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

Regional synthesis paper: The linkages between land use change, land degradation and biodiversity across East Africa

LUCID Working Paper Series Number: 42

By

Joseph Maitima, [1] Robin S. Reid, [1] Louis N. Gachimbi, [2] Amos Majule, [3] Herbert Lyaruu, [4] Derek Pomery, [6] Simon Mugatha, [1] Stephen Mathai, [5] Sam Mugisha[6]

[1]International Livestock Research Institute; P. O. Box 30709. Nairobi, Kenya
[2] Kenya Agricultural Research Institute, P.O. Box 14733. Nairobi Kenya
[3]Institute of Resource Assessment, University of Dar Es Salaam, Box 35097 Dar Es Salaam, Tanzania
[4]Botany Department, University of Dar Es Salaam, Box 35097 Dar Es Salaam, Tanzania
[5]National Museums of Kenya, P.O. Box 40658, Nairobi
[6]Makerere University Institute of Environment and Natural Resources, Makerere University, P. O. Box 7298 Kampala, Uganda

June, 2004

Address Correspondence to:
LUCID Project
International Livestock Research Institute
P.O. Box 30709
Nairobi, Kenya
E-mail: lucid@cgiar.org
Tel. +254-20-4223000
Fax. +254-20-4223001

A regional synthesis paper:

The linkages between land use change, land degradation and biodiversity across East Africa

The Land Use change, Impacts and Dynamics Project
Working Paper Number: 42

By
Joseph Maitima, [1] Robin S. Reid, [1] Louis N. Gachimbi, [2]
Amos Majule, [3] Herbert Lyaruu, [4] Derek Pomery, [6] Simon Mugatha, [1]
Stephen Mathai, [5] Sam Mugisha [6]

[1] International Livestock Research Institute; P. O. Box 30709. Nairobi, Kenya
[2] Kenya Agricultural Research Institute, P.O. Box 14733. Nairobi Kenya
[3] Institute of Resource Assessment, University of Dar Es Salaam, Box 35097 Dar Es Salaam, Tanzania
[4] Botany Department, University of Dar Es Salaam, Box 35097 Dar Es Salaam, Tanzania
[5] National Museums of Kenya, P.O. Box 40658, Nairobi
[6] Makerere University Institute of Environment and Natural Resources, Makerere University, P. O. Box 7298 Kampala, Uganda

June 2004

Address Correspondence to:
LUCID Project
International Livestock Research Institute
P.O. Box 30709
Nairobi, Kenya
E-mail: lucid@cgiar.org
Tel. +254-20-4223000
Fax. +254-20-4223001

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.
.

ACRONYMS AND ABBREVIATIONS

AWF = African Wildlife Foundation
BOD = Biological Oxygen Demand
CBS = Central Bureau of Statistics
CIAT = International centre for Tropical Agriculture
CITES = Convention on International Trade in Endangered Species
COD = Carbon Oxygen Demand
DD = Data Deficient
E = Erosion
EA = East Africa
ESP = Exchangeable Sodium Percentage
FAO = Food and Agriculture Organisation
GEF = Global Environmental Facility
GOK = Government of Kenya
GTZ = German Technical Co-operation
H_2O = Water
ICRAF = World Agroforestry Centre
ILRI = International Livestock Research Institute
K = Potassium
KARI = Kenya Agricultural Research Institute
KEBS = Kenya Bureau of Standard
KEFRI = Kenya Forestry Research Institute
KWS = Kenya Wildlife Service
LH = Lower Highland
LM = Lower Midland
LMNP = Lake Mburo National Park
LUCID = Land use change, Impacts and Dynamics
MENR = Ministry of Environment and Natural Resources
N = Nitrogen
N/A = Not Applicable
NEMA = National Environmental Management Authority
NGO = Non Governmental Organisation
NSID = National Spatial Data Infrastructure
P = Phosphorus
PLE = People Livestock and Environment
PRSP = Poverty Reduction Strategy Papers
RELMA = Regional Land Management Unit
SAP = Structural Adjustment Programmes
SBA = Sango Bay Area
SOC = Soil Organic Carbon
UM = Upper Midland
UN = United Nations
UNEP = United Nations Environmental Programme
URT = United Republic of Tanzania
USDA = United States Department of Agriculture
WHO = World Health Organisation
WMES = Welfare Monitoring and Evaluation Survey

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Executive Summary

We summarize here over 30 years of research on the linkages between land use change, biodiversity loss and land degradation across a diversity of sites in Kenya, Tanzania and Uganda. We investigated these linkages from lowlands to high mountains, in a diversity of farming and herding systems. Please see over 40 individual site reports on the website, www.lucideastafrica.org.

Our principle findings are:

- **Farming, grazing and settlements have expanded at the expense of native vegetation over the last 20 years across East Africa.**
  Cultivation started in the middle zones and moved to upper zones in search of wetter and more fertile soils but now due to scarcity of land in the upper and middle zones more expansion is to the lower zones.

- **As native vegetation is lost, indigenous plant and animal biodiversity and plant cover are lost.** Many indigenous species, products of long-term evolution of these ecosystems, do not tolerate heavy land use by farmers, grazers and settlers. Indigenous plant species decline and exotic, common species increase. This means that availability of wild resources that people value, like food plants, medicinal plants, and other traditional plant resources is declining. Indigenous wildlife species have become fewer and fewer.

- **Sometimes, there are more species of birds, small mammals and plants in places where people used land in a moderate fashion**. This happened in grazed and cultivated areas in Kenya and Uganda. People can create new habitats for these species. However, in croplands, the new cover is often from prolific weeds with little economic or cultural value.

- **However, large mammals are universally lost as cultivation expands.**

- **Pastoralism maintains native plant and animal species more effectively than crop cultivation.** Pastures with moderate grazing support more plant species than un-grazed pastures. Some of the new species in grazed areas are weeds, but the majority are native plants. Pastoral areas are the only places outside protected areas that are still rich in large wildlife

- **As croplands expand, soil fertility and moisture drops and soils erode more easily.** Expansion of farms, pastures and settlements removes plant cover and replenishment of soil nitrogen, phosphorous, potassium and soil organic matter. Water in bare soil evaporates quickly. Bare soils loses fertile top soils through increased erosion.

- **As plant biodiversity falls, soil erosion increases.**

- **Soils in dry lowlands are less fertile and contain less organic carbon than highlands soils.** This suggests that these soils are more susceptible to land degradation.

- **As farming and settlement expands, less water is available for people, livestock, and wildlife. Irrigation for crops pollutes water sources,** increasing salinity and acidity as well as leaving behind high concentrations of residues from fertilizers and pesticides.

- **Farmers who grow many crops conserve native plant species better than those who grow only one crop.** Single cash crops demand more intensive land management compared to mixed cropping grown for subsistence by farm families. More intensive management is incompatible with high native plant diversity.

- **Land is heavily fragmented into small parcels in the highlands while dry rangelands are just beginning to be fragmented.** Intensification of land use and privatization of land are major causes of fragmentation.

