LUCID's Land-use change Analysis as an Approach for Investigating Biodiversity Loss and Land Degradation Project

The linkages between land-use change, land degradation and biodiversity in Embu and Mbeere Districts, Kenya

LUCID Working Paper Series Number: 32

By

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5th June, 2004

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The Land Use Change, Impacts and Dynamics Project
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Cite working paper as follows: Author. Year. Title. Land Use Change Impacts and Dynamics (LUCID) Project Working Paper #. Nairobi, Kenya: International Livestock Research Institute.

Working papers are available on www.lucideastafrica.org or by emailing lucid@cgiar.org.

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Executive summary:

Land use change in Embu/Mbeere like in other places has caused major changes in biodiversity. In the upper altitudes where cultivation started many centuries ago, it is difficult to find natural vegetation and wildlife particularly the large mammals is completely wiped out. Intensive cultivation of monocrops for cash has lead to poor soils that require farm inputs inform of fertilizers and animal manures in order to produce.

In the lowland where land use change is taking place now there are patches with natural vegetation with remnants of indigenous plant species. However, in the cultivated areas the soils are bare most of the year due to planting of annual crops that are seasonal and also due to lack tree planting within the farms. Selling of animal manure, harvestable grass materials, crop residues, and charcoal by farmers in the lowland areas to those in the upper zones is a major threat to sustainability of land uses within the lowlands. The following is a summary of observations:

1. Higher densities of ecosystem patches have higher numbers of total plant species but lower numbers of species of conservation value because the new species are common weeds and exotics.

2. Increase in land use intensity reduces plant cover linearly; exposing soils to wind and water erosion, reducing the potential for soil organic matter, and hence increased loss of soil micro-nutrients.

3. Increase in land use intensity increases biodiversity (number of species) to a certain threshold beyond which the number of species declines steadily. This has been observed in plants and small mammals.

4. Despite increase in the number of plant species with increase in ecosystem patches due to cultivation in natural areas, loss of structural diversity due to removal of tree and shrub canopies cause degradation.

5. Movement of organic matter synthesized in the lowlands to the uplands has contributed to nutrient rich soils in the uplands and nutrient deficiency in the lowland soils where soils are already poorer due to higher erosion.

6. Grazing alters vegetation structure and composition by the removal of palatable native shrubs and herbaceous perennials. Severity of this alteration varies with vegetation type.

7. Grazing induces weed invasion, but different vegetation types display different susceptibility to weed invasion.

8. Grazing increases species richness and percentage cover of the herbaceous plants but does not increase plant biomass

A. NTRODUCTION

Embu and Mbeere districts are located along the wetter eastern slopes of Mt. Kenya, but Mbeere district located at lower elevation is much drier than Embu. Human settlement along these slopes start from about 2000m above sea level and extends down to the plains lower than 800m in altitude. Land use varies greatly along the altitudinal gradient following the different agro-ecological potentials. Land use varies from the tea dairy farming in the upper Embu through the mid altitude coffee cultivation zones to the lowlands where cotton and annual cereal crops are the main crops.

Vegetation cover varies from montane forest in upper Embu through a mixture of agro-forestry species comprising mainly of *Grevillea* and *Eucalyptus* within the mid elevations to open fields of annual crops and scattered bushes in the lowlands. There are two frontiers of vegetation change in Embu Mbeere. One is the encroachment into the montane forest in the upper Embu where the recent Nyayo Tea Zones have been established and in some parts the widespread Shamba System is practiced. The other frontier is on the edges of hill slopes where natural vegetation still exists. Within the mid elevations land use change has taken place over many hundreds of years and many generations have passed still using the same land. The original natural vegetation within the mid elevations exist only in very few areas as protected forests mainly in hilltops and water catchments. Land use changes in the mid elevations at the present time are either changes in the crops planted or reverting to fallow for a period of time or change from cultivation to grazing. This is because conversion from indigenous vegetation to cultivation or grazing or to other uses happened much before the baseline time for this study. However, according to local respondents riverine areas were not cultivated until recently when a prolonged drought when people were allowed to cultivate in the riverine areas where the wetter conditions made it possible for crops to do better. Currently there are no new areas for the increased population to cultivate or settle. The trend is migrations to the lower zones where land is still available and to urban centers to do business and seek employment.

Within the lower areas conversion of natural vegetation into cultivations and grazing lands is taking place now as compared to the mid-elevated areas. Indigenous vegetation is being cut down to give way to cultivations. Due to presence of many uncultivated areas people are migrating from the upper areas where land is scarce to the lower zones Observable implications of these migrations from Upper to lowlands is that land management is changing as new settlers bring in new ideas, crop types and animal breeds. Also since most of the settlers still have small land parcels in the upper regions movement of organic matter (livestock manure, crop residues, charcoal and grass harvests)from the lowlands to the uplands is high.

Wildlife in most of the Embu District was eliminated on the advent of commercial agricultue and is currently restricted in Mt. Kenya National Park and the surrounding forest. For instance by 1909, elephants were abundant in Mt. Kenya where they lived permanently. They were, however, found to move to the bamboo forest in dry period and when it was wet, they moved onto the lower slopes and raided the farms bordering the forest (Roosevelt, 1909). Roosevelt (1909) also reported entire seasonal migrations of elephants although the movements were not regular. By 1924, however, the sighting of elephants in the open country was becoming less common and elephants had become adapted to forest life seeking refuge from man (Percival, 1924). By 1950s elephant crop raiding had become a long-standing problem warranting the building of moats to protect farms and shooting on control. Similar trends were observed for other wildlife species depending on level of conflict with human activities. However, there were fewer conflicts between human and wildlife within the marginal arid areas of Mbeere District.

Most of the marginal agricultural potential areas, in much of the now Mbeere District was not inhabited before 1914 and wildlife roamed the area with several wildlife species common to this eco-climatic zone well represented (Van de Weg and Mbuvi, 1975). The wildlife kept on decreasing with increasing human populations. For instance, the area with shallow and very shallow soils, rolling topography and dense bush north and south of the Kindaruma Dam along the Tana River was considered of no agricultural value, and was only considered suitable for range activities (Van de Weg and Mbuvi, 1975). Van de Weg and Mbuvi (1975) recommended this poorly productive land to be set aside as a game reserve. Other areas for instance Masiga block, Mavuria and Riakanau were recommended for extensive range management. The Gategi area was recommended for extensive rainfed arable farming with intermediate technology and/or large-scale rainfed arable farming to large-scale irrigation farming. The northern portion of Gategi and

The Mbeere District has undergone drastic human population transformation since the 1960. The district retained much of its wildlife up to 1970s until human pressure through poaching, subsistence hunting and habitat destruction drastically continued reducing their numbers. Most human pressure was emanating from increasing agricultural activities due to more human settlements by migrating communities who were primarily from the higher altitude area where they practiced agriculture. In comparison the Embu district had lost its wildlife earlier in the century due to escalating crop raiding conflicts resulting to erection of barriers, construction of moats and shooting on control.

Mbeere enjoys a hot dry climatic conditions characteristic of much of the Eastern Province. The rainfall is bi-modal and is not well distributed over the year making it a marginal agricultural potential area. The rainfall peaks in April during the long rains and again in November during the short rains when most of the rainfall is received. There are three vegetation types characteristic of this eco-climatic zone. These vegetation types are the wooded grasslands, the bushland and woodlands (Pratt and Gywnne, 1977). Changes in vegetation types within a short distance are attributed to both changes in total rainfall and soils. For instance, at regional scale, change from forest through woodlands to grasslands could be a reflection of decline in total rainfall. Similarly, changes in vegetation over a short distance on the other hand is more likely to be a reflection of changes in soils, where changes may be due to geology or topography changes or from shallow soils on slopes to deep alluvial plains. Such a change may also reflect an interaction between geology and topography.

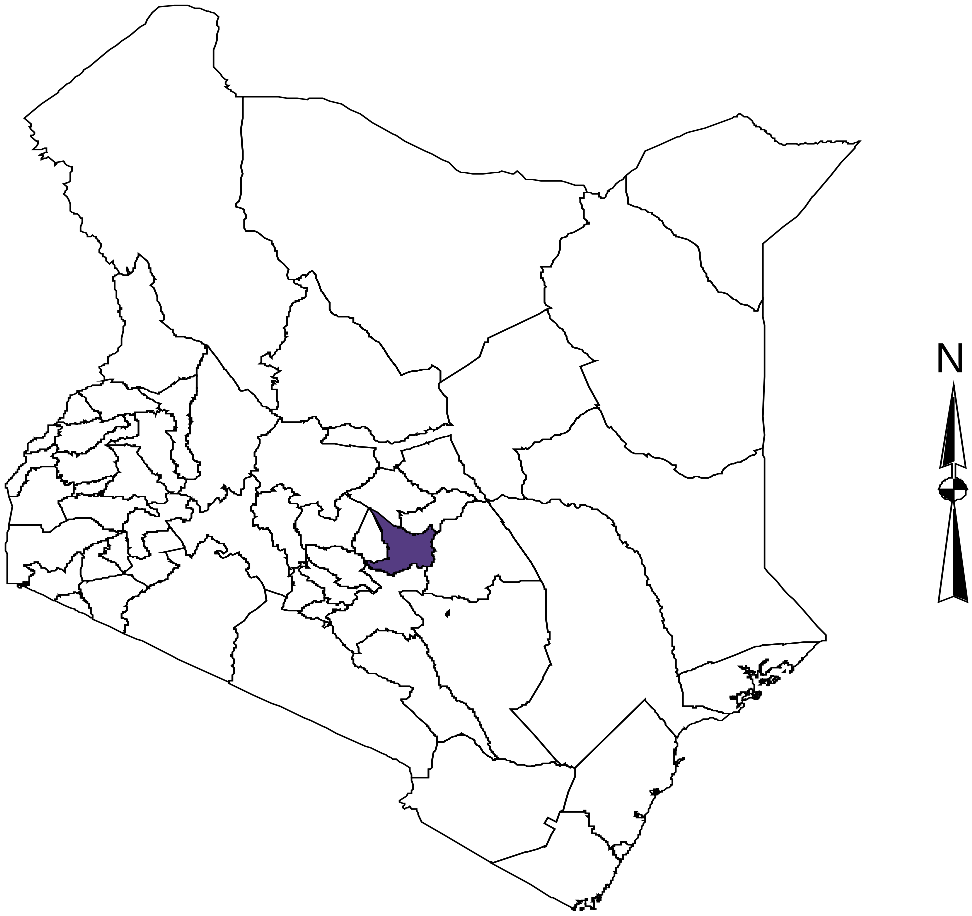


Figure 1: Embu and Mbeere Districts in the National context

Species exhibit considerable interspecific variation in sensitivity to habitat alteration. With the ensuing land use mediated changes in habitat conditions, spatial and temporal distribution of quality food sources, shelter and breeding sites for small to medium mammals are highly modified resulting in much intra and interspecific competition as well as escalation of human-wildlife conflicts. Vertebrate species that due to their behavioural plasticity are able to adapt to the changing ecology and survive in agricultural systems often come into direct competition with humans and are persecuted as pests whereas those that do not are forced into small marginal patches.

