-
Woodland	-	-	174	71.4
Bushland	26	22.1	135	28.6
Grassland	19	24.1	24	35.3
Pasture	21	16.9	81	6.5
Fallow	29	10.1	50	71.7
Cultivation				
• **Annual mono-crop**	30	33.9	87	90.6
• **Annual mixed crop**	81	53.7	87	95.5
• **Perennial mixed crop**	11	13.1	-	-
Settlements	22	31.2	-	-

We expected perennial croplands and mixed cropping to support more native plant species than either annual croplands or mono-cultures. Unfortunately, we had few opportunities to compare plant diversity among these types at Loitokitok because few farmers grew perennial crops. Our one comparison of mono-crops with mixed crops showed that mixed croplands can support more than twice as many species as mono-cropping, but there was no difference in the number of species in these two cultivation types in swamps in the lowlands. This weakly supports the notion that mixed cropping conserves biodiversity.

Table 2. Percentage of plant species that were weeds in different agro-ecological zones at the Loitokitok site, Kenya.

Land-use types	**LH3**	**UM4**	**LM5/LM6**
Forest	-	34.4	-
Woodland	-	-	29.3
Bushland	-	30.8	45.6
Grassland	-	47.4	50.0
Pasture	57.1	33.3	42.0
Fallow	-	69.0	70.0
Cultivation			
• **Annual mono-crop**	-	70.0	77.0
• **Annual mixed crop**	38.5	73.1	73.6
• **Perennial mixed crop**	-	90.9	-
Settlements	-	68.2	-

Table 3. Percentage of invasive, rare, endangered and threatened plant species the middle and lower agro-ecological zones at the Loitokitok site, Kenya. Only the land-use types with these types of species are listed.

ZONE	Land use cover	Invasive	Threatened	Endemic	Endangered	Rare
Middle (UM) zone	Pasture	4.8%				
	Annual mono-crop	3.3%				
	Annual mixed crop	0.8%				
	Settlement	4.5%				
Lower (LM) zone	Woodland		1.1%			1.1%
	Bushland			0.7%	0.7%	
	Pasture		1.2%			1.2%
	Annual mono-crop	1.1%				

We rarely found trees in croplands or fallows in any of our plots. The trees we did find in these plots were mostly those species useful to people. Pasture and grassland areas fell intermediate between these two extremes. There was no difference in the number of trees in perennial cropland, annual cropland, fallows and settlements. It appears that establishing pasture for livestock has less impact on tree species than crop cultivation.

Tree cover followed similar patterns as tree species, except that pastures tended to have similar tree cover as bushlands, woodlands and forest. In general, the non-cultivated or settled types supported up to 20 times (about 6-8% cover) more tree cover than the croplands and settlements (about 0-0.3% cover, data not shown). Woodland, bushland, pasture and grassland supported about the same cover of tree canopies, and usually significantly more than any of the cultivated types. Again, this suggests that cultivation removes both tree cover and tree species more than grazing land use.

There were 6-20 times more shrub species (3-13 species) in pastures, bushland, woodland and forest than other types (data not shown). We found either few or no species of shrubs in grasslands, fallows and croplands. Pastures often fell in the middle ground with a moderate number of species. Shrub cover was low in all land-use types, but higher (up to 3% cover) in woodlands, forest, pasture and bushland than in the more heavily used types.

Herb species showed the fewest clear responses to use by people, but this may reflect a complex and varying response rather than no response. Farming and grazing does remove herb species, but not to same extent as shrubs or trees (as above). Similarly, there was no significant effect of land use on herb cover, but the variation was wide (from 0.3 to 5.5%), potentially masking a complex response.

Grasses responded more clearly to farming, grazing and settlement than herbs. Not surprisingly, there were more species of grasses in grasslands than in any other type of land cover. For example, in the upper midland zone, there were 8 species of grasses per square meter in grasslands and only 1.5 species in the same area around settlements. In lower midland zone, even though there were only 4 species of grasses in grassland, we found a quarter of that number (1 species) in bushland and cropland. Pastures tended to support an intermediate number of grass species. We found the lowest numbers of grass species in a combination of heavily used areas (croplands, settlements) and wooded land covers (forest, woodland).

In all of the quadrats sampled in all land use types, we found only one rare and threatened species, the hardwood tree, *Dalbergia melanoxylon*. This hardwood is used by people in Kenya to make carvings, instruments and for charcoal. We found this species only in the lower midland zone. We also found one endemic herb, *Cyphostemma kibweziense*, in the same zone. This means that about 1% of the flora that we captured in our sampling was of conservation significance.