- **Some farmers cope with land degradation by increasing crop diversity.** Increased crop diversity encourages regeneration of indigenous plant species.

- **Moderate farming in less forested areas is found to increase tree cover thus increasing the diversity of bird species**
  Farming in grassland, woodlands and bushland areas where there are fewer trees, increases the diversity of habitats due to introduction of agro-ecosystems that attract new species of birds. However, if the farming is intensified and the diversity of habitats is reduced the diversity of birds is also reduced.

- **Use of livestock manures and crop vegetative residues by farmers maintains more fertile and more productive farms**
  Farmers who combine livestock raring with cropping, use livestock manure to replenish soil nutrients in their farms and are thus able to maintain higher productivity.

2. INTRODUCTION

Expansion of cultivation in many parts of East Africa has changed land use and land cover. These changes are fueled by a growing demand for agricultural products that are necessary to improve food security and generate income not only for the rural poor but also for the large-scale investors in commercial farming sector. Food production in Kenya, for example, is reported to have increased steadily between 1980 and 1990, but because of population increase, the food supply in calories per head fell slightly during that same period (Lang 1995). Although this applies to the whole of sub-Saharan Africa, Uganda and Tanzania have never experienced severe food shortage due to favourable weather

Historically, humans have increased agricultural outputs mainly by bringing more land into production (Lambin et. al. 2003). Indeed, land conversion to agriculture in East Africa has outpaced the proportional human population growth in recent decades. Natural vegetation cover has given way not only to cropland but also to native or planted pasture (Lambin et. al. 2003). Also of considerable importance to land use change in East Africa is the expansion of urban centres. Between 1960 and 2000, urban population in Kenya has grown from 7% to 30% of the total population (Tiffen 2003). Many urban and peri-urban areas are heavily degraded.

During the last few decades the area under cultivation has more than doubled in Kenya and Tanzania, but in Uganda the change has been moderate (Olson et al. 2004). In Mbeere, Kenya, LUCID team member Olson (2004) reports that cultivation expanded 70% between 1958 and 2001, leaving only isolated pockets of forest and bush. Similarly, in Tanzania, LUCID team members Misana et al. (2002) report a significant expansion of cultivation in the Moshi area over the same period. However, in Uganda, LUCID team member Mugisha (2002) reports that agriculture only expanded in the drier rangelands, not in the wetter highlands. Land scarcity in the highlands caused farmers to intensify their land use (increase inputs per hectare) because there was little land available for extension of their farms.

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 (Lambin et. al. 2003). 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 (Kaihura and stockings 2003). 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 (Hoare 1999, Campbell *et. al.* 2003b, Western 1976; Wells and Brandon 1992).

Land use change has occurred since humans started to domesticate their own food resources and with better technologies, they became more and more able to alter or modify ecosystems to suit their own interests. It is well known that these alterations have direct effects on biodiversity (Maitima 1997). What is not known is what types of changes in land affect biodiversity more than others, how and which types of biodiversity are most sensitive to land use change, and when and how land use change leads to land degradation. It is possible that removal or absence of one or a group of organisms creates room for another that may be favoured by the change. When and why does land use change cause land degradation? Do changes in land use affect biodiversity differently in different spatial and altitudinal situations?

In this paper we report a summary of over 30 years of research generated by members of the LUCID team in East Africa. 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 report here the effects of different land uses in East Africa on biodiversity and land degradation by comparing the trends in multiple sites representing all major ecological production units in the region. 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.

2.1 Objectives

These investigations are aimed at contributing to the conservation of biodiversity and prevention of land degradation by providing useful instruments to identify and monitor changes in the landscape associated with biodiversity loss and land degradation. The tools will assist conservationists, researchers and decision makers including the GEF and other donor agencies in the design and implementation of multi-focal area projects. Work reported in this paper shows the linkages between land use change, biodiversity and land degradation so that land managers, policy makers and all involved in various aspects safeguarding sustainability of land production can understand the consequences of different land use practices.

2.2 Analytical framework

Definitions of land use, biodiversity and land degradation

Land use represents the human use of the land (for example, small-scale agriculture, grazing, wildlife reserves or industrial zones). ***Land cover*** represents the biophysical cover (for example, savannah, broadleaf forest, tea or built up areas). Clearly, there is some overlap in the description of land use and land cover. ***Biodiversity*** is defined by the Convention on Biological Diversity as "the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (http://www.biodiv.org/). In this project, we define biodiversity at both the species and ecosystem levels, recognising the importance of the genetic diversity that we did not measure.

The LUCID project adopted the U.N. Convention to Combat Desertification definition for ***land degradation,*** which is the definition adopted by GEF, is as follows:

> *Land degradation is a 'reduction or loss, in arid, semi arid and dry sub humid areas of biological or economic productivity or complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including process arising from human activities and habitation patterns such as: soil erosion caused by wind and /or water; deterioration of the physical, chemical and biological or economic properties of; and long term loss of natural vegetation.*

Figure 1 shows the general conceptual linkages that we will address in this paper. We will focus most of our attention on the one way linkages between land use change and biodiversity and land use change and land degradation, but we will also discuss the feedbacks of changes in biodiversity and land degradation on land use. We will also address the two-way linkage between biodiversity and land degradation.

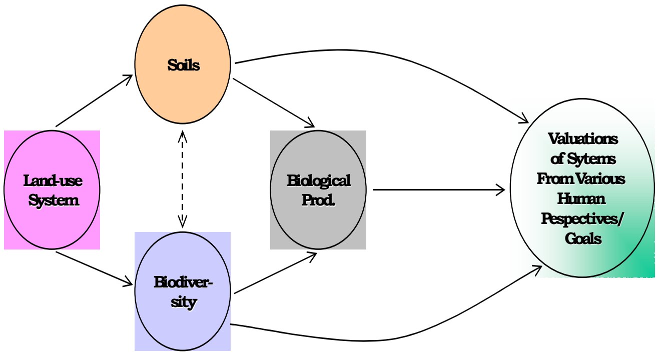

Figure 1. Conceptual linkages among land use, land degradation (represented by soils and biological productivity), biodiversity and human values used in this paper. (from Maitima and Olson 2001)

This simple conceptual model is made more realistic (and complicated) when we add some key concepts. The model fits into the 'environmental' part of the KITE framework that appears in our LUCID 'driving forces' paper (Campbell and Olson 1991; Campbell *et. al*. 2003). As such, one key concept is that these linkages differ depending on the ***spatial scale of resolution***. At the fine scale of an individual farmer's field, for example, declining soil fertility can reduce plant species diversity as farmers shift from coffee cultivation to maize in a single field, or from long fallows to short fallows. However, at the broader scale of the entire kihamba system of a Chagga family on Mt. Kilimanjaro, the loss of fertility and plants species in a maize field may be balanced, at the whole farm level, by increases in fertility and plants species numbers through integration of the maize with other crops and trees including Eucalyptus, in comparison to a farm with a maize mono-crop. At a broader scale, the juxtaposition of many different types of family farms may create very complex systems of small-holder farming that have very different consequences for biodiversity conservation and sustaining land productivity than large commercial farms that grow maize alone. Thus, in order to understand the emergent sustainability of the system, we must consider these linkages at several scales of resolution.