Since increased land use replace natural vegetation with agricultural crops, most resilient foragers are forced to shift their diet to plants that are available as a strategy to minimize foraging cost. Consumption of crops is therefore high where there is high density of animals and low alternative food resources. Such areas are also the hotspots for wildlife – land use conflicts.

B. **LAND USE CHANGE 1958-2001**

The main pattern of land use over the past 30 years has been the expansion of area under cultivation within the lowland areas of Mbeere, extending into the much drier areas on the basin of river Tana. The expansion of the area under crops has restricted free range herding into small small isolated patches mainly within individually owned lands, resulting in increased competition of land use between cultivation and grazing. Wildlife populations have also been affected by the expansion of cultivation that has reduced the area of natural vegetation and limited access of wildlife to water. Increase in cultivation is targeting areas with key resources and unique habitats like the swamps and riverine woodlands with richer plant diversity.

The text and tables presented in this section are obtained from another Lucid working paper number 20 (Olson *et al* 2004) that focuses on patterns and causes of land use change in Embu Mbeere. The following is a summary of land use changes in Embu Mbeere districts from 1958 to 2001. The most significant change is the change from 23% of bush cover in 1958 to the levels that are undectectable from Land Sat Satellite image of 2001. Forest cover has reduced to less than half of that during 1958 (table 1)

Land use	1958		1985		1958-1985		1995		2001		1985-2001	
	Km2	%	km2	%	km2	%	km2	%	km2	%	km2	%
Forest	11.4	17.5	11.1	16.9	-0.4	-0.6	12.3	18.8	13.5	20.6	2.5	3.8
Bush	23.1	35.4	0.0	0.0	-23.1	-35.4	0.0	0.0	0.0	0.0	0.0	0.0
Shamba system	0.4	0.6	0.5	0.7	0.1	0.1	0.8	1.3	0.9	1.4	0.4	0.6
Tea Plantation	0.0	0.0	1.2	1.9	1.2	1.9	1.9	2.8	3.1	4.7	1.9	2.8
Tea/Coffee	29.8	45.6	52.6	80.2	22.7	34.6	50.1	76.5	47.7	72.9	-4.8	-7.3
Urban	0.6	0.9	0.2	0.3	-0.4	-0.6	0.4	0.6	0.3	0.4	0.1	0.1
TOTAL	65.4	100	65.5	100			65.5	100	65.5	100		

Table 1. Land use change statistics, northern Embu site (Mbuvori)

The largest land use and cover change that occurred in the Mt. Kenya region since the 1960's has been the expansion of farmland from the higher elevation areas into the mid-elevation, then low elevation and most recently to the semi-arid bush. Responses from Farmers indicate that the earliest settlements were in the mid elevation areas, later spreading to the upper elevation areas and recently to the lowland areas. This may be because farmer's reflections go back beyond the 1960s that is the baseline for satellite image records. The result is a "ring" of recent land cover change at the base of Mt. Kenya. The landscape of the semi-arid zones of Mbeere and Tharaka has changed from one dominated by bush savannah and woodland to one almost completely covered by farms, if not all cropped. The only large areas remaining of natural vegetation are on the rocky, steep hills, but even there many of the woodlands have been cleared or thinned. The large scale conversion from bush to farmland was precipitated in many places by the implementation of a land adjudication program of the national government, and sustained by rapid population growth due to high fertility rates and some in-migration. Land use and tenure changes that may have otherwise occurred gradually and unevenly with an increase in population densities and intensification of the agricultural system were mandated as part of the government's land program. The Mbeere and the neighbouring Tharaka people, previously agropastoralists raising herds of goats and cattle on communal clan land, have found themselves confined to family plots and to cropping. Much of the farmland in the drier zones is not intensely cultivated, however, due to low returns to labour. The crops are of low value, and risks of drought and pests are high. Indeed, these areas are the poorest despite low population densities, and many husbands and adult children have left the family farm to search for other sources of income. The semi-arid zones appear to be in danger of worsening soil degradation due to this expansion of cropping into environmentally fragile and climatically risky areas, and the land cover change has had a large impact on native vegetation and wildlife.

On the other hand, the well-watered, densely populated Embu and Meru districts on the upper slopes appear to represent a success story, with the development of a highly productive, profitable agricultural system that includes intensive soil management. Governmental and parastatals programs were instrumental in the development of the tea and coffee sectors to such an extent that farmers here bought most of their food, and very high population densities have been supported primarily by agriculture. Here, too, however, farmers have been forced to respond to changing economic circumstances by modifying their farming system. Coffee and tea prices declined precipitously and many farmers eventually removed their coffee bushes to plant other, if less remunerative, crops. Land shortage is seen as a major problem and wealthy farmers since the 1970's have been renting or purchasing land ever lower into semi-arid zones. It is also being addressed by measures to reduce dependency on the land: farm families have focussed their investments on their children's education since the 1970's so that they learn a trade other than farming, many young people seek non-farm employment, and birth rates and population growth rates have declined rapidly.

1950's: Grasslands and woodland, patches of **shifting cultivation**.
Economy based on goat herding.
1970's **Expansion** of cultivation into pasture, use of plough
1980's Initial intensification near settlements:
from shifting to fixed cultivation
1980's **Adjudication** from clan to family, private landholdings, rapid **bush clearance**.
fewer animals: economy changes
1990's Further **intensification** of the core area:
from animal grazing to crops
permanent cultivation or short fallows of seasonal crops
limited tree planting, some soil management: manure, erosion control
Crops bring *limited* wealth, much poverty.
Out-Migration and income diversification
by fathers and children to cities, other farms

Table2. Pattern of land use and economic change in semi-arid zones (from Olson et al. 2004)

In the small-scale farming and herding systems around Mt. Kenya, therefore, the pattern of land use and cover change appears to have followed a non-linear path of intensification and extensification, with variations in rate and with reversals. The generalized pattern is summarized in Table 2 and includes an initial intensification (sedentarisation), followed by extensification (search for land, associated with much of the visible land use change) and continued intensification (increased use of inputs and labour). Across the region, economic conditions and land tenure programs have greatly influenced how and when this has happened:

- the upper zones were able to continue to economically benefit from increased intensification of their system until a drop in the international price of coffee and tea, and decline in governmental support of the coffee sector. Farmers then reversed course, changed to less intense if marketable crops, and adopted demographic and other responses to reduce land pressure and their dependence on the land.
- In the mid and low elevation zones, the extensification of cropping has been dramatic. Where marketing and environmental conditions are conducive, this has been followed by an intensification of the system and development of a productive, market-oriented system. An example of this type of intensification later reversing was the arrival then

departure of cotton production within a 15 year period. Maize is the current basis of the farm economy.

- In the semi-arid areas where marketing and environmental conditions are marginal, however, an initial clearance of bush has been followed by low and in some cases declining intensity of use. Land adjudication initially led to bush clearance, land sales and in-migration, but after it became clear that crop production and sales were undependable, out-migration especially by members of the poorest families has reduced labour availability. Some fields have reverted to bush or were planted with low-maintenance trees. Decisions on whether to stay or leave, or whether to work on one's own farm or elsewhere, are linked to evolving local and national economies and can change quickly.

Agricultural intensification and extensification processes, therefore, have been closely tied to national and international economic and political forces, and to non-agricultural sectors (Table 3). Rather than being a uniform success story, the impacts on poverty, soil management and fertility particularly in the semi-arid zones are mixed. This is somewhat different from in neighbouring Machakos, which benefited from high capital and technological investments (Tiffin et al. 1994).

Rather than population pressure being the main driver of extensification and intensification processes, population dynamics themselves have varied quickly in response to changing circumstances. First short-distance migration to clear new land, then longer-distance moves to search for land in remote or less productive, drier areas, along with high rates of temporary labour migration, were critical responses to changing economic constraints and opportunities—a familiar pattern in East Africa (Gould 1995). Migration patterns were primarily from Embu and surrounding highland areas into Mbeere and were instrumental in affecting the clearance of new land. First the mid-elevation areas, then the semi-arid lower elevation zones, were destinations for migrants especially after the privatisation of land holdings permitted easier land sales. Some migrants have found the semi-arid areas risky and untenable for agriculture and have left. Meanwhile, temporary labour migration by members of the poorest households, and particularly from the semi-arid areas, is a common response to diversity the family's income. Poverty rather than population pressure is associated with out-migration. The poorest households are investing little of their outside income in the farm. Their poverty is being perpetuated by distress land sales and low investment in children's education . The pattern of labour migration, however, is bi-modal with the poorest and the richest families most engaged. A second demographic change has been a decline in population growth rates due to a decline in fertility rates, especially in Embu. It was due to increased availability of family planning and a desire to have fewer children. Currently, the extensification of agriculture in the semi-arid zones is slowing, as both in-migration and local population rates decline. Future increases in the percent of land being cropped will be highly tied to relative returns of semi-arid agriculture vis a vis other activities. Development opportunities such as irrigation or introduction of a high value crop would change both the extensification and intensification dynamics.