We did not, however, find many species that were not native (exotic) to the Kenyan flora. Excluding crop species, we found only 5 of the 110 species (4.5%) in the upper midland, 2 of 94 species (2.1%) in the lower midland and 1 of 107 species (0.93%) in the rangeland were exotic plant species. The exotic species were *Lantana camara*, *Nicandra philisoides*, *Stelleria medica*, and *Tagetes minuta*. The fruit of *Nicandra* is poisonous to people and livestock. However, *Stelleria* is used to treat eye infections and the seeds used to feed caged birds. *Tagetes* is cattle feed during droughts. Even Lantana is useful for hedges and for treating colds (but it is reported to be toxic to cattle).

Moreover, invasive species were even more rare, with only two, *Lantana camara and Datura stramonium*, appearing in our samples. Lantana is a common invasive shrub throughout East Africa, and Datura often grows in disturbed areas and in abandoned livestock corrals. The latter has seeds that are poisonous to people and livestock alike, but they also have medicinal value.

There is no evidence, in these agro-ecological zones in Loitokitok, that people conserve or improve the number of trees or shrubs in any way, either by grazing or cultivation. In fact, the picture is most clearly the opposite. Farmers clear most if not all trees and shrubs from their fields when they grow crops. It does not seem to matter if these crops are perennial or annual crops; farmers remove trees and shrubs in both these cultivation types.

Trees and shrubs clearly were more sensitive to farming and grazing than either herbs or grasses. Grasses responded more than herbs. Removal of the woody overstory by people likely promotes the establishment of some grasses and herbs, but only if the area is not cropped. Farming, across all the life forms, causes the most biodiversity loss. Grazing has moderate or even promotive effects, if woody canopy cover is removed.

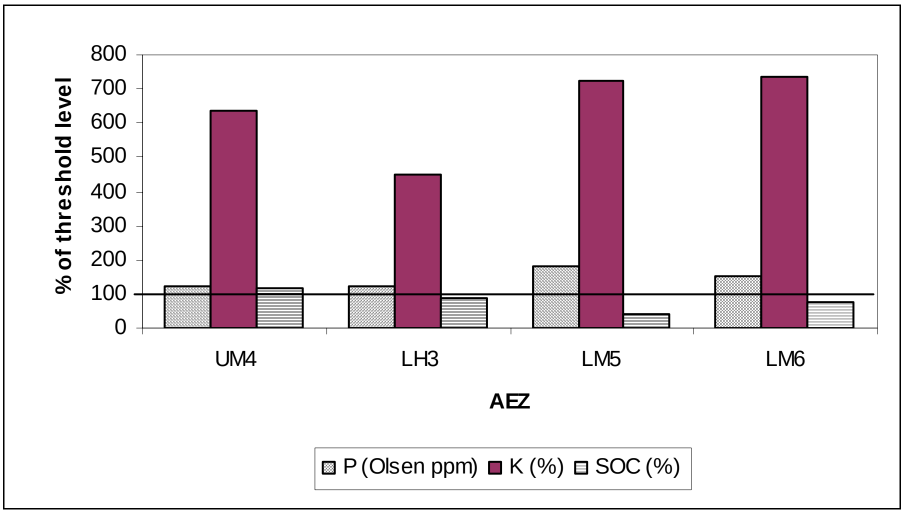
8 Implications of Land-Use Change for Land Degradation

The LUCID team examined land degradation in terms of soils and water. The team conducted surveys soil characteristics (Gachimbi) along the same two transects surveyed for plant species, as described above. Information on peoples' perceptions of soil conditions, gathered during the socio-economic survey (Campbell et al.), supplemented the chemical and nutrient analysis. Water quality indicators were obtained from a sampling of rivers and swamps (Githaiga and Muchiru). This information was examined in conjunction with reports of declining water quantity and quality provided by respondents to a household survey in 1996 (Campbell et al. 2000).

8.1 Impacts of land use on soils

Soil fertility decline (also described as soil productivity decline) is deterioration of chemical, physical and biological soil properties (FAO, 2001). It has also been shown that soils in sub-Saharan Africa have inherently low fertility and do not usually receive adequate nutrient replenishment in the form of mineral or organic fertilizer (Dudal 2002). However, in most cases in Loitokitok, nutrient levels are generally adequate in uncultivated soils, unless there is significant natural erosion or heavy grazing. For example, forests, woodland and bushland all have adequate fertility and soil organic matter. However in lower drylands (LM5 and LM6), there is very low soil organic matter natural erosion in bushlands near inselbergs, which is probably aggrevated by livestock grazing (Figure 6).