Second, we need to consider the concepts of **bi-directionality** of some of our processes. Just as land use does not always intensify over time (it can 'dis-intensify too, see Conelly 1994), we should not assume that intensifying land use universally causes land degradation and biodiversity loss. It is possible that expansion or intensification of human land use will result in expansion of forest in place of savanna (Fairhead and Leach 1996), more soil conservation methods (Tiffen, Mortimore et al. 1994) , and better grazing lands for wildlife (Reid, Rainy et al. 2001). Thus, we must allow (and search for) positive synergies between people, land and biodiversity, despite the many negative examples.

It is important to be clear that processes are often ***not linear*** and that one process can ***feedback*** on the other. For example, expanding croplands may have no affect whatsoever on the diversity of large mammals until the croplands prevent animal access to critical key resources (like the swamps in Amboseli) or key corridors (like elephants in the Kitendeni corridor on Kilimanjaro). This is a ***non-linear threshold*** effect, with the potential for rapid change in wildlife populations over short periods of time once a threshold is reached (Hoare 1999). This means that it is important to understand these linkage relationships over a wide range of circumstances if we hope to have reliable information to create robust scenarios for the future. In addition, feedbacks may also create unexpected connections. For example, while we recognise that land use clearly can affect biodiversity, we are less aware of the feedback between biodiversity and land use. For example, at our Kilimanjaro site, soil fertility loss in cropped fields leads people to plant *Eucalyptus* woodlots on old fallows, which may further deplete soil fertility as would any crop unless there are adequate inputs.

Finally, it is critical to recognise the ***dynamism*** of land use systems over time and that the speed of change can vary strongly from place to place and process to process (e.g., there are ***fast and slow*** variables). For example, a classic slow variable, climate change, will likely gradually change the relationship of land use and biodiversity in our sites, as some sites become wetter and others drier over the next several decades in East Africa. On the other hand, fast variables like sudden economic shocks (terrorism effects on tourism) or armed insurrection can completely alter the relationship between land use and biodiversity over the short and long term. In addition, some changes will be **cyclic**, with rises and falls in biodiversity over time that fluctuate around a general mean condition. Others will be directional (like climate change effects), causing great concerns that changes will be irreversible.

In this paper, we will summarise what we found with what is known about the linkages between land use change, biodiversity and land degradation by posing questions under five areas:

1. **Effects of land use on biodiversity:** What have been the long-term trends in diversity (wildlife) in East Africa? How and why do different types of land use change affect biodiversity? Are some types of biodiversity more sensitive to land use change than others?
2. **Effects of land use on land (and water) degradation:** How do changes in land use affect land degradation and what are the feedbacks?
3. **Linkages between land degradation and biodiversity:** How and why does land degradation (soil nutrient depletion and soil erosion) affect biodiversity (specifically plant diversity)?
4. **Linkages between land degradation and poverty:** Are there linkages between land degradation and poverty?
5. **Future viability of land use systems in East Africa**: What are the implications of changes in land use, biodiversity and land degradation for the future viability of different land use systems of East Africa?

2.3 Methods

In the LUCID project, the working definition of biodiversity is the variability and distribution of above ground, terrestrial flora and fauna species, both natural and human managed. An emphasis was placed on measuring vegetative species and ecosystem diversity, because changes in vegetation are more easily determined and are directly impacted by alterations in land use. Changes in habitat extent and fragmentation, vegetative composition and structure, and wildlife corridors were measured and interpreted in terms of their impacts on wildlife.

Indicators of changes in land use: Changes in land cover / use and habitat fragmentation were determined by remote sensing techniques and participatory studies to obtain the following:

- Changes in area covers for classical land cover and lands use types over time
- Changes in spatial continuity in ground area covers for different habitat types
- Human perceptions on general changes in the environment.

Indicators of changing biodiversity that were examined included:

- Changing availability of important plant resources (medicinal plants, wild food plants, plants used for handicraft purposes, pollen producing plants for bees) as noted by key informants.
- Comparison of flora and fauna in land use/cover classes representing different types and intensities of human use.
- Changes in habitat extent, distribution and fragmentation determined by interpretation of remote sensing data.

Indicators of land degradation that were examined included:

- Variation in the extent of soil erosion in different land uses.
- Variation in soil fertility measures in different land uses.
- Changes in crop productivity over time.

Methods used to link changes in land use, biodiversity and land degradation included:

- Comparing patterns of different land uses and the biodiversity measures from same sampling points.
- Comparing the numbers and abundance of indicator species for various forms of degradation.
- Comparing biodiversity measures with soil fertility measures and soil erosion indicators from the same site.
- Statistical comparison of the three sets of data sets.

3. SEQUENCES OF LAND USE CHANGE IN EAST AFRICA

The sequences of land cover/land use change in East Africa can be complex (Figure 2). We present two pathways of land use change that lead to biodiversity change and sometimes to land degradation. The first one applies to pastoral systems, in places that pastoral peoples modify wooded landscapes into more open landscapes with grass by burning. Pastoralists can change land cover in this way, but here, the changes are quite subtle, and pastures can quickly revert to bushland and woodland when burning ceases, or when cattle grazing is particularly heavy (around settlements and water points = bush encroachment). This sequence applies to the largest parts of East Africa, which are rangelands in dry areas. The second shows the changes that occur in the wetter lands when farmers convert land to cultivation, which applies to much less land area than the grazing lands in East Africa. However, we highlight these changes because they represent the largest impacts that people are having on the land. This schematic will help the reader interpret the evidence for the linkages among land use, biodiversity, and land degradation in the next sections.

1) Sequence sometimes applicable to pastoral areas without cultivation:

Woodlands → Bushland → Grassland → Pasture

2) Sequence applicable to wetter, cultivated areas:

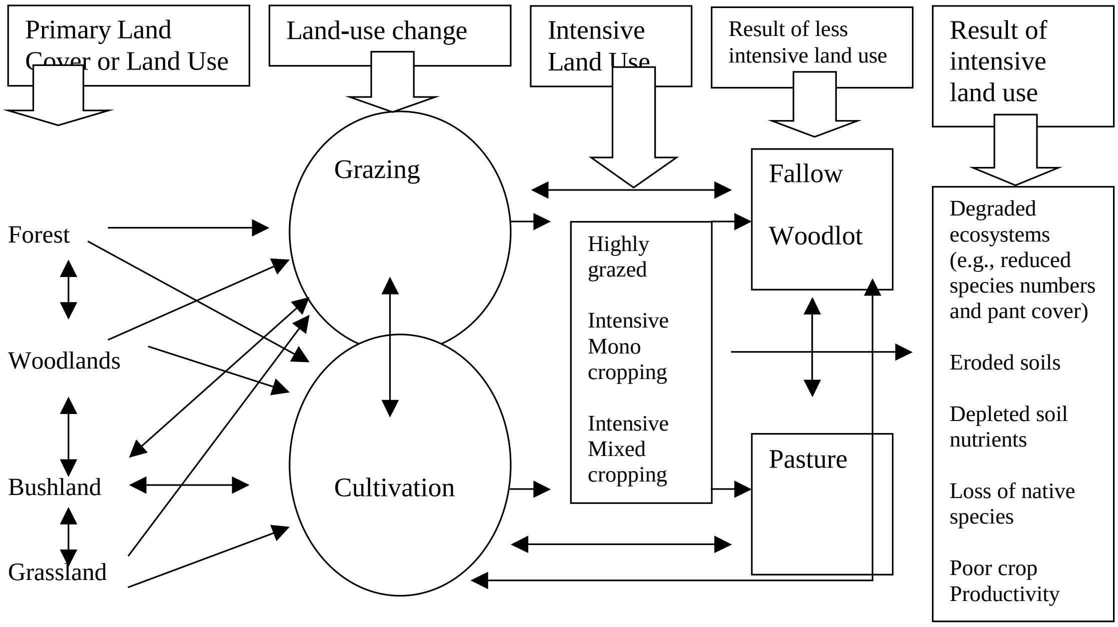

Figure 2. Two schematic representations of land use sequences in East Africa. The top sequence (1) is applicable to change in pastoral areas, the bottom (2), more complex sequences is applicable to wetter, cultivated areas.

4. EFFECTS OF LAND USE ON BIODIVERSITY

4.1 Trends in the biodiversity over time in East Africa

4.1.1 Methods

The method used to study changes in biodiversity over time was the collection of human perceptions of changes in their own environments. Individuals who were old enough to remember the appearance of their surrounding environment in 1950 were interviewed either individually or in group discussions. Structured questions guided respondents to recall different aspects of their environment. This method is explained in greater detail in the methodological guide prepared for use in the field (Maitima and Olson 2001) and the methodology synthesis paper also published in the LUCID working paper series (Maitima, *et. al*. in prep.).

4.1.2 Trends in wildlife diversity over time in East Africa

Wildlife diversity is generally on the decline across East Africa. In Uganda, expansion of farming around Lake Mburo and armed insurrection in Karamojong have caused strong losses in large mammals in the last 20 years (Lamprey and Mitchelmore 1996). Our data from interviewing local residents in Sango Bay, Rubaale and around Lake Mburo National Park supports these findings (Figure 3, LUCID team member, Nanyunja 2003). Her data suggest that residents perceive no decline in wildlife inside Lake Mburo National Park, but strong declines in Sango Bay and Rubaale. Aerial surveys of the same area show that many species of wildlife have declined strongly around the park, particularly impala (Lamprey and Mitchelmore 1996). Residents think the loss of wildlife in Rubaale started at least in the 1950's, with little wildlife left today. In Sango Bay, residents think wildlife losses started in the 1970's and that some wildlife are still abundant today.

Similar to Uganda, Kenyan wildlife is in strong decline. Between the 1970's and 1990's, most of the 17 rangelands districts lost over 50% of their wildlife (Said 2003). In the Mara ecosystem of Narok, 70% of the wildlife disappeared during this period (Ottichilo, de Leeuw *et al*.; Serneels and Lambin 2001). Wildlife in one district, Kajiado, has not changed, and in Laikipia, wildlife numbers have increased. 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, de Leeuw *et al*.).

In contrast, wildlife in Tanzania are only in decline in the wetter farming areas. Increased poaching from farmers and expansion of farming and settlement heavily impacts wildlife in the western Serengeti (Campbell and Hofer 1995). Just on the other side of this park in the pastoral areas to the east, wildlife populations appear to be healthy. Around Tarangire National Park, wildlife appear to be in decline, probably from overhunting and expansion of cultivation.

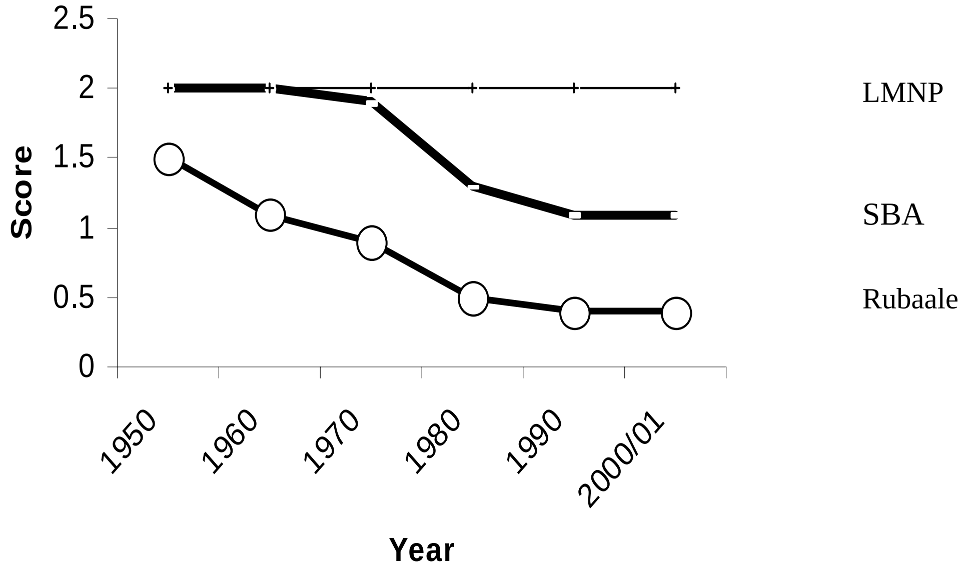

Figure 3. Trends in the relative abundance of wildlife species in Lake Mburo National Park (LMNP), Sango Bay (SBA) and Rubaale, Uganda. A score of 2.0 indicates that a species is common 0.0 indicates least abundant (from Nanyunja 2003).

4.1.3 Trends in economically useful plants over time in East Africa

Information from questionnaires in the three countries revealed that a number of plants are useful to people in many ways. People said they used plants for medicine, timber, fodder, and shade on the farm and in cultural rites. For example, there are herbal treatments for many human and livestock diseases that have been in use by many ethnic groups for many generations. The identity and distribution of these medicinal plants are very well known among the herbalists who make their living by collecting them (see Appendices 1 and 2 for lists of plant uses).

Interviews of groups or individuals specialized in gathering and trading these economically useful plants revealed that there has been a tremendous loss in plant biodiversity over the last half century (Figure 4, Nanyunja 2003). This observation was consistent across all our sites in Kenya, Uganda and Tanzania (Nanyunja 2003, Misana 2003, Wangui 2003). Plant diversity has also been lost in all agro-ecological zones, although at different magnitudes depending on the intensity of land use in each area. This trend of loss in plant biodiversity is associated with the intensification of land use and privatization of land, which serves to fragment ecosystems. In Uganda, a comparison of plant diversity in protected and non-protected areas shows that humans are responsible for the disappearance of medicinal plants in their neighbourhoods that are still present in nearby Lake Mburo National Park (Nanyunja 2003). This selective removal of plant species, often accompanied by poor methods of removal, has created disturbance leading to or contributing to fragmentation of ecosystems. Generally, the diversity of medicinal plants was highest in the uncultivated land with scrubland having the highest density. Elsewhere, medicinal plants are already on the verge of extinction and therefore there is an urgent need to promote the conservation of these species wherever they occur.