Political:
Kenya government: land polices (adjudication, conservation), changing enforcement of regulations, elections/ stability, infrastructure investment, coffee & tea promotion, health of cooperatives/ parastatals
International: environmental organisations, structural adjustment, aid, commodity prices
Economic:
Changing relative labour and economic returns to crops vs. animals, to farm vs. non-farm
Changing markets for maize, coffee, charcoal, timber , miraa, horticulture
Availability of off-farm employment
Demographic:
Local pop. growth and low land availability→in-filling and intensification
Migration: to look for land (upper to lower zones)→extensification, to look for employment
Falling birth rates, HIV-AIDS
Social/ cultural: power from clans to families, changing gender roles, wealth differences, high value placed on education, on sacred forests
Locational context: remoteness, marginal environment, strength of national ties

Table 3. Major driving forces of land use change (obtained from Olson, et. al. 2004)

The other major actor affecting land use and cover in the eastern Mt. Kenya region is the Kenyan government. It directly manages around 21% of the land surface—under parks, reserves, research land, and reservoirs. It, too, has been a very active agent affecting land cover. It reversed years of how it managed the Mt. Kenya forests, and started strictly enforcing regulations restricting logging, grazing, cultivation and other uses of the forest. During the thirteen year interval between the satellite images that were interpreted, one large section of forest was cleared, cultivated, and then allowed to revert to secondary forest growth. The reasons for these turns in governmental action include: 1) as a response to international and national pressure by environmental groups and activists; 2) power reversals at the local to national level (of individuals, agencies, political groups), and 3) attempts by a politician to please voters prior to an election. These types of reasons, and thus future land cover changes, are difficult to predict. International governmental forces affecting the agricultural and other sectors, such as structural adjustment and aid, are similarly difficult to predict.

Implications of Trends in Land Use Change for Land Degradation and Biodiversity.
These trends in land use and land cover change are altering the soil, water, and vegetation characteristics of the 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 effects from these altered conditions and interactions in the soil/water/vegetation system feedbacks to the human-ecological system – to cultivation, herding, and wildlife.

III. A. Land Degradation.
Land degradation is here understood to be the loss of biological or economic productivity or complexity, deterioration of chemical, physical and biological soil properties, and long term loss of vegetation (Maitima and Olson 2001).

The LUCID Team has examined land degradation in terms of soils, water, biodiversity, and vegetation. The team conducted surveys of vegetation (Maitima and Olson 2001) and soil characteristics (Gachimbi, 2002) along identical transects from the upper slopes of Mt. Kenya to the adjacent lowlands. Information on vegetation characteristics within land various land use categories was collected from the same plots where soil samples were collected in order to link soil characteristics with vegetation types. Animal biodiversity has bee studies in three case studies two of which focuses on the effects of land use changes on animal biodiversity (Mugatha 2002) and (Mutugi, 2003). The third study focuses on the impacts of grazing on vegetation dynamics (Kamau, 2003).

The present vegetation in the upper and mid elevation areas is significantly different from the original natural vegetation because it comprises of planted trees. Within the lowland areas remnants of natural vegetation still exists and although disturbed by harvesting and grazing in many places they still show substantial amount of native plant species. At landscape level the mid and upper zones have less diverse ecosystem types as they are mainly cultivations. In the lowland areas the presence of patches of natural vegetation and cultivations makes the ecosystems to be more diverse and therefore has a higher diversity of plants and wildlife. At farm level cultivations in the mid and upper zones have more perennial crops more planted woody trees than the cultivations in the lower zones of Mbeere. Farms in Mbeere are planted mainly with annual crops and for most part of the year they are bare with exposed soils that is very prone to soil erosion. Lack of adequate vegetation cover on the farms in the lowland areas has resulted in lack of sufficient mineralization leading to deficiencies in soil organic matter. This problem is exacerbated by poor land management where palnt residues rather than decomposing to recycle nutrients into the soil they are in many cases harvested and sold to richer farmers from the upper zones.

Relationships between human population density and soil fertility.

Upper areas comprises of high to medium quality rainfed intensively managed lands in the Manyatta and Nembure Divisions of Embu District. Land holdings range from 0.9 – 2.3 ha and these are areas, with more than 660 people Km^{-2} and considerably good soil fertility areas e.g. upper zones have good stable fertile soils and reliable rainfall with annual means of more than 1000mm per year (Jaetzold and Schmidt, 1983). It has the following farming systems attributed with good fertility status.

a) Small-holder mixed farming systems (with complete crop-livestock integration with subsistence farming (maize, dairy, potatoes, horticultural crops and bananas) which in most cases is dominated by cash crops (coffee, tea)

b) Large scale farming with plantation crops like Nyayo tea zones.

c) Integration of agro-forestry practices (‘bush fallow”, home gardens and agro-forestry trees)

The lower part comprises semi-arid regions with less than 100 people Km^{-2}. These are areas that are currently experiencing the greatest population change, compared with the high potential agricultural areas, with a natural rate of increase of 3.5 to 4% in East Africa and a higher actual growth rate due to migration from the crowded fertile areas of the highlands (Nandwa 2003). Farm sizes in these regions are thus getting smaller, ranging from 16 to 2.5 ha per household (Gachimbi, 2002.), in East Africa. Traditionally, farmers have always grown maize (*Zea mays L.*), beans, sorghum, millet, cowpeas and pigeon peas. The migrants into the semi-arid regions have traditionally brought along with them crops more suited to the high potential regions, with no requisite change in production technology to optimize the production of these crops in the semi-arid regions.

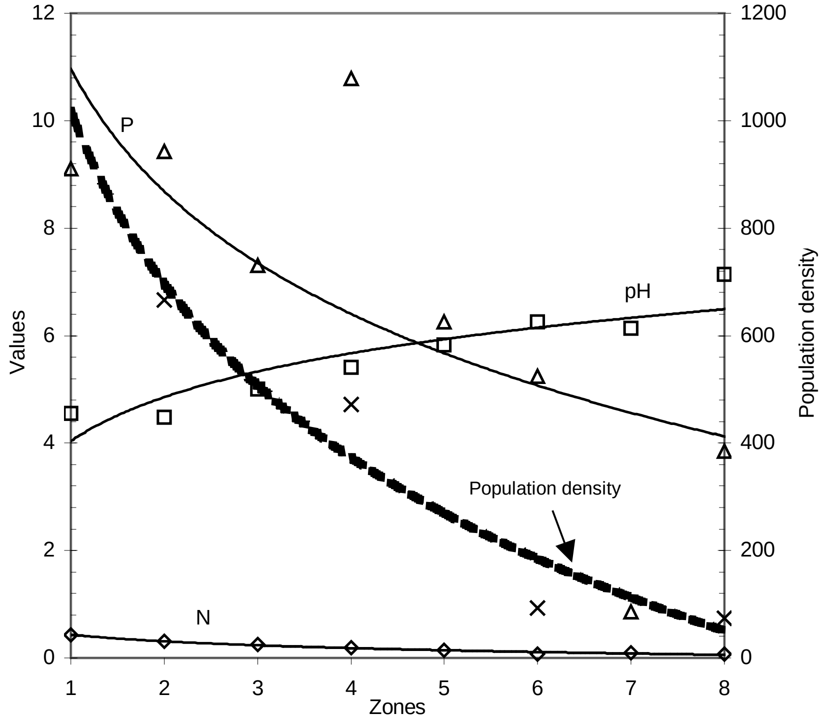
The topography is variable and areas with slopes as high as 30% or more are commonly used for crop production despite the unstable soils exposing them to severe soil erosion and nutrient depletion. Many of the soils in the semi-arid lands (ASAL) are deficient in some essential mineral nutrients especially phosphorous and nitrogen as shown in (Gachimbi *et al* 2002, Nyathi *et al 2003.).* Declining crop yields is evident from Embu- Mbeere districts maize yield data.

Many of the soils in the Mbeere are deficient in some essential mineral nutrients especially phosphorous (P) and nitrogen (N) as shown in figure 2 and as described elsewhere **(**Okalebo, 1987; Hikwa *et al*, 1998;. Low soil fertility (especially P and N deficiency) is a major biophysical constraint to successful agriculture in semi-arid areas of East Africa (Yates and Kiss, 1992;).

In the past, soil conservation has been advocated as a necessary starting point to raise crop yields. Soil erosion has conventionally been perceived as one of the main causes of land degradation and the main reason for declining yields in tropical regions. Based on these assumptions, conservation measures were directed at three main components from 1950s especially in the upper zones of the transect (Wenner, 1980):

- Physical works; Cut off drains and channel terraces to catch, disposal and prevent damage by run-off.
- Pressures to stop people from deforesting the area and to reduce the number of grazing animals by designating lower Embu (currently Mbeere) to be grazing areas.
- Planning of different land uses according to Land Use Capability Classifications based on the assessment of different degrees of the erosion hazards Tea and dairy with subsistence crops next to the forest, coffee, maize, dairy or a combination of these in the lower midland zones (LM_{4-5}) to grazing.

Figure 2: Variation of soil fertility and population density (N, P and pH) across the AEZ's



C. SOIL.

3.1 Land use, soil fertility variation and soil erosion within different AEZ

Land use varies within an AEZ and across different AEZs. This is from forest, tea, coffee/ maize beans and dairy zero grazed animals to drought resistant crops like cow peas, sorghum, millet e.t.c. in the marginal areas of lower midland zones. In the lower midland areas free range grazing dominated by crossbreed dual-purpose animals becomes dominant. Specific farm slope in various land use type differs across the AEZ and within AEZ. Altitude decreases 2007-1060 above sea level from forest zone (TA)/ lower highland zones to lower midland zones. This coupled with other factors such as human population, plant cover, rainfall amount, intensity and finally soil type, contributes immensely to soil fertility and subsequent low crop yields.

Studies conducted elsewhere (Onduru et al 2002) show major crop production constraints and options for increased food production Different soil conservation or improvement measures have been devised, installed and constantly improved. During the survey, major soil and water conservation practices in the district include terracing (*fanya juu*, cut off drains and retention ditches), stone lines, grass strips, trash lines, unploughed strips, river bank protection, contour bunds, semi-circular bunds, basins/9 seeds in a hole and plating pits. In addition to the above practices, gulley control using vegetative materials, gabbions and mixed materials are also being practiced. The dominant soil and water conservation practices in the district at farm level were *fanya juu* terracing and the use of trash lines in the lower midland zones and channel terraces in the upper midland zones which were not well maintained.

D. VEGETATION.

Summary of findings of vegetation survey

The land use in Embu Mbeere is characterized by certain specific land management activities like ploughing and weeding, use of manure and fertilizers, use of insecticides and herbicides. These different management activities have direct impact on the dynamics of vegetation due disturbance. From a management point of view the land use could be categorized into three major types namely: livestock grazing, commercial mono-crop farming and subsistence mixed crop farming. Comparing species abundance between these systems showed that grazing systems have the highest plant diversity while cultivations of monocrops have the lowest As land use intensification increases, cultivation replaces natural vegetation in agro-ecosystems and the number of species decline due to the loss of native species as weeds start to invade.