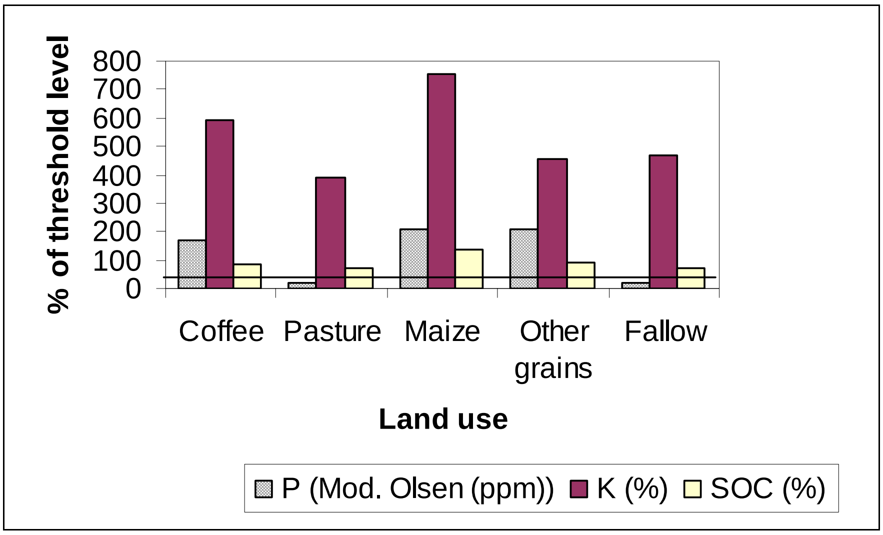
Figure 6. Percent threshold level of phosphorus, potassium and soil organic carbon (SOC) for various land uses by AEZ along the Amboseli-Loitokitok transects.



Phosphorus and soil organic matter only fall below fertility thresholds where organic matter is naturally low or where farmers use practices that mine soil nutrients. Particularly in the lowlands, the soils show a characteristic wide range in available P, from moderate to high. This reflects that strongly weathered soils of the non-dissected erosional plains and the weakly weathered soils of the plains, both on gneisses, have a low P-status. The same low levels of available P were recorded in some of the strongly weathered soils in lower zones.

Soil organic matter is naturally high in the upper, wetter zones on the slopes of the mountain, but are low in the hotter and drier zones around the base of the mountain, in agro-ecological zones LM5 and LM6. Soil organic carbon (SOC) and phosphorus (P) are generally low in grain fields, irrigated fields, fallows, and sometimes in maize fields, pasture and bushlands (Figures 7-10). This is due to continuous cultivation in all zones and possibly grazing in the lowlands, and the high mineralisation rates of soil organic carbon caused by high temperatures and adequate moisture, the latter particularly in the lowlands. The low P and SOC levels are due to continuous nutrient mining through crop products without sufficient replenishment in the form of fertilizers or farmyard manure. High soil nutrient levels are due to the presence of many weatherable primary minerals, which occurred during volcanic ash enrichment of chemically poor soils or during rock formation. The soils have inherent high K reserves as observed by Legger and van der Pouw (1980). K levels are adequate in agronomic terms from the upper to lower zones. However, the stock is threatened by nutrient mining through continuous cultivation and erosion.

Figure 7. Percent threshold level (horizontal black line) of phosphorus, potassium and soil organic carbon (SOC) by land use type in the lower highland (LH3) zone at Loitokitok, Kenya.



Soil pH ranges from slightly acidic to moderately alkaline in the lower zones (not shown). This range makes most crop nutrients available to the plants when required. This was also evident by visual observation in the field.

Figure 8. Percent threshold level (horizontal black line) of phosphorus, potassium and soil organic carbon (SOC) by land-use type in the upper midland zone (UM4) zone at Loitokitok, Kenya.