Fragmentation of land (as seen by different patches of contrasting land cover side-by-side) is more noticeable in the lowlands than in the high altitudes, only because the land in the highlands has already been completely fragmented, forming large contiguous blocks of cultivated land. In the highlands, population pressure is high and almost all available land is cultivated while within the lowlands, land is still available and continues to attract investors from the highly populated, wetter areas. Clearance of vegetation for cultivation targets areas where land is suitable for agriculture based on soil fertility, proximity to water resources and infrastructure like roads. This situation has been reported in all study sites (Misana *et al.* 2003, Ntiati 2002, Campbell 2003, Mugisha 2002).

4.2 Effects of current land use systems on plants

4.2.1 Effects of livestock grazing on plant species diversity and biomass

Unexpectedly, there were 50% more plant species, a higher diversity and a more even distribution of species in grazed than in un-grazed sites in Embu, Kenya (Tables 1 and 2; Kamau 2004). On the other hand, biomass and shrub cover were greater in sites with no grazing. In our other sites, pastures (planted and native) supported more weeds than other land uses and only occasionally were homes to plant species of conservation value. There were significant differences ($p<0.05$) in pH, organic matter, percent carbon, total nitrogen, moisture, bulk density and percent clay between the grazed and un-grazed plots. Except for the pH and bulk density that was higher in grazed area the rest were all higher in the closed un-grazed area. Livestock grazing appears to reduce competition for resources between different plant species, thus increasing the number of species that can co-exist in grazed sites compared to areas with no grazing (Kamau 2004).

Table 1. Total number of plant species, herbaceous (grasses and herbs) species, and total plant biomass (gm^{-2}) between grazed and un-grazed sites. * Means significantly different at ($p<0.05$), t-test.

	Grazed	**Not grazed**	**p-value**
Total species numbers	184	125.5	0.03*
Herbaceous species numbers	91.5	49.5	0.03*
Total biomass	**91.63**	**887.8**	**0.04***
Herbaceous biomass	**429.09**	**387.24**	**0.48**

Table 2. Comparisons of percent plant cover of different growth forms in grazed and un-grazed sites. *Means significantly different at ($p<0.05$), t-test.

Growth form	**Grazed**	**Not grazed**	**p-value**
Herbs and grasses	72.5	17.4	0.04*
Shrubs	40	62.5	0.04*
Trees	25	62.5	0.12

4.2.2 Effects of cropping, settlement and native vegetation on plant species numbers and cover

Detailed information on the number and cover of plant species in each land cover and land use type appears in Appendix 3, while weed status among types is in Appendix 4 at the end of this report. In general, there was very little native vegetation at any of the sites, so it is not possible to compare the effects of farming, grazing and settlement on native plant diversity in vegetation that is used less intensively by humans. The comparisons here are thus between moderately used places (forest, woodland, bushland and grassland) and places heavily used by people for various activities (pasture, fallow, woodlots, mono-crops, poly-crops, annual crops, perennial crops, settlement).

In general, Kilimanjaro stands out as the place where people, through intensive agriculture, encourage high plant diversity in perennial, croplands with many crops (perennial poly-culture). These farms often supported more species than nearby woodlots, bushland or pasture (Appendix 3). About 50% of these plant species were weeds, but this is actually lower than many of the land use types that supported fewer species (Appendix 4). These systems thus appear to be relatively bio-diverse and support a significant number of indigenous species.

Embu, Kenya, is remarkable because annual croplands (with either single or multiple crop species) often supported the most species and certainly more than the forest and woodland plots sampled (Appendix 3). However, these croplands were more than 90% weeds. Other, less used areas, like woodlands and grassland, had fewer species, but more than 50% of these were natives. This means farming is not diversifying the flora here, natives have been lost, and invasive species are common.

In Uganda, farming systems are dominated by plantain plantations. These plantations support few plant species and the few they do support are more than 75% weeds (Appendices 3 and 4, more details below in section 4.3). Woodlands and bushlands support more species and few of these (<20%) are weeds. Thus, these sites are similar to those in Embu and are examples of farming practices removing biodiversity.

In Loitokitok, Kenya, just on the other side of Kilimanjaro from the Tanzanian transects, a somewhat different picture appears, depending on the zone. Here, the middle zone is similar to Embu: annual croplands support the most species, but nearly all these are weeds. Less used forest, bushlands and woodlands have fewer species, but 75% of these are natives. However, in the lowland pastoral areas, we find 50% more species than any other site we sampled and more than 55% of these are natives. This is the one dominantly pastoral site we sampled and suggests that pastoral land use heavily conserves native plant species compared with upland farms, with the exception of the perennial farms on the Tanzanian side of Kilimanjaro, which are quite diverse.

Our findings indicate that cultivation affects the numbers and cover of plant species. In Embu and Loitokitok sites in Kenya, 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 (Tables 3 and 4). 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 was found to vary while in Loitokitok there was no variation. 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 3. Results of a two way analysis of variance for plant species richness and percentage cover in various land uses in the upper, middle and lower zones of Embu Mbeere (from Maitima et al 2004)

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*

* *Indicates significance at P < 0.05 (comparing between land uses within the indicated zones)*

Table 4. Results of a two way analysis of variance for plant species richness and percentage cover in various land uses in the upper, middle and lower zones of Loitokitok, Kenya (from Reid et al 2004)

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 (comparing between land uses within the indicated zones)*

4.2.3 Effects of mono-cropping and mixed cropping on plant diversity and abundance

In Tanzania, species diversity was low in monoculture and high in poly-culture systems (Figure 4). The observed loss of biodiversity in monoculture could be partly due to management practices in monoculture systems. In many if not all monoculture systems, production is market-oriented, although on a small scale, markets demand high quality products. To maintain high quality products and good harvests, farmers have to manage the crops more closely by not allowing weeds to establish, ploughing more regularly and applying more efficient techniques like use of oxen in weeding and tractor or oxen in tilling the land. The most common monoculture crops are tea, coffee, cotton and horticultural crops grown mainly in irrigated lands. On the other hand, mixed farming systems are not heavily market-oriented, and those products that are sold are sold locally. In these mixed farming systems, farm management is less intensive. This therefore gives room for weed growth, and maintenance of some native species, thus increasing the overall diversity of plant species and improving plant cover.