It is well known that land use change from more natural vegetation to one that is more intensively used creates ecosystem fragmentation to smaller patches that are more heterogeneous than the undisturbed continuum (Reid et al. 1997, Foran et al. 2000). However, if the disturbance is much more intensive like in cultivation of horticulture, non-desirable plant species are not let to grow due constant removal of invasive weeds and harvestable plant materials. The linear decline in the number of native species with land use change from polyculture to monoculture suggests that as land use changes from natural to grazing lands and to cultivation, there is always loss of indigenous species. Human land use is known to homogenize the distribution of bird species (Bo et. al. in prep.) and that these species are the commoners which in the case of birds are called pests. A similar observation is here inferred that the number of unique species within the samples collected in the cultivated areas was very low indicating that the rare species of conservation interest decrease with increasing land use intensity.

From the results we observed that as land use intensity increases, plant cover decreases linearly. Although the number of plant species appears to increase before a continued decline as explained above, the plant cover shows a steady decline. In this analysis we note that as land use starts to intensify there is first a period of increasing plant diversity while the vegetation cover is decreasing. As dominant higher canopies (e.g, trees) are removed due to land use change there is a room for invasive species to grow in the lower canopies to cover the exposed areas but since these are structurally with less crown cover, the overall cover is generally reduced. This shows that although land use change from forests to woodlands to pasturelands appear to increase plant diversity in terms of species numbers, the loss of structural complexity and plant cover suggests a degradation. Examples highlighting the impacts of land management techniques on vegetation are discussed below.

i) **Crop Cultivation Land use systems**

Crop cultivation in this area mostly involves clearing of natural vegetation which causes fragmentation and reduces the stature of woody layers and occasionally the number of vegetation species. In terms of species numbers, land conversion may be positive in that it could result into an increase in total number of species (Reid et al. 1997). The increase in species numbers was shown to result from conversion of uncultivated lands to cropland through invasion by weeds; augmentation of the structural diversity through planting of hedge rows and woodlots, introduction of exotic species, cultivation of crops of different stature and leaving patches between cultivated fields. These will definitely increase both vertical and horizontal heterogeneity of the environment, a correlate for high species diversity (Reid at al. 1997). Even though areas under crop agriculture showed high tree assemblages, they contained very few native vegetation species compared to natural forest stands and grazing land. In Embu-Mbeere area, the main exotic species include *Eucalyptus, Grevellia*, and *Jacaranda* species. Also those tree stands within farmlands do not support as many wildlife species compared to natural habitats.

Methods of cultivation and land management also affect the vegetative structure and species within this area. In comparison with smallholder farms growing subsistence mixed crops and ploughed by oxen, the larger commercial farms of monoculture crops are structurally simpler and biologically less diverse. The efficiency achieved by mechanization in crop production is therefore achieved at the expense of natural vegetation. To support this, other studies have reported heavy use of chemicals to control weeds in large commercial farms, which in turn reduces vegetation species diversity within these systems. From our study, abundance of herbaceous and gramineae species was highest within the annual crops, coffee and fallow land use systems compared to tea and horticulture plantations. This may relate more to management aspects and field sampling time rather than land use intensity in the case of coffee and annual crops. However, low abundance of herbaceous species in tea planted areas could also be due to the nature of the tea crop itself since tea crop is usually maintained as a low shrub covering ground and leaving no room for undergrowth.

From the study we can conclusively observe that in some context, conversion of land into cultivation doesn't necessarily cause negative impacts in terms of vegetation dynamics. For example, small holder agricultural systems can be compatible with high levels of wood vegetation cover and moderate levels of biodiversity (Tiffen, Mortimore & Gichuki 1994). However, the clearance of native forests for cultivation would lead to loss of native vegetation species a key concern for biodiversity conservation. Field observations showed crop cultivation insurgence into the mountain forest sections and this poses a real threat to the existing forest biodiversity both in terms of *flora* and *fauna*.

ii) **Livestock Grazing Land use systems**

From the study we do know, however, that prolonged use of native vegetation for livestock grazing results in profound ecosystem changes, including altered vegetation structure and composition changes. The most obvious changes were in under-storey composition, with a reduction or removal of the native shrubs and herbaceous perennials. But the severity of the grazing influence varies among vegetation types. Trampling by livestock also has a marked influence on soil structure, particularly in soils with relatively high clay content. Trampling can lead to significant reductions in litter and soil crust cover and increases in penetration resistance, which in turn lead to reduced water-infiltration rates and a less-buffered soil microclimate (Gachimbi 2003). This changed soil structure is thought to contribute to the inability of dominant tree species in woodland systems to regenerate. From other studies, grazing has further, subtler influences in fragmented systems. For instance, mistletoe is less abundant in grazed woodland fragments than in ungrazed fragments, presumably because of the influence of under-storey plant distributions on the birds that disperse mistletoe berries.

The other major influence of livestock grazing is its interaction with weed invasion. Several studies have clearly indicated that weed invasion is much more prevalent in systems that have been grazed by livestock for long periods (Scougall et al. 1993). Different vegetation types display different degrees of susceptibility to invasion, but in all cases livestock grazing significantly increases the level of invasion. Weed invasion is enhanced by disturbance and nutrient addition in the relatively nutrient-poor systems. Some studies however indicate that weed invasion can be restricted to the edges of fragments, where nutrient deposition from adjacent farmland may occur. In *Eucalyptus/Acacia* woodland, Scougall et al. (1993) found that livestock grazing effectively increases edge by altering the physical and chemical properties of soil and increasing weed invasion much farther into woodland fragments than in ungrazed woodlands. Smith et al. (1996) found that grazing and weed invasion are covarying disturbance factors influencing the abundance and species richness of a number of faunal groups in fragments of *Eucalyptus salubris* woodland. These studies indicate that the internal condition of the fragment is as important or more important in determining the abundance of some groups than biogeographic variables such as size and isolation. The role of livestock grazing on vegetation is therefore quite remarkable and should not be overlooked.

Implications of changing vegetation structure on biodiversity conservation

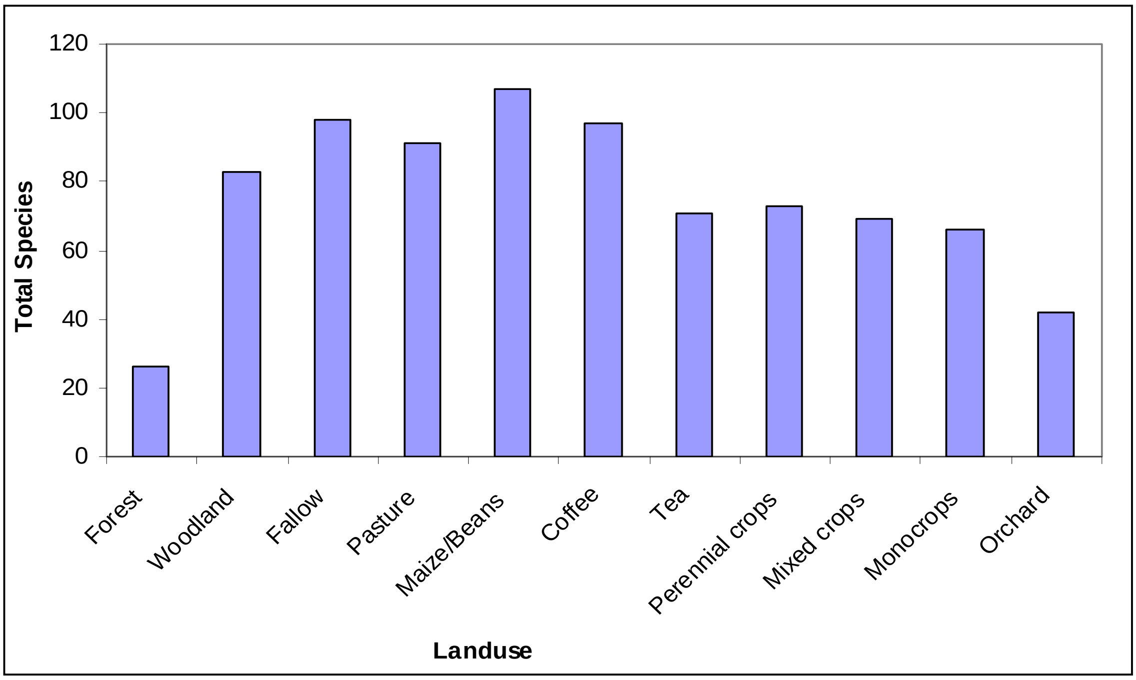
Differences in the number, diversity and cover values of vegetation patches resulted from differences in land-use systems within the study area. Land clearing for cultivation, integration of livestock and other uses have resulted into fragmentation of large and extensive areas of native vegetation. As farmers clear more land for agriculture, smaller cultivated fields coalesce to form larger fields thereby creating large homogenous patches of farmland. The rapidly growing population within the study area has likewise led to intensification of agricultural activities along the slopes of the mountain and widespread sparse cultivation on the suitable regions in the lowland areas of Mbeere.

Substantial changes have been observed for different vegetation cover types such as bushed grassland, forests, pastures and cultivation. The remaining natural vegetation within the study area has become lone habitats for wildlife species outside the protected areas. As the land-use changes, fragmentation of the cover-types by human activities into smaller patches have contributed to increased heterogeneity and reduced landscape complexity (Western and Gichohi 1993; Smith 1996). It has been shown that spatial landscape pattern can strongly influence biotic community characteristics (Ellis et al. 1999), for example, vegetation composition and structure influence faunal composition and richness within any given ecosystem (O’Neill et al. 1988). Therefore, the emerging more open land use systems might result into local and regional loss of vegetation species that could have originally existed within the former intact landscape conditions.

The ecological implications of the present landscape development within the study area are reflected by the initiation of vegetation succession processes and subsequent changes in cover type distribution, areas, and transitions from one type to another within the different land use systems. These succession processes may imply changes in the ecological contents of the different cover types. For example, expansion of crop cultivation into natural vegetation areas has led to fragmentation of those specific patches by splitting of the existing continuous ones. Connections between similar and dissimilar patches usually facilitate movement of individuals and propagules across a landscape (Dunn et al. 1990). If these connections are absent, the future survival of biodiversity within this landscape is threatened. In conclusion, populations of endangered plant and animal species may become vulnerable to the fragmentation of the rangeland vegetation, which will include reduced patch sizes and increased distance to similar sites due to isolation (van

Dorp et al. 1997). This pattern is particularly evident in the areas being converted into agricultural use.