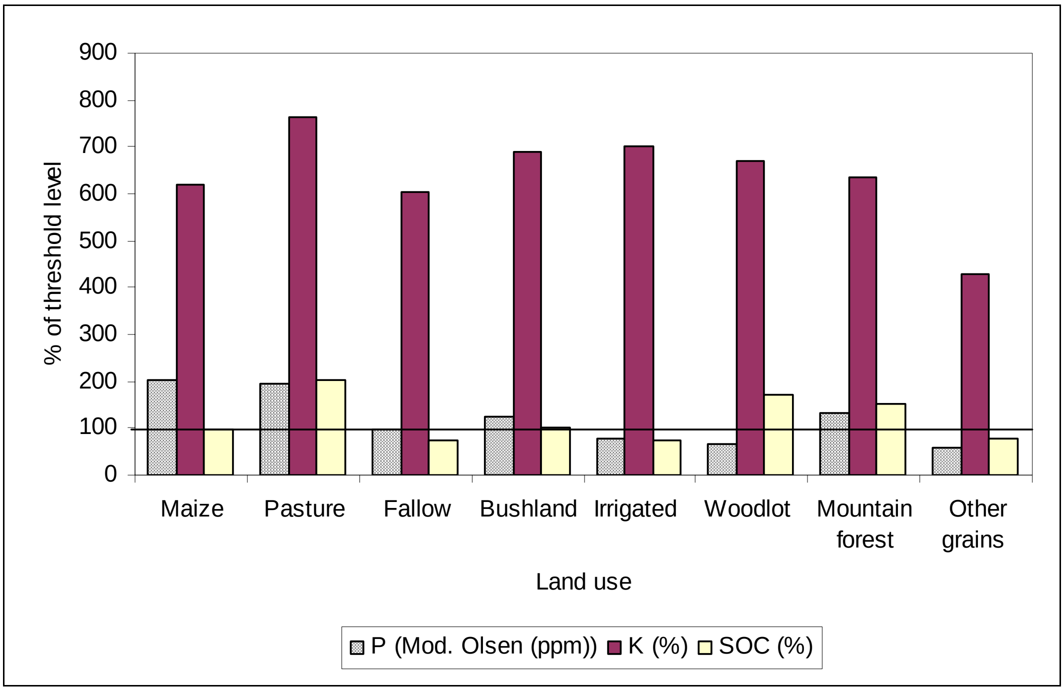


Figure 9. Percent threshold level (horizontal black line) of phosphorus, potassium and soil organic carbon (SOC) by land-use type in the lower midland zone (LM5) zone at Loitokitok, Kenya.

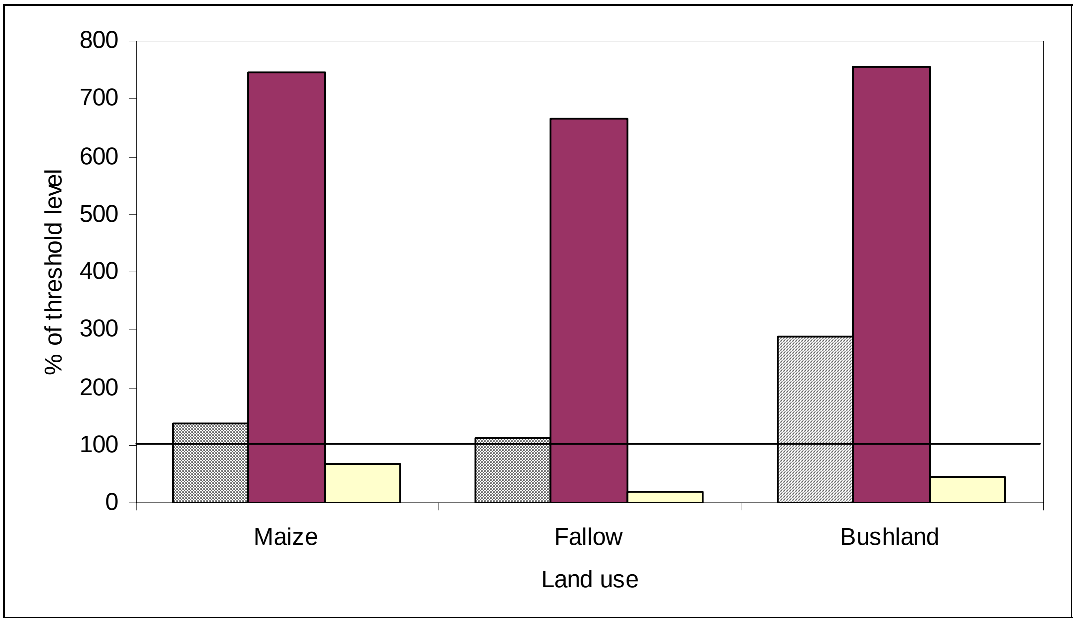
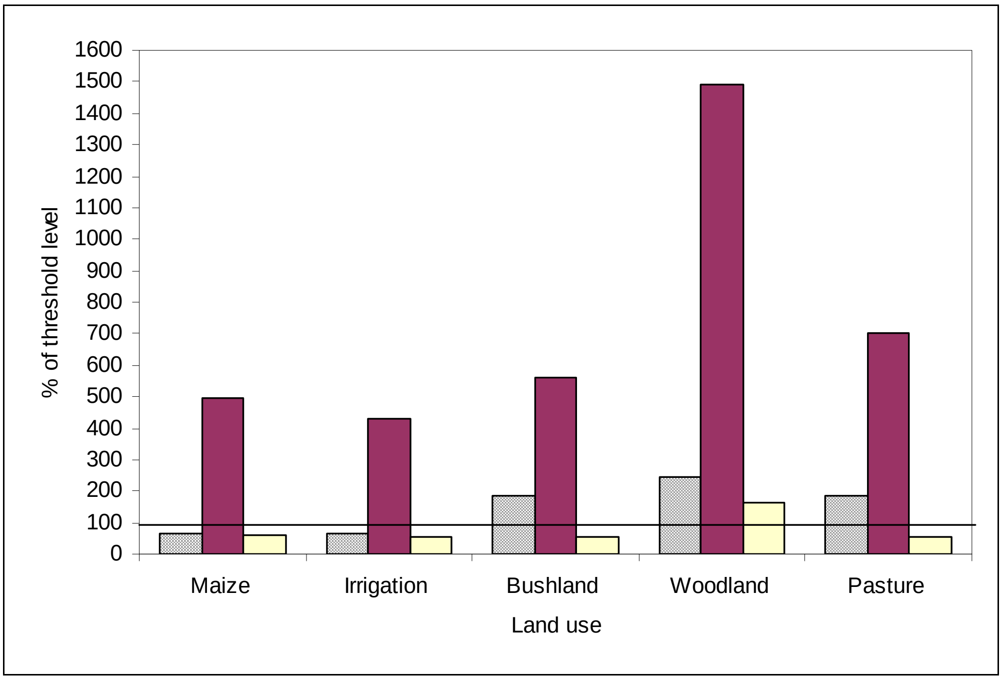