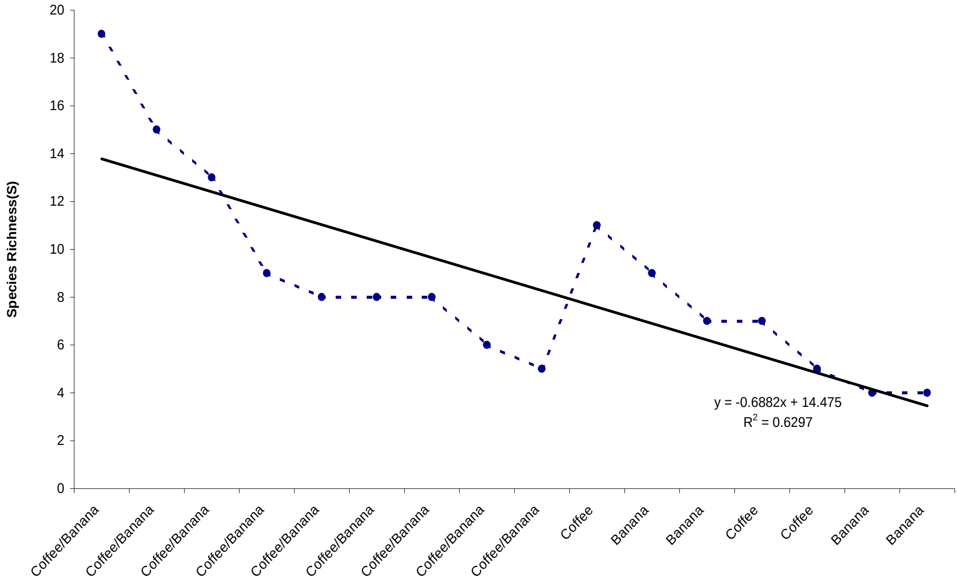

Figure 4. The effects of many crops (poly-culture, highest at left end of the bottom axis) and single crops (mono-culture, highest at right end of bottom axis) on the number of plant species along the Mbokomu transect on Mt. Kilimanjaro, Tanzania. (from Lyaruu 2002)

However, except for tea and maize, much of the land that was formerly under monoculture crops, like cotton (across East Africa) and coffee (in Kenya and Tanzania), is now being converted into mixed cropping because of poor international market prices for coffee and cotton. Also, many farmers are changing from mono-crop to another mono-crop in many parts of East Africa. An example is the change from the traditional coffee farming system to horticulture as a result of the high market prices for horticultural products. Farmers are uprooting coffee and replacing them with tomatoes, green peas, onions, cabbages, and sweet potatoes in Kenya and Tanzania (Lyaruu 2003). Generally, vegetable farming requires high amounts of agricultural inputs such as fertilizers and pesticides that consequently have detrimental effects on the plant biodiversity. Also the practice of using blue copper (copper sulphate) and thiodan in coffee farms has an effect of increasing soil acidity and consequently favoring certain groups of plants (Table 5). For example, the dominance of the weed *Oxalis corniculata* throughout the coffee/banana zone may be an indication of the acidic conditions of the soil.

4.2.4 Effects of grazing, cropping and settlement on plant species of conservation value

In the context of this work, we consider species of conservation concern as any species which fall in any one of the following categories: endemic species, overexploited species that are threatened (e.g., species used for timber), species with a narrow range of distribution, medicinal plants that are harvested in a destructive manner, species difficult to propagate and keystone species. An example of keystone species are fig trees, which have fruits all year round and are important cultivated fruit crops. Among the timber trees, *Olea welwitschii*, *Cordia africana* and *Albizia gummifera* were overexploited where they occur. Although two of the cited trees are coffee shade trees, they are declining in number due to timber production. Such species decrease in number as one moves from the highlands to lowlands.

On the issue of sustainability of harvesting medicinal plants, the harvesting mode is not sustainable because harvesting often involves de-barking of the individual plants or removal of the roots. This kills trees and could be disastrous when the species is very rare. *Erythrina abyssinica*, *Grewia burtii*, *Lannea stuhlmannii* and *Terminalia sericea* are the four species most affected by this unsustainable harvesting. Such species could be grouped under CITES categorization as data deficient (DD) species, since they are becoming overexploited in their natural habitats all over the region and the amount remaining in the natural habitats is unknown.

Our investigations indicate that land use change reduces the number and abundance species of conservation concern. The strongest evidence to support this is seen in the analysis of the impacts of land use change on birds in Uganda (Pomeroy et. al. 2002) and plants (Lyaruu 2003; and Maitima et al. in prep) in Tanzania and Kenya respectively.

We strongly recommend that intensive studies be carried out for all those species that are likely to disappear in the near future. Such studies should include an assessment of their ecological and silvi-cultural aspects, and also to confirm their distributional patterns in the region. Such data could be used in future to update CITES records.

Table 5. Percentage of species of invasive, rare, endangered and threatened plants in different ecological zones in Kenya (Loitokitok and Embu/Mbeere) and in Uganda. (a table showing percentage cover by weeds and the dominant weed species is shown in appendix 4)

SITES	**ZONE**	**Land use cover**	**Invasive**	**Threatened**	**Endemic**	**Endangered**	**Rare**
LOITOKITOK	Middle (UM) zone	Pasture	4.80%				
		Annual mono-crop	3.30%				
		Annual mixed crop	0.80%				
		Settlement	4.50%				
	Lower (LM) zone	Woodland		1.10%			1.10%
		Bushland			0.70%	0.70%	
		Pasture		1.20%			1.20%
		Annual mono-crop	1.10%				
EMBU MBEERE	Upper (LH) zone	Forest			6.70%		
	Middle (UM) zone	Woodland	8.30%	8.30%			
		Woodlot		3.10%			
		Pasture	3.40%				
		Fallow	1.40%				
	Lower (LM) zone	Woodland	5.60%				
		Pasture	13.00%				
		Fallow	4.40%				
		Annual mono-crop	2.20%				
		Perennial mono-crop	4.30%				
UGANDA	Sango bay = higher rainfall at 1500 mm	Grassland					0.80%
		Perennial mono-crop	4.90%				
	Ntungamo = moderate rainfall at 900 mm	Woodland	4.50%				0.40%
	Lake Mburo = moderate rainfall at 850 mm	Perennial mono-crop					6.20%

4.3 Effects of land use on bird species diversity and conservation value

We only sampled bird species diversity in Uganda. The number of bird species is much lower in plantations of tea, sugar and cotton than in mixed farming systems in Uganda (D. Nakwanga and D. Pomeroy, personal communication). In addition, land use change reduces woody canopy cover, and at the same time alters the composition of woody plant species so that weeds replace natives. Birds species depend on the disturbed habitat for food and shelter. Reduction in their habitats therefore forces the species to migrate to other areas permanently. This has been demonstrated from our study (Figure 5) in Uganda (Pomeroy *et. al.* 2003). The data shows that loss of tree cover strongly reduces the diversity of birds.

There is a paradox here, however. When farming in less forested systems, farmers can actually increase tree cover, thus increasing bird species diversity {Wilson 1997,). Birds not only flock to trees planted on farms but also to the rich grain crops grown by farmers. Thus, farming does decrease bird species in forested systems, but can increase habitat for birds in grasslands, bushlands and sometimes woodlands.