Figure 4. Variation in the total number of plant species in different land uses arranged in increasing order of land use intensity.



E. LAND DEGRADATION: INTERACTIONS BETWEEN SOIL, AND VEGETATION.

Reduction in vegetation cover reduces the amount of soil organic carbon in the soil. Available soil organic carbon (SOC), in agronomic terms (Mehlich *et al.* 1964), is adequate in forest and bush lands in the upper zones but deficient in the lower zones. This is due to reduced plant cover and high rate of decomposition and mineralization of organic matter in the lower zones unlike in the upper zones. Soil organic carbon was found to be higher in annual crops, pasture and fallow as a result of the addition of farmyard manure or use of inorganic fertilizers.

Relationship between vegetation cover and soil fertility in different land uses across different zones.

Chemical fertility in agronomic terms *(Mehlich et al 1964)* differs with land use and zones. All fertility data from the mass analysis range from adequate in the upper zones to moderate to low in the lower zones. This in effect has different effects on vegetation cover and diversity in different land uses in the area. Soil results are shown as a percent of threshold level below which nutrients are deficient. The percent have been calculated and plotted on one graph by dividing laboratory measured values by specific critical values set out by Mehlich et al (1964) then multiplied by 100.

High nutrient status of soils in the upper zones is due to the presence of fertile weatherable soils, which have been enriched with volcanic ash dominated by Nitisosls or Andososls. Workability of the soils is in general good with exception of valley bottom soils (vertisols). Available P, SOC (%) and N decreases from forest and Lower highlands dominated by perennial crops such as tea, coffee, pasture (dairy) and horticulture to the lower midland zones under pasture, annual crops (maize, beans), perennial crops (Miraa, cowpeas, pigeon peas), woodland and other food crops as detailed in

Grass cover is dominant in the pasture fields in the upper zones compared with other land uses from the lower midland zones. Herbaceous material increases from woodland to perennial, annual and fallow fields exponentially especially in upper midland zones even though soil fertility levels are all below the threshold. Shrubs in this case decreases from 1.5% to near zero in perennial, annual and fallow fields. Grass cover increases from woodland to the fallow fields from (zero to 1%). Amount of grass/herb cover decrease in the lower zones giving way to 15% shrub cover especially in pasture fields compared to near 35% grass cover in the same area. Herbs cover in pasture fields could be 3%. In the lower zones, grass/herb/shrub cover in perennial crop fields is lower than in annual fields possibly due to low fertility status and constant cultivation in perennial fields.

Figure 5: Effect of soil fertility on mean percent cover in different land uses in zone- UM2

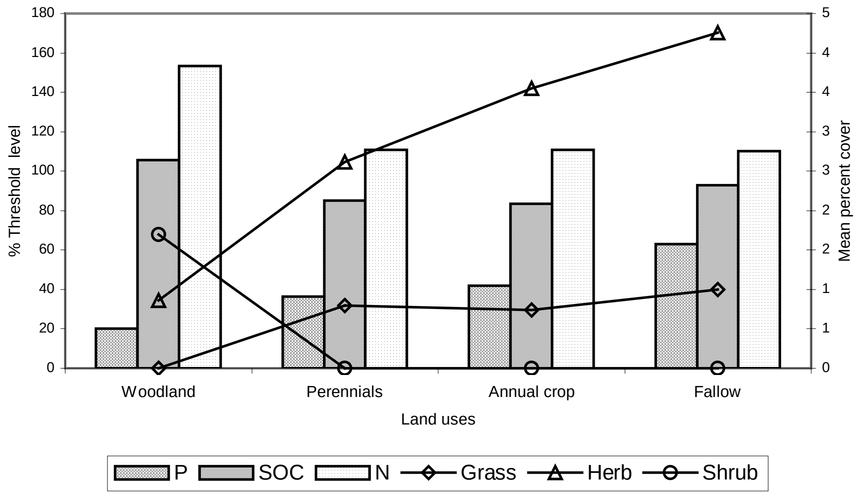
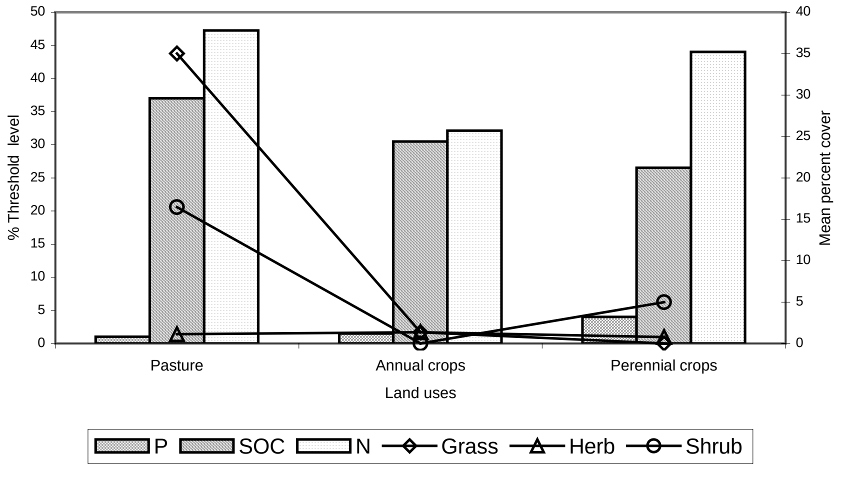


Figure 6 Effect of soil fertility on mean percent cover in different land uses in zone- LM4



F. BIODIVERSITY

Effects of land use change from non-cultivated to cultivated on ecosystem diversity

Changes in land use from non-cultivated to cultivated affects ecosystem diversity at two scales: first as cultivated patches are introduced the new species associated with agro-ecosystems create new habitats in an otherwise extensive natural vegetation. The new habitats comprise of mainly herbaceous species that establish themselves in the opened up areas. The effects of the new habitat is an increase of ecosystem heterogeneity as long as there are still some of the natural habitats left. As the extent of cultivation continues, patches of natural habitats become fewer and fewer and agro-ecosystems become more and more. The reduction in natural habitats reduces the heterogeneity therefore making the ecosystem less diverse. From these findings we conclude that higher densities of ecosystem patches have higher densities of total species but lower numbers of species of conservation value.

Our findings indicate that cultivation affects the numbers and cover of plant species. In Embu Mbeere, we found that tree cover varies significantly between land use types due to presence of more trees in the uncultivated areas than in the cultivated areas both in the upper and in the middle zones. Shrubs show significant variation in both species numbers and cover due to higher representation in the uncultivated than in the cultivated areas. Despite the fact that herbs comprise mainly of weeds our study show no significant variation in cover across the land uses.

The comparison of grass species numbers between the various land use types was found to vary only in the upper zones. On the other hand a comparison in grass species cover between different land uses in the middle and lower zones in Embu Mbeere was found to vary. Inter site variability was noted in the patterns of species distribution and cover where it was greater in Embu/Mbeere than in Loitokitok. This difference in distribution and cover of plant species could be due to variation in production systems where in Loitokitok, farm sizes are relatively larger and the changes are more in extensification rather than intensification. In Loitokitok farming is more towards monoculture while in Embu farming is more towards mixed farming.

Table 4. 2 way Analysis of variance for species richness and percentage cover of plants in various land use cover types and agro ecological zones in Embu Mbeere

Life forms	Upper (LH) zone		Middle (UM) zone		Lower (LM) zone	
	Species	Cover	Species	Cover	Species	Cover
Tree		35.53*	29.95*	11.22*		
Shrub	71.32*	7.19*	44.80*	10.46*	15.85*	9.20*
Herb	4.77*	1.01	2.43*	0.32	2.22*	0.67
Grass	4.22*	0.79	1.72	12.75*	0.57	4.06*

* *Indicate significance at P < 0.05*

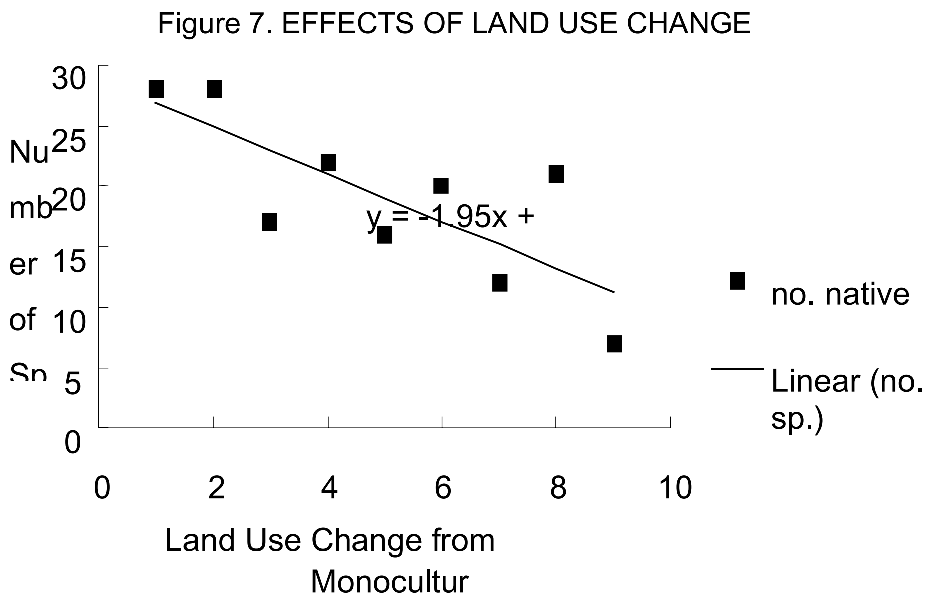
Table 5. 2 way Analysis of variance for species richness and percentage cover of plants in various land use cover types and agro ecological zones in Loitokitok

Life forms	Middle (UM) zone		Lower (LM5) zone		Lower (LM6) zone	
	Species	Cover	Species	Cover	Species	Cover
Tree	41.45*	20.60*	69.58*	10.59*	15.23*	6.17*
Shrub	187.82*	11.76*	31.60*	2.12	20.00*	7.61*
Herb	1.64	1.98	7.35*	1.11	2.39	1.25
Grass	12.78*	6.64*	3.13*	4.32*	1.35	6.84*

* *Indicate significance at P < 0.05*

Effects land use change from poly culture to monoculture on the number of species of conservation value.