Figure 10. Percent threshold level (horizontal black line) of phosphorus, potassium and soil organic carbon (SOC) by land-use type in the lower midland zone (LM6) zone at Loitokitok, Kenya.



Soil erosion was low to absent in forests, woodlands, coffee and irrigated fields (not shown). Maize, other grains, pasture, and fallows varied from moderate to severe sheetwash, with shallow rills, depending on the geomorphology of the area and the management. Bushlands were the only areas with occasional severe sheetwash and gully formation, particular where pediment slopes occur below bare rocky inselbergs. Farmers cause moderate to severe erosion when they fail to install soil and water conservation measures. This situation will clearly call for a combination of changed land use, special management practices, or major land improvements. But there is good variation in the erosion status of farmer's fields showing that some farmers are successful at erosion control and thus local knowledge exists to arrest further degradation.

9 Effects of land-use change on water quantity and quality in swamps and rivers

John Githaiga and Andrew Muchiru measured the quality and quantity of water in swamps inside Amboseli National Park (wildlife use), in Namelok (fenced and cultivated), Kimana (livestock-wildlife use) and along the Nolturesh and Rombo Rivers (Githaiga and Muchiru 2003). They found that changes in land use strongly reduced the quality and availability of water in swamps at the base of Mt. Kilimanjaro, Kenya.

Levels of Carbon Oxygen Demand (COD) and Biological Oxygen Demand (BOD) in the areas used for domestic water indicate low pollution levels with means of COD and BOD at 124 mg/lt. and 129 mg/lt., respectively. The highest mean COD of 429 mg/lt. was found in water samples collected from discharge canals from irrigated fields and this indicates high levels of pollution. Livestock/wildlife land use around the swamps leads to pollution with dissolved solids due to excreta from the animals as well as high soil from trampling along the edge of the swamp. Pollution with suspended solids was highest where land was used by livestock and agriculture, especially irrigated agriculture. The colloidal nature of the soils prevents rapid flocculation of the suspended particles, accentuating the suspended solid concentration values.

The irrigated fields had high conductivity due to dissolution of artificial fertilizer applied in the farms, evaporative concentration of irrigation water by high temperature prevalent in the area, and the elution of crystallized salts from the soils in the field. Salanization of the soils in the irrigated farms was high. The pH was elevated where land use consisted of irrigated agriculture and livestock/wildlife. Artificial fertilizer inputs, alkalinisation of the slightly alkaline water and urea inputs from livestock could be responsible for the rise in water pH. There was a build up of organic matter in canals collecting water from the irrigated farms leading to the high BOD content, low-oxidation reduction potentials and the slight decline in pH. The negative reduction potentials in areas under irrigated agriculture, livestock/wildlife and livestock agriculture indicate enhanced organic loading in water under these land-use types.

There was an increment in nitrogen nutrient concentrations from irrigated farms and from livestock as well as from removal of aquatic vegetation. Irrigation caused a decline in phosphate concentrations possibly due to phosphate binding to soil particles within the irrigated fields and uptake by phytoplankton, sedges and macrophytes that were common in the canals. Livestock and wildlife grazing did not cause any change in phosphate concentrations.