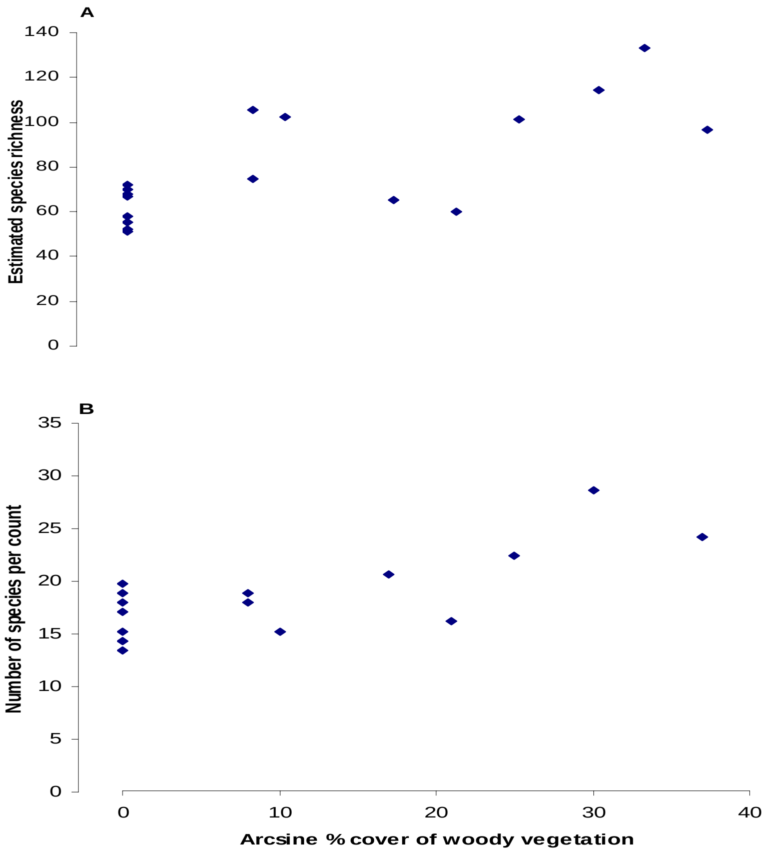

Figure 5. Effects of woody canopy cover on bird species numbers in Uganda (Pomeroy et al 2003).

A comparison between Lake Mburo National Park (LMNP) in Uganda and the surrounding grasslands found that changing land use through cultivation has a profound effect on the occurrence of flowering plants. The study confirmed that cultivation removes most of the native species, replacing them with more common weeds and non-native plants (Appendix 3 and 4). It was also found that cultivation can support quite large numbers of plant species: for example, of 115 species recorded at the LMNP sites, 28 also occurred in the cultivated areas, which included banana plantations, areas of cassava, and fallow land. But only 15 of these can be considered as native to the area, in the sense that they also occurred in the nearby natural vegetation. Of those

15, only four were woody species, the rest were all shrubs. Results from the LMNP and Rubaale areas were similar. One of the woody species at LMNP that was found in both natural and cultivated areas was the common weed, *Solanum incanum*. As would be expected, the majority of plants in cultivated areas are either for food, or they are weeds. In either case their contribution to the conservation of biodiversity is negligible, since almost all of these species are widespread in tropical Africa and sometimes throughout the tropics.

Pastoralism maintains native plant and bird species more effectively than crop cultivation. Studies in Uganda indicate that the average numbers of species of both plants and birds are higher in pastoral than cultivated areas, and within pastoral area they are higher in woodlands than in grasslands. Bird species numbers in pastoral areas as a whole (mean values 73 (93)) are higher than for LMNP. Well-wooded sites hold more species than do open grasslands. For example, the estimated species numbers of three pastoral sites studied in the Sango Bay Area arranged in decreasing order of woody vegetation cover was found to be 112, 102 and 66 respectively indicating that the lower the woody cover the lower the species numbers (Pomeroy *et. al*. 2003). A similar trend is apparent for the natural sites in LMNP, and for overall means of wooded and grassland sites in the pastoral areas. A detailed account of this analysis is presented in Appendix 4.

4.4 Effects of land use on small and large mammals

Increasing the intensity of land use to moderate levels increases the diversity of species of small mammals due to the increase in habitat diversity. However, as land use further intensifies, species diversity of small mammals decrease as habitats start to simplify into large blocks of cropland without intermittent patches of native vegetation (Figure 6). Our study in Embu/Mbeere, Kenya, indicates that there are more small mammals where there are more plant species, and then both plants and small mammals decease in tandem as land use further intensifies.

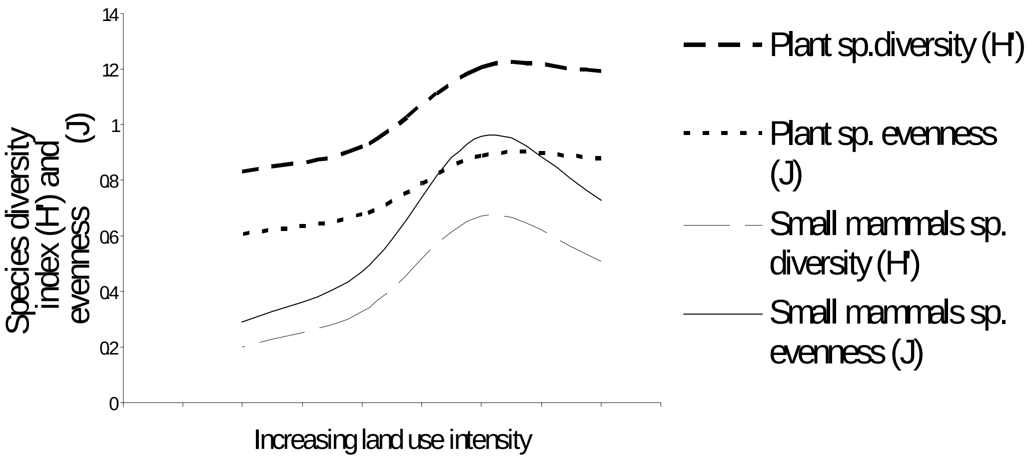

Figure 6. Shannon-Wienner diversity index (H) and evenness (J) of plant and small mammal species along a land use gradient during September 2001, in Mbeere District, Kenya (from Mumbugua 2002)

Land use change has had a large impact on large mammals in areas outside the protected national parks and reserves. Our LUCID work in Kitendeni wild life corridor (Noe 2003) shows big declines in animal numbers and animal types due to an increase in cultivation and sedentary settlements that have interfered with animal movement. In Embu and other areas, where cultivation and human settlements densities are high, wildlife has disappeared entirely except for the pests like baboons that exist in forest remnants along rivers and around hills (Mutugi 2003).