Our findings indicate that a change from polyculture to monoculture reduces the number of species of conservation value. The figure below shows a continuous reduction in the number native species along a gradient of from mixed to mono crops. There is a progressive loss of native species as land use continues and as we change from mixed farming to mono-cropping. Native species here refer to total plant species that are indigenous (irrespective of whether they are of conservation value or not) to the area as opposed to introduced species.



An assessment of the impacts of land use change on the number of species of conservation value (rare species) also show a linear decline similar to the native plant species. Information on the rare species was obtained from Flora of tropical East Africa (FTEA) where distribution patterns of plant species are indicated region by region and information on their distribution is given. For many species FTEA gives information on whether plants of that species are rare or common.

The figure below illustrates the impacts of land use change on plant species of conservation value. Similar observations reported for birds in the LUCID study sites in Uganda (Pomeroy et al. 2003).

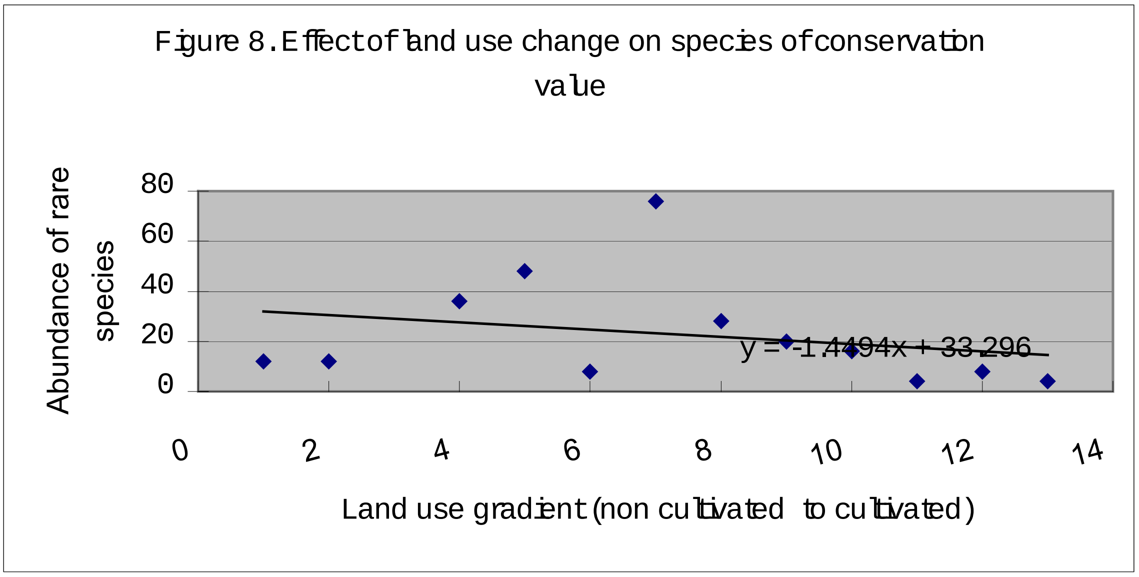


Figure 8. Effect of land use change on species of conservation value

G. IMPACT ON FLORAL DIVERSITY.

Effects of Land use change on plant species composition and abundance of common species.

Land use change reduces vegetation complexity by removing tree canopy cover and if cultivation continues even the shrub canopy does not re-establish itself. Removal of tree and shrub canopies reduces the number of tree and shrub species but the number of herbaceous species increase. However, most of the increased species are only to common ones

The figure below shows the number of tree species in different life forms and different land cover types. Surprisingly maize and beans cultivation followed by pastures have the highest number of tree species, more than those found in the forests. Maize and beans also have the highest number of herbaceous species and the highest number of total plant species.

Table 6 Distribution of plant species by life form in different land use/cover

Land use	Climbers	Cyperacea	Ferns	Grasses	Herbaceous	Shrubs	Trees	Total
Forest	1	1	1	1	13	4	5	26
Woodland	4	1	1	6	49	13	8	82
Fallow	4	1	1	8	58	13	11	96
Pasture	4	1	1	6	51	13	13	89
Roadside	1	1	1	4	33	2	1	43
Maize/Beans	5	1	1	9	60	16	14	106
Coffee	4	1	1	8	58	13	11	96
Tea	3	1	1	6	36	12	10	69
Monocrops	2	1	1	7	41	9	5	66
Mixed crops	3	1	1	5	43	11	5	69
Perennial crops	2	1	1	8	47	9	4	72
Orchard	1	1		4	29	7		42

How do changes in soil fertility associated with LUC affect the number of plant species?

The number of plant species decreases after opening up the forest to cultivation. This decrease in plant species numbers and cover results in decreases in the amount of soil organic carbon. Comparison of soils in uncultivated with soils in the areas with perennial crops, pasture or even in annual crops shoe reduced amounts of soil organic matter. Soil carbon in the cultivated areas is lowest in the horticulture areas than in any other land use. This may be due to the high intensity of land use in horticulture farming. Grass cover increases from the lowest in the in the forest to the highest in the pasture fields. This is due to a combination of many factors i.e. reduced forest cover to specific land uses like dairy in the higher altitude areas. However, in the upper zones soil fertility is not a limiting factor to land use due to the ability of farmers to many farmers make inputs in form of animal manure and fertilizers. The number of shrubs crops decreases from upper midland to lower midland zones, giving way to increased herbaceous materials and grass cover. High pH promotes release of most plant nutrients like phosphorous although its level is low due to high levels of soil erosion and conducive environment for nitrogen losses through volatilization, leaching and fast decomposition of soil organic matter.

Effects of land-use type on large and small mammals

The diversity and abundance of small mammals depend on the complexity and diversity of the landscape itself. Our study in Embu Mbeere indicate that the species richness of small mammals related closely to the diversity of plant species, some of which constitute critical resources in terms of food and shelter. The intensification of land use was found to impact negatively on the resident plant community by altering species richness, plant cover regime and the related microhabitat interactions as new plant species become introduced or invade the modified sites. As a result, diverse number of small mammals species were unable to establish in sites that were undergoing intensive use.

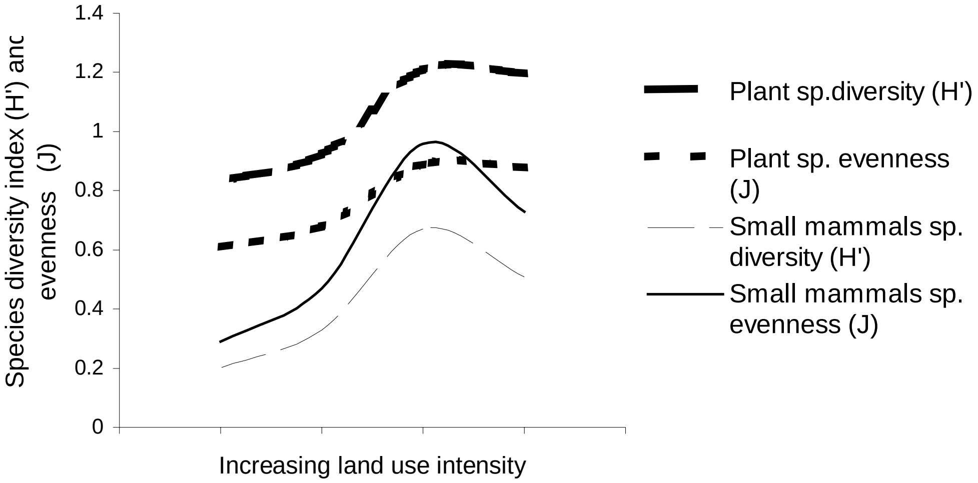


Figure 9. Shannon-Wienner diversity index (H') and evenness (J) of plant and small mammal species along a land use gradient during September 2001, in Mbeere District, Kenya.

2. How have the animal populations responded to the changes? Local extinctions, grazing in cropped areas.

Changes in land use in Embu Mbeere have almost eliminated wildlife due destruction of habitats and poaching. The only wildlife still present, are those that are pests on crops like primates and rodents (Mugatha, 2002, Mutugi, 2003). These remaining wild life are in constant conflicts with people due to destruction of crops. The primates are now confined to hills and riverine forests ehere there is less conflict with humans. Due to these conflicts a national reserve was established and fenced to keep the animals with in the park. The park is now with many animals ranging from elephants to antelopes.

Factors that led to wildlife declines in Mbeere District

Several factors may have led to drastic decline of wildlife and in some cases, to species local extinction. Some of these mammalian species used to be abundant in the area in the 1960s and before. The factors leading to mammalian declines in the area are mainly anthropogenic starting with the burgeoning human population early in the 1970s. Some of these factors are discussed below.

Human population increases

The district was scarcely populated by 1960s where for instance Mwea location had a population density of 10-19km^{-2}. Similarly, its sub-locations Gategi and Riakanau had a population of 16km^{-2} each (Van de Weg and Mbuvi, 1975). By 1979, Mwea location had tripled it population density to 59km^{-2} in approximately 20 years period (Jaetzold and Schmidt, 1983). The Mbeere communities were hunter gathers and cattle herder and had no or very little impact on wildlife and its habitats. In the later years, migration by other ethnic communities into the area predominantly occupied by Mbeere and Embu ethnic groups had become common and frequent. The main causes of these migrations were in search of land for subsistence cultivation. At the same time a few ranching schemes were established for instance the Mwea Ranching Scheme. This led to clearing of bushes and woodlands, decreasing the acreage available to wildlife. After the collapse of the schemes the ranches were subdivided for settlement driving wildlife out. A case in point is the Mwea ranching scheme where by 1989 there were a few remnant wildlife species for instance the kongoni, zebra and other plains game. None of these mammalian species are found here due to present human settlements. Currently, for instance in Makima location cultivation has extended from the riverbanks to marginal drier area. These activities have interfered with wildlife habitats to an extent where the adjacent area was declared a national reserve in 1975, to protect the remaining wildlife.

Satellite image analysis shows a general decline in land cover types in the two districts where for instance the areas under bush had declined by 27.3%, those under grasslands by 13.2% while areas under woodland had declined by 17.7% in a period of 14 years. These changes are also reflected in changes in landuse types over the same period. The land use types indicate that the areas under mixed bush/crops had increased from 420.9ha to 465ha while those under grazing land had decreased from 59.6ha to 36.7ha between 1987 and 2001. Information on land use changes is corroborated by changes in land use type within the same period. For instance as agricultural activities increased in the two districts, rainfed-mixed bush/cultivation and rainfed-wheat and pasture had also increased by 10.4% and 16% between 1987 and 2001 respectively. The two-landuse practices were mainly concentrated within the marginal areas of the districts where wildlife was plenty during the 1960s and 70s.