Iron concentration in the water samples increased with land use, high levels in the irrigation discharge areas but highest in areas where land use upstream was livestock/agriculture. Manganese was the only other heavy metal detected in the study area,and concentrations were found to increase due to cultivation.

10 Effects of water diversion on ecosystems and people

Inter-basin water diversion and abstraction causes serious water shortage to downstream users. Salinity increases downstream and water levels decline, leading to changes in plant community structure, loss of plant communities dependent on water and establishment of salinity tolerant plant species.

In Loitokitok, the diversion of a majority of the Nolturesh River flow to areas near Nairobi has destroyed downstream riverine ecosystems and displaced the local people from their traditional home area at Ol Laika. Water is scarce in this area and residents were observed digging holes in the dry riverbed to draw water for domestic purposes from pools that formed. Large numbers of *Ficus sycomorous* and Acacia trees had dried due to the water diversion (Githaiga and Muchiru 2003). The residents said a large number of people formerly living in the area had moved to the Leinkati area, compounding the ecological problems in this site. Desiccation through water diversion may explain the reduction in extent of the *Leinkati swamp* and use of the swamp by livestock for grazing and watering. Over utilization of water resources within the water bodies studied has already led to a shortage leading to implementation of water rationing regimes. The amount of water available is not adequate to sustain the current level of irrigation within *Leinkati*, *Namelok* and *Kimana* and there were several abandoned fields in *Namelok* as well as in *Leinkati*.

11 Conflicts between people and wildlife in Loitokitok

David Campbell, Helen Gichohi, Robin Reid, Albert Mwangi, Lucy Chege, and Thor Sawin, all part of the LUCID team, examined peoples' concerns about wildlife conflict over a 20-year period during which a variety of initiatives to address community-wildlife conflict were undertaken. Issues of competition and conflict over resources among and between the three dominant land uses - herding, farming and wildlife-based tourism - were investigated in 1977 and 1996 employing similar research methods. Information was derived from a variety of sources including archives, scientific and policy documents, household surveys, community workshops, and discussions with key informants. While similar studies have been conducted elsewhere in Africa, this study is unusual in that it has examined people-wildlife interactions across a 20-year period during which a series of initiatives designed to reduce conflict were implemented.

This longitudinal study of competition and conflict between people and wildlife shows that reports of conflict have increased since 1977 such that in 1996, despite intensive efforts at community involvement in wildlife management, seventy-five percent of herders and ninety percent of farmers reported problems with wildlife in the previous five years. In both periods eating and trampling of crops were the most frequently reported problems. The principal difference between the two surveys is that the latter included farmers who began farming in the lowlands between the two surveys. These lowland systems included sheep and goats alongside crop cultivation. Thus one of the principal differences between the two time periods is addition of conflicts related to livestock in 1996. Interestingly, the Maasai, once they became farmers, faced the same conflicts as non-Maasai farmers. Much of the increase in conflict with wildlife in the lowlands can be attributed to the fact that cultivation extended to riparian areas where wildlife congregated. These included loss of access to resources inside national parks, predation, crop damage, and personal injury.

The actions taken by herders to reduce damage by wildlife changed between the two surveys, reflecting the fact that many herders are now also farmers. In 1977, herders' responses were limited to hunting and reporting to game wardens, and many did nothing. In the 1996 survey herders reported scaring the animal and building fences much more frequently, and more contacted the game warden. Fewer herders report killing the animals involved. Herders were less likely to build fences in response to conflict than farmers in either year. There was a substantial decline in reporting to the game warden among farmers between 1977 and 1996. About the same proportion of farmers, around 60%, build fences and in 1996 more of them reported scaring or killing the animals.

The high degree of friction between people and wildlife reflects ongoing competition over access to scarce land and water resources between herding, farming and wildlife, that has been conspicuous for over 30 years and is intensifying. To be better accepted, wildlife management policy will need to address both the sustainability of peoples' livelihood systems and that of wildlife populations.

12 The Linkages between Changes in Biodiversity and Land Degradation

We tested the links between biodiversity and land degradation by relating the number of plant species (all species and then native species alone) and percent plant cover to soil phosphorus, soil organic carbon and soil erosion level (Table 4). The results compare these relationships across all the land-use types, so the changes in these variables caused by land use are inherent in the analysis. The results from the upper midland zone were unexpected. There were more plant species and plant cover in plots with less soil carbon and more erosion (and possibly less phosphorus). Because this zone is wetter and has been cultivated more intensively, the correlation of higher species in poorer soil conditions may be related to the large number of weeds in the flora. When we remove the weeds from the analysis, we find more native species where there is less erosion, more phosphorus, and possibly less soil carbon. This means that weed diversity is greater in poor soil conditions and native diversity in better soil conditions. This reflects land use: native diversity is higher in the forests and bushlands that are not cultivated or little grazed, while weeds are more common in places that are cultivated and thus have poorer soils.