Poaching

Before 1914, the Mbeere district was scarcely populated. The human population gradually built up giving way to poaching and other wildlife malpractice. Hunting was a traditional activity before then but as the human population increased and land became scarce, hunting went beyond the subsistence level. In the later years poaching became a norm for professional commercial hunters climaxing in the 1970s and early 80s driving the rhinos to local extinction in this area. Although commercial poaching abated by late 80s, subsistence hunting continued wiping out some medium size mammalian species. Some of the mammalian specie wiped out were the lesser kudu, the bushpig and the kongoni, which were still common in the area up to late 1980s. The carnivores were a source of conflict with livestock herders and were mainly exterminated through poisoned allows and treated meat. At present only a few herbivore species are remaining in the reserve and hardly any carnivores at all.

Tree felling and land clearing

Population increase in Mbeere District resulted in a number of subsistence activities such as charcoal burning and clearing more land for agriculture. The two activities have since been increasing causing reduction to woodlands and other wildlife habitats. These environmentally exploitative activities were severe on government land where the people had no responsibility for the land's long-term productivity. The situation was made worse after the collapse of the cotton industry, which to an extent formed the main backbone of the communities' economy. Currently tree felling is putting more pressure around and within the conservation areas where woody resources are still abundant. This has cascade effect on wildlife species by interfering with their habitats hence reducing their numbers.

H. LIVESTOCK PRODUCTION

Effects of grazing on biodiversity

Table 7. Comparisons (t-test) between total and herbaceous species richness, biomass (gm^{-2}) between the enclosure and open site.

	Open	*Enclosure*	**p**
Total species richness	184	125.5	**0.03***
Herbaceous species richness	91.5	49.5	**0.03***
Total biomass	91.63	887.8	**0.04***
Herbaceous biomass	429.09	387.24	0.48

*Means significant difference at ($p<0.05$)

Table 8. Comparisons of % cover of growth form in enclosed and open sites.

Growth form	Enclosed	Open	p
Herbs	17.4	72.5	0.04*
Shrubs	62.5	40	0.04*
Trees	62.5	25	0.12

***Means significant difference at (p<0.05)**

Total species richness in enclosed and open sites were significantly different (p< 0.05). Higher species richness were encountered in the open site than in the enclosed site. Species richness in enclosures varied from 122-129 species while in open site it varied from 167-201 during the dry and wet seasons respectively. There were 93 and 18 plant species that were site specific in open and enclosed sites respectively. There was a significant difference in herbaceous richness between open and enclosed sites (P<0.05). There was no difference between herbaceous biomass in the enclosed and open site.

Table 9. Comparisons (t-test) of physical and chemical variables of soil between pen and enclosed sites

Variables	Open	Enclosed	P
pH	6.7	6.02	0.03*
Avail. P	17.37	24.72	0.229
Nitrogen	0.26	0.32	0.03*
Ex K	0.3	0.38	0.14
Ex Ca	4.5	5.76	0.159
Ex Mg	1.37	1.51	0.32
Ex Na	0.84	0.16	0.33
TOM	1.57	1.84	0.042*
% Carbon	8.65	15.91	0.036*
Sand	73.2	75.5	0.31
Silt	17.46	12.2	0.14
Clay	9.33	12.3	0.02*
Colour	3.3	3.9	0.08
Bulk density	1.81	1.46	0.002*
Moisture	1.1	5.32	0.03*

* means significant difference at P<0.05

Implications for livestock and crop-livestock livelihoods

The fragmentation and alteration of natural habitats into large areas of croplands has eliminated the option of free range grazing. Grazing is now in secluded patches of within individual farms. The situation has increased livestock density with the areas designated as grazinglands, which has subjected these areas to heavy forage utilization. The situation has led to increased competition between livestock production and crop production. There are two scenarios of change in relations to implications on livelihood. First there is shift from being predominantly livestock keepers to mixed crop-livestock producers. The second scenario is that among the crop-livestock producers, changes in economics of production has forced many to adopt to new livestock breeds that are able to pay off for the extract cost required in the changed management systems.

Most farmers in Embu Mbeere are small scale farmers and practice livestock keeping and crop cultivation. Livestock is seen by many as a bank and insurance for the farmer. Many farmers sell their surplus farm produce to buy livestock to keep(Bourn, and Maitima, in Press). In view of the trends in changes in land use livestock production is going to grow as a means of intensifying production in the declining land sizes. The livestock sector that may grow is dairy production because it requires less land and milk is a commodity that has market.

Impact of grazing on soil properties

Available phosphorous remains more or less constant in both the grazed and ungrazed plots, with an indication of possible decline in enclosed plots. Rock weathering may be the only significant source of additional phosphorous for range soils (Heady and Child, 1994). This uniformly low content is attributed to the fact that this element is stored in unavailable forms to plants Juo (1978) H_2PO_4 which becomes available to plants at low pH. It also suffers from fixation by hydrous oxides and silicate minerals. This element is doubly critical, because of low total amount and a very low availability.

Quantities of exchangeable cations were relatively low in both enclosed and grazed plots. The availability of the cations depends on the parent materials. This can be attributed to the fact that the soil in all the plots was more or less acidic with low pH values (Oba *et al*., 2000a). Except for calcium that showed a slight increase in the enclosed plots all the other nutrients remain relatively low. These inorganic nutrients are only made available through the active release of cations from the additional litter accumulating under the trees (Skarpe, 1991; Hatton and Smart, 1984).

There was an appreciable increase in organic matter content in the enclosed plots as compared to grazed plots. Organic matter and organic carbon are correlated within any single type and as the results indicate there was an increase in the amount of organic carbon in the enclosed sites. Similar finding are reported by Hatton and Smart (1984). This was expected in the enclosed site which was dominated by trees and shrubs which deposits litter on the soil. Through decomposition, the organic matter is returned to the soil and hence the percent carbon also increases.

Both temperature and moisture regime affects the equilibrium of organic matter contents of soils. Increased temperature decreases organic matter content while increased moisture increases organic matter (Sikora and Stott, 1996). Again in sites where there was no disturbance it is expected that the microbial activity and other decomposer populations would be more intense, and the role of these organisms as agents of litter breakdown and humus formation is well known (Skarpe, 1990).

There was a significant difference in the percent moisture content with a range of 1.4-6.6% and 0.2-3.8 % in enclosed and open site respectively. This can be attributed to the fact that the soils in the enclosed sites are not directly exposed to the sun due to the canopy cover which prevents evaporation rates. Litter deposition/accumulation from the trees and shrubs additionally keep soil covered most of the time and hence reduces heating of the soil which would cause the reserved water to evaporate. In addition, the shade from the trees and shrubs play a major role in moisture retention (Skarpe, 1991). Again, the high amount of organic matter in the enclosed site maintains the moisture at a higher level. In most cases grazing induces shortage of moisture, reduces infiltration rate and other nutrients and to some extent causes soil erosion.

Total nitrogen was higher in the enclosed site than in the open site. The increase in the total nitrogen is as a result of the increase in organic matter content of the soils in the protected sites. The low level of nitrogen content in the grazed sites can be attributed to low nitrate content which are easily lost through soil erosion (Belsky *et al.,* 1989). The total nitrogen is often a good indicator of the degraded rangelands and in this it indicates a higher level of land degradation in the grazed sites as opposed to the enclosed sites.

Bulk density was higher in the grazed plots than in the enclosed plots. The soils with high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. In the enclosed sites due to high proportion of organic matter the pore space is higher hence the low bulk density. The bulk density range in the enclosed site was 1.2-2.3 g/cm^3 while in the open site it was 1.3-3.0 g/cm^3. In the communal grazing sites grazing increases bulkiness of the soil through the soil compaction and hence the higher bulk density. Due to exposure of the soils in open sites the evaporation rate is high reducing moisture content and soil density changes with moisture content (Sikora and Stott, 1996).

The composition of the particle size assay was relatively uniform except slight variations in the clay contents. The high amount of clay content in the enclosed site can be attributed to the hydropower dam which spills off water during the rainy season to the adjacent enclosed site. This water is always carrying different types of soil which is eventually deposited in the study site. Again river Thiba that borders the study site is another potential source of clay soil. In general all the soils in both sites were either loamy sand or sandy loam.

There was no significant variation in the soil colour. In all the soil samples the hue (the dominant spectral colour or quality was consistently 5YR. The value (apparent lightness as compared to absolute white) varies significantly from 3-8. The chroma (the apparent degree of divergence from neutral grey or white) varies from 3-7. The general colour of the soil ranged from red to brown.

The comparison of the soil data from the grazed and ungrazed plots indicates nutrient enrichment of the soils in enclosed site, in part this could be due, to nutrient inputs by tree litter. On the other hand, trees transport nutrients from the surrounding surface and subsurface soils to their canopy and drop the nutrients in leaf and stem litter (Belsky *et al.,* 1989). 12 years of grazing exclusion can conclusively be said to be useful in relation to the soil properties whereby most of the nutrients are relatively higher in the enclosed site than in the open site. Poor nutrients content, is a symptom of land degradation in the open site. This was more pronounced in the plots which were falling in the more degraded area.

Low soil nutrients values indicates that natural process such as weathering are unable to replenish soil nutrients at a sufficient rate to replace those lost by the direct or indirect effects of grazing. Nitrogen and cation concentrations decline at a more rapid rate than can be explained by grazing effects (McIntosh, 1997). Processes like nutrient loss, continued grazing without nutrient inputs are unsustainable. To maintain or improve soil nutrient balance, new approaches to soil and vegetation management will be required.

From the ongoing discussion, the study results are consistent with the general pattern that pastoral development enhances richness of plant species at a local scale providing opportunities for increasers species to establish. Conversely, it has the potential to decrease it at a regional scale by removing the most grazing sensitive decreasers species from the regional species pool (Landsberg *et al.,* 2002). Those species, which were substantially less abundant in open sites than in the enclosed sites, were presumably the most sensitive to grazing overall.

Some plant species, such as *Andropogon greenwayi* and *Sporobolus ioclades* (*poaceae*) and *Indigofera cliffordiana* Herlocker (1999) and *I. spinosa* (dwarf shrub) have adapted to grazing and browsing to the extent that they depend on it for their existence (Oba, 1995). However, overgrazing reduces ground cover vegetation, plant height, forage quality and productivity. The impact of grazing on rangeland vegetation depends on three factors. First, the type of herbivores (grazers and browsers), secondly the number and type of animals utilizing an area, and lastly the distribution of use in time and space (Pratt and Gwynne, 1977). Cattle and sheep, which are primarily grazers and goats and camels, which are primarily browsers directly affect the herbaceous and woody components of the vegetation respectively.

Walker (1993) suggested that in arid rangelands lack of grazing is ineffective in inducing revegetation until the right combination of weather conditions occurs. Grazing has a greater influence on species composition, perhaps suggesting a better adaptation of vegetation of the study site to grazing as a result of the long association of plants and livestock and to some extent small mammals like rabbits and dik dik.

Long term grazing exclusion studies attempt to test the hypothesis that grazing causes degradation. Several studies comparing the effects of excluding grazing with those of continuous grazing have been conducted world wide, including in arid zones of sub-Saharan Africa, for more than a century. According to the current study grazing exclusion did not improve or increase range production any more than continuous grazing. This is because forage production is influenced more by rainfall than by herbivory. .

Areas of rangeland where grazing has ceased have been invaded with woody plants and a ban on livestock grazing in the rangeland would almost certainly result in the loss of this species-rich habitat. A similar trend was observed in the study site where grazing exclusion did not increase species richness though there was substantial increase in above ground biomass. The hypothesis that grazing history is the main factor determining plant community composition in the rangeland was supported by the species richness, vegetation cover and high level of organic matter and moisture contents because these factors are likely consequences of herbivory.

The forage yield of the grazed rangelands was significantly less than that of the ungrazed ranges in both seasons. The most interesting fact concerning the dried forage yields of the investigated rangelands was that the yield differences in the grazed areas for both seasons (i.e.dry and wet) were negligible. This lack of difference is another indication of the heavy and uncontrolled grazing taking place in the common grazing lands in both seasons. Heavy grazing would not allow the more palatable grasses to regrow during the growing period. Dried forage yield was appreciably different in the ungrazed areas between the seasons. This difference may be explained on the basis that the enclosed site is dominated by shrubs and trees which provide high biomass during the wet seasons. In the dry season most of them are deciduous and hence shed off their foliage parts giving low biomass.

Relationship between land management practices (tillage, use of fire, mulching) with soil fertility.

Mulching

The technique of spreading the crop residues or other materials on the surface soil is known as *stubble mulching* and was developed in Northern America originally as a defence against rain erosion in the grain-growing prairies. It was later used against rain-erosion, where it is equally effective as the surface mulch provides excellent protective cover.

Decomposition rates of used mulch material vary. It can take from a few months to several years for the material to completely disappear, depending upon chemical composition and climate (Anderson and Swift, 1983), in the lower zones decomposition is faster due to adequate temperature and moisture than upper zones where temperatures are relatively lower.

The decomposed organic matter fractions contribute to binding the aggregate structure of soils (improving root penetration, erosion resistance and water relations), increasing the exchange capacity in acid soils as is the case in the upper midland zones, reducing P fixation and aluminium toxicity.

Amount of grasslands, properties of mulch and soil organic matter fractions are an important buffer to seasonal variations and nutrient cycles, particularly when virgin lands are converted to temporary or permanent agriculture. Natural forests or contain a wide spectrum, of dead plant materials with different spatial and temporal patterns of deposition and different rates of decomposition. Hence, even in strongly seasonal environments with rapid decomposition rates, the high mass and varied composition of litterfall protects the soil surface throughout the year and promotes high soil organic matter content. Clearance of natural vegetation for arable agriculture changes the amounts and qualities of organic matter inputs into soils, soil temperature/moisture regimes, and biological process affecting mulch decomposition.

Use of fires.

The most common practice of changing the forest into food production involves slashing and burning the vegetation. The use of fire modifies the biological soil environment. When fire occurs, the temperature of the surface layers of the soil is raised. The actual heating rate and depth depends on the amount of moisture in the soil and the type of fire. Temperatures during the burn at the surface always exceed 100^0C and can reach as high as 720^0C for brief periods of time (Fehlberg, 1989). The temperatures are dependent on the type and amount of biomass and the moisture content, all of which influence the intensity of the fire.

The burning of the aboveground organic materials usually combusts most nitrogen and organic acid components, returning inorganic cations of the soil in the ash, which has a liming effect. The amount of liming effect depends on the intensity of the fire and the thoroughness of the burning. The hot temperatures can also greatly reduce the amount of organic matter in the upper layers of the soil. For example, at temperatures of $200\text{-}300^0$C for 20-30 minutes, there may be as much as 85% reduction in organic matter (Fehlberg, 1989). Generally, most of the abiotic effects are short-term in nature. Under ideal conditions, regeneration of the vegetation rapidly begins the process of recovery. However, frequent fires can lead to more lasting change.

Depending on the dryness of the biomass, the weather and the amount of biomass, burning is described as complete or incomplete. Soil organic matter (SOM) is affected by incomplete burning. SOM content in the top few cm decreases but addition from leaching of burned organic material may mask this process. As a result of these processes the carbon (C) content of the soil and the CEC may even be higher than before the burn. Burning may lead to increasing values of C, N, P, organic matter and CEC. The content of plant available P increases slightly after burning as a result of the partial destruction of SOM. The influence of burning of slashed vegetation on N content due to volatilisation has an important effect on soil nutrient supply. Gichuru *et al* (2003) reported that with medium burn temperatures (300^0-400C), the total N content of the top 2 cm decreased by 20-50% but that the ammonium content increased with lower temperatures of $200\text{-}250^0$C**.** In addition, burning may have a positive effect on the N cycle. Nitrifying bacteria responsible for NO_3 formation are partially inhibited in converting ammonium to nitrates. These changes result in increased soil fertility and improved conditions for crops.

Shifting cultivation

In shifting cultivation farmers cut and burn relatively small plots of forests or woodland and produce crops in the burned-over area. They grow crops on these plots for 2-3 years, until the nutrients are depleted and /or when weeds become a problem (Gichuru *et al* 2003). The farmers then abandon the plots for 10-20 years, allowing the forest species to re-grow and replenish the soil fertility. The farmers move on to slash and burn another forested plot and repeat the process. A farmer may shift in turn five to ten such small plots before returning to clear and burn trees in the first one that was fallowed 10-20 years previously and restart a new cycle. After a cropping period the land is abandoned and will be re-cultivated after its fertility is judged to be restored, or sooner if other land is not available.

Shifting cultivation has received a great deal of international attention because one of the suspected environmental consequences of the system is its contribution to global warming. It has been estimated that the tropical rainforests contribute substantial amounts of greenhouse gases from deforestation. Therefore, slash and burn agriculture could have global implications because of its contribution to these gaseous emissions as a result of the burning of the forests products and of the subsequent decay of trees and other unburned debris and soil organic matter. Furthermore, slash-and –burn agriculture causes disturbance, if not loss, of the biological diversity accumulated for over a long period. The maintenance of the multiple roles to play, which are increasingly being recognized, particularly in soil fertility management (Kotto-Same *et al*., 1997)

H. CONCLUSIONS

Vegetation varies significantly across the altitudinal gradient that characterizes the Embu Mbeee transect, mainly due to the different agro-ecological zones across the region. The upper zones are much wetter and are characterized by evergreen broadleafed forst species while the lower areas are characterized by dry savanna type of vegetation. Land use reflects a similar pattern ehere the upper zones are mainly used for commercial perennial cash crops and thelowere areas are used mainly for annual cereal crops. Livestock kept by farmers also varies from the predominantly diary production in the upper zones to the grazing of animals for beef in the lower zones.

With the upper zones are natural vegetation is almost entirely replaced by exotic in cultivated land but in the lowlands patches of disturbed natural vegetation still remains. Wood harvesting and charcoal burning in the lowland threaten the existence of the remaining natural trees.

Animal biodiversity is very rare in upper regions and where they occur they are only along the Mt. Kenya forest margin where they are protected. In lower parts of Mbeere there still exist some wildlife but mainly the pests like primates and small mammals that feed on the crops. The only place where wild animals are found is in Mwea National reserve.

The composition and distribution of small mammals is significantly affected by land use change. Conversion of natural vegetation into cultivated lands causes local extinctions of rare species of animals but increases the abundance of the more common species. The number native plant species decrease as cultivation or conversion from natural vegetation to farmlands increases.

All soils across all AEZ have inherent good soil fertility but do not receive (after continuous nutrient mining) adequate nutrient replenishment in form of organic manures or inorganic fertilizers or biomass transfer through agro-forestry or short fallow due to shortage of land per unit household. Soil productivity in the upper zones are constrained by acidity, which decreases as one moves to the lower areas. Although little production increase (in terms of hectarage) has taken place, this has led to cultivation of poor and marginal lands with the productivity of most existing lands has been declining.

With population continuing to increase there is need to reverse nutrient mining (Smaling 1988). Improving soil fertility could trigger rural and national economic development, achieve long-term food security and improve farmers' standards of living, while mitigating environmental degradation and rural migration. This could be done through participatory introduction of integrated nutrient management technologies (Gachimbi et al 2002, Onduru et al 2001). However, soil fertility and productivity enhancement has to be supported by policies with regard to credit facilities, produce and input prices and access to markets.

The diversity index (H') and evenness (J) of small mammal species increased with increase in heterogeneity of habitats, as exemplified by diversity of plant species in fallow and bushy sites. Diversity of plants relate to habitat complexity and perhaps function through modifying microclimatic conditions like humidity, temperature, shelter and availability of food favourable to the establishment of small mammal populations. However *Otomys*, one of the small mammal species that dominated cultivated sites, build nest below ground level in burrows. Consequently it may suffer lower nest damage and is sheltered from the effect of environmental change experienced by the surface nesting species after clearing. Nevertheless, such species may also have a narrow microclimatic range.

The findings of this study demonstrate that land use practices could have resulted in the destruction of shelter and elimination of subterranean and herbaceous plants species some of which comprise food sources for the small mammals species. Therefore, land use factors influences the diversity, distribution and abundance of small mammals with diversity declining in highly used sites.

There is need for urgent policy interventions to promote better farm management in Mbeere or the lower zones in general. These policy interventions should target prevention of soil erosion, promotion of more vegetation cover within the farmlands by planting of trees.

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