The relationships changed in the lower midland, where farms are uncommon and pastoralism dominates. Here, there were more of all species and natives and plant cover where soil conditions were better. This likely reflects the lower proportion of weeds in the flora and the less intensive land use (grazing) in this zone.

Table 4. Relationships between different measures of plant diversity/abundance (biodiversity) and soil fertility and erodibility (land degradation), comparing data collected on the same plots within upper midland (UM) and lower midland (LM) zones and across all zones.

Variables correlated	UM4	LM5/LM6	All
All species numbers vs phosphorus	-0.33	0.22	0.04
Natives species numbers vs phosphorus	0.20	0.90	0.67
Percent plant cover vs phosphorus	0.023	-0.52	-0.09
All species numbers vs soil carbon	-0.69	0.84	-0.19
Native species numbers vs soil carbon	-0.12	0.86	0.05
Percent plant cover vs soil carbon	-0.71	0.23	-0.30
All species numbers vs erosion level	0.95	-0.36	0.003
Natives species numbers vs erosion	-0.45	-0.38	-0.12
Percent plant cover vs erosion level	0.96	-0.70	-0.21

LH3 n=2, so this zone was only included in the 'all' analysis. Pearson correlation coefficients (r-values), n=5 for both UM4 and LM5/LM6, n=12 for 'all'.

13 Implications for management, policy and development

13.1 Land management to reduce land degradation and biodiversity loss

- All soils across the agro-ecological zones have inherently good soil fertility. They do not, however, receive adequate nutrient replenishment to compensate for continuous nutrient mining. This replenishment could come in the form of organic manures, inorganic fertilizers or biomass transfer through agro-forestry or short fallow. These practices, are within the means of people in the area as many already practise agroforestry, those producing horticultural and other cash crops obtain sufficient income to purchase inputs, while others combine livestock raising with cropping and have access to manure.

13.2 Implications of sub-division of group ranches

Paul Ntiati predicts that subdivision of group ranches will increase permanent settlement along permanent streams and water points (Ntiati 2002). Some of the effects of settlements near these key resources that we see today in Loitokitok include the following:

- More emphasis on subsistence agriculture and less on commercial production
- Pressure on natural resources will increase substantially
- Limited availability of water
- Increase in areas under crops and decrease in areas under livestock production
- Demand for fuel wood will greatly increase
- The social situation will become complex, new comers will tend to stick together and there will be conflict with previous land holders

These changes imply that land tenure policy is having strong impacts on the livelihoods of herders and farmers, and will have consequences for land management practices, water availability, agricultural production, fuelwood production, and conflicts among different land users. Policy makers and land managers need to clearly understand both the positive (tenure security) and negative (possible land and water degradation, increasing conflicts) that privatisation of land will bring to these drylands. As has been shown in other parts of Kajiado District, land privatisation of land may make herders and farmers more vulnerable to drought because their safety net of mobility has been removed (Njoka 1979, Rutten 1992).

13.3 Focus of development: need for more consideration of gender issues

The results of the gender and land-use study have important implications for agricultural development programmes in pastoral communities. Livestock development programme officers need to recognize the gendered nature of labour allocation and even more importantly, the significance of women's labour in livestock production. The failure of livestock development projects have been attributed to the neglect of the role of women in livestock production (Kettel 1992, Hodgson 2000). Livestock development programmes need to be formulated with the importance of women's roles in mind. For example, since women are increasingly engaged in activities associated with cross-bred and exotic livestock (e.g. watering, collecting fodder, collecting manure), livestock development programmes that advocate a shift towards cross-bred and exotic livestock will increase their chances of success if women's opinions are incorporated from the beginning. This is likely to be a challenge because in many pastoral societies, men own the livestock and subsequently make decisions regarding livestock. Livestock development officers need to actively seek and engage women in the spaces that women feel comfortable to express their opinions. The popular format of general community meetings does not always provide the appropriate setting for women's voices to be heard. Usually women do not attend general community meetings, and when they do, they remain silent. Women's only meetings would be more appropriate than general community meeting. During such meetings, women's time demands and availability for participation in livestock development projects should be addressed.

The results of this study also have important implications for natural resource management. There are many natural resource management projects that rely on local labour availability for their success. Examples range from wildlife community conservation efforts (Western and Wright 1994) to village forestry programmes (Maathai 1988). It is important for those involved in formulating such projects to recognize that both men and women's labour is already highly committed to crop and livestock production. The need for food and money to meet health and education needs is a large factor influencing decisions on where labour is allocated. Natural resource managers relying on local labour inputs need to recognize this fact while formulating their projects. Natural resource management needs to be understood as a land use competing for land and labour with such land uses as crop and livestock production, and subsequently designed so as to provide short term economic gains to land and labour investment.

13.4 Wildlife policy: should people be compensated for wildlife damage?

The issue of compensation to people after personal or livestock injury or crop destruction illustrates clearly the importance of finding effective means to address societal concerns so that people living in and adjacent to areas inhabited by wildlife can support the presence of wildlife (Campbell in prep). That the levels of conflict have remained high over the last twenty years suggests that the variety of initiatives to engage communities in wildlife management have had limited success. The causes lie locally as livelihood systems have changed and demand has increased for critical resources shared with wildlife, and externally as global interests in conservation and national economic interests in tourism have emphasized policies designed to protect wildlife. Wildlife management issues such as those discussed above, provide a clear example of the elusive processes whereby what happens locally has a direct bearing upon policy outcomes.

Greater power to design and implement policy lies with global and national institutions than with local ones. Yet it is at the local level that the goals will be realized or not, and that the conflicting claims on resources by local and external interests are mediated. Approaches such as Integrated Development and Conservation Projects, and Community Based Wildlife Management, have attempted to improve local communities' tolerance of wildlife. However there is a growing body of evidence that such approaches have not met their objectives (Alpert 1996, Songorwa 1999, Turner 1999, Kellert et al. 2000, Twyman 2000). Some see participation being used as a means of extending government control of rural communities (Neumann 1997); others emphasize a need to fully involve local people to empower their role in establishing the goals and priorities of community-based development (Wells and Brandon 1992), while still others, recognizing that they have been implemented during a period of rapid cultural, economic and demographic change, call for more comprehensive approaches that reflect the complexity of ecological systems, human systems, and their interactions (Newmark and Hough 2000). The challenge is to establish goals for economic development and for conservation, set priorities, and develop strategies to achieve them in ways that are broadly acceptable and viable.

Goals of economic growth, at individual, community and national levels, and global concern for biodiversity illustrate the variety of pressures demanding supportive policy initiatives. There is considerable discussion about which management strategies are appropriate (Heinen 1996) and whether anthropocentric approaches can achieve the goals of conservation and also the capacity of science and technology to find solutions to conservation problems when the functioning of the ecosystems and their patterns of interaction with society are poorly understood (Stanley 1995).

Given the diverse interests at play, it is relevant to ask whose goals and priorities are to be promoted? Is social equity an issue? For whom and to what end are the strategies to be acceptable and viable? The existing conflicts between local communities and wildlife represent a clash of interests. Each of the interested parties (local communities and wildlife representatives in the conservation community) has a measure of power with which to enact or negotiate outcomes. Is a goal of conserving biodiversity superior to one of maximizing horticultural production? Are these activities in a zero-sum game or can compromises yield greater combined benefits? Such questions may not be readily answered, or answers may imply politically impractical outcomes. It is important however, to pose them and to make explicit that the control and use of power will ultimately define future outcomes regarding broad land use questions, and human-wildlife conflict specifically.

14 Conclusion

This paper has discussed linkages among changes in land use, plant and mammal biodiversity, and land degradation on the northern side of Mt. Kilimanjaro in Kenya. It has adopted a multidisciplinary approach involving analyses that combine land-use change with ground measurements and assessments of biodiversity change and land degradation to give a thorough analysis of the impacts of land-use change. Historical trends in land-use in the study area from 1970-2000 formed the basis for an assessment of the impacts of these changes on wildlife, soils, plant species and water quality. The study has established links between land use dynamics and plant species diversity (a proxy for biodiversity) and soil fertility and erosion (a proxy for soil conditions). It has also explored the sensitive issue of wildlife conservation effectively complementing sustainable development of local livelihood systems.

As discussed in a number of the LUCID working papers, policy by its very nature contributes significantly to land use change. In some cases the results enhance sustainability, but in other cases, particularly where policy is defined sectorally, long-term implications for the societal-biophysical system may be undesirable and unintended. This paper has identified a number of issues that policy-makers in government and in NGOs, as well as land managers should consider in formulating future strategies for sustaining both livelihoods and the natural resource base of the Loitokitok area.

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