4.5 Effects of excision of key resources on wildlife diversity and abundance

Land use change has profound effects on key resources upon which wildlife and livestock depend. Our study in Amboseli has shown that human settlement is partly responsible for reduction in availability and quality of water resources leading to a decline in vegetative resources and wildlife. Creation of protected areas for purposes of wildlife conservation tends to limit animal movement by confining them within the park. Depending on the size of the park and the population of wildlife in the park, availability of key resources like feeds and water resources may diminish which may have negative impacts on wildlife.

Land use change alters the interactions of people and wildlife. This is very well demonstrated in Loitokitok where cultivation around the swamps has blocked access to water for wildlife and increased contacts between wildlife and people. Our study has shown that wildlife are generally attracted by the presence of water, but presence of people around water point tends keep animals away (Worden et al. 2003, Ogutu et al. in press).

Land use change impedes wildlife movements. Studies on the effects of land use change in a wildlife movement corridor on the slopes of Mt. Kilimanjaro, has shown an increase in animal numbers along the corridor due to increase in cultivation on the outskirts of the corridor. This has resulted into an increase in human-wildlife conflicts (Noe 2003). A similar observation has been made on the Imenti forest of Mt. Kenya, which also serves as a corridor for wildlife movement to and from Mt. Kenya (Gathara 1999).

5. EFFECTS OF LAND USE ON LAND (AND WATER) DEGRADATION

5.1 Long-term trends in soil nutrients in East African soils

We have observed a remarkable decline in soil nutrients (also described as a decline in soil productivity) due to deterioration of chemical, physical and biological properties. The main reasons for the decline, besides soil erosion, are: 1) decline in organic matter and soil biological activity, 2) degradation of soil structure and loss of other soil physical qualities, 3) reduction in availability of major nutrients (N, P, K) and micro-nutrients and 4) increased toxicity, due to acidification and salinisation (FAO 1983, Gachimbi 2002).

The decline in soil productivity in most cultivated soils in East Africa leads to yield declines (Nyathi *et al.* 2003). This decline in yield has been attributed to the loss of plant nutrients through plant removal, erosion, leaching and deterioration of soil physical conditions (Okigbo and Lal 1979). Further observations indicate that soil organic carbon, and major plant nutrients, e.g., potassium (K) and phosphorous (P), are the soil properties most affected by cultivation over time (Smaling *et al.* 1997).

Farmers in the study areas perceive an increase in soil erosion and a decline in soil fertility as the main constraints to crop production (Gachimbi *et al.* 2003; Thomas *et al.* 2003). Farmers in all the countries perceive shallow soils and poor water retention as additional problems. A comparison of soil fertility trends in the study sites is summarized in Table 6 below. The decline in soil quality is common in all the three countries, but dramatic in Kenya and Tanzania, where nutrient levels (SOC, P and K) have sunk to very low levels since the 1980's. K and pH levels fell in Kenya, probably because of the use of sulphur- based fertilizers in tea fields in the upper zones. The reasons for this depletion are many and varied as exemplified above and made worse by removal of subsidies in fertilizer in 1980s and poor agronomic practices. Rates of nutrient depletion also vary according to soil properties, with the sandy soils in Kenya sustaining higher losses than the predominantly clayey soils in some study sites as observed elsewhere (Sanchez *et al.* 1997, Jager *et al.* 2001).

Table 6. Soil fertility changes in continuously cropped East African soils.

Country	Temporal variation of soil chemical properties (0-20 cm)							
	SOC%		P (mg/kg)		pH-H_2O		Exch. K (cmo_c/kg)	
	<1985	2002	<1985	2002	<1985	2002	<1985	2002
*Kenya Andosols	3.7	1.84	31	8.08	4.6	5.35	0.77	0.32
Tanzania ** (*Andosols*)	N/A	0.97	N/A	59	N/A	5.1	N/A	0.35
Uganda *(Andosols)*	N/A	1.51	N/A	3.50	N/A	5.30	N/A	0.19

** Braun 1975: ** Values for ≤ 1985 soil data from natural forest average representing bench mark soil (Majule 2003) and* ***N/A****. No available data.*

5.2 Effects of land cover and land use on soil chemical and physical properties

Soils in areas with continuous cultivation without appropriate management practices have low fertility levels due to over utilization (Majule 2003, Gachimbi 2003). A detailed description of soil fertility levels in different land use / land cover types in Kenya, Tanzania and Uganda are presented in Tables 7 and 8 below.

Table 7. Linkages between land cover/land use and soil fertility Kenya and Tanzania across an altitudinal gradient.

Country	Major land use types	Major Soil Chemical Properties: Upper zone [a,b]					Middle zone [a,b]					Lower zone [a,b]				
		pH (H_2O)	*P**	*SOC%*	*K†*	*Erosion*	*pH (H_2O)*	*P**	*SOC%*	*K†*	*Erosion*	*pH (H_2O)*	*P**	*SOC%*	*K†*	*Erosion*
Kenya	Forestry	4.0	6.0	6.55	0.22	E0						-	-	-	-	
	Woodland											8.0	049	3.29	2.98	E0
	Bushland						6.43	57.33	0.87	1.51	E2	6.6	1.9	0.06	0.66	E0
	Grassland						6.4	12.7	61.46	1.44	E2	8.1	37.3	1.1	1.4	E1
	Woodlots	4.4	13.6	2.11	0.2	E1	6.6	13.6	3.39	1.34	E1					
	Pasture	4.7	16.2	4.27	0.7	E0	6.3	3.4	1.47	0.78	E1					
	Fallow						6.5	3.6	1.47	0.94	E2					
	Cultivation						5.85	11.05	1.19	0.88	E1	6.4	22.5	0.87	1.33	E2
	• Coffee	4.6	14.2	2.22	0.5	E1										
	• Maize/beans	5.3	7	1.92	0.66	E1	4.6	4	1.35	0.63	E2					
	• Tea	4.1	8.8	4.08	0.17	E0	4.1	21	1.88	0.24	E2	6.7	1.9	0.65	0.5	E2
Tanzania	Forestry	4.8	105	1.50	0.33	E0	-	-	-	-		-	-	-	-	-
	Woodland	-	-	-	-	-	-	-	-	-		-	-	-	-	-
(*Andosol*)	Bushland	-	-	-	-	-	-	-	-	-		-	-	-	-	
	Grassland	4.8	105	1.50	0.28	E0	4.9	19	1.15	0.33	E0	5.9	100	1.30	0.29	E0
	Woodlots	4.7	127	2.25	0.32	E2	3.8	5	1.25	0.31	E0	-	-	-	-	-
	Pasture	4.0	82	2.73	0.18	E0	-	-	-	-	E0	-	-	-	-	-
	Fallow	-	-	-	-	-	5.7	45	1.30	0.34	E0	5.1	12	3.50	0.35	E1
	Cultivation															
	• Rice	-	-	-	-	-	-	-	-	-		3.5	14	0.70	0.36	E0
	• Maize/beans	-	-	-	-	-	-	-	-	-	E1	5.7	178	1.70	0.36	E1
	• Tea	4.7	112	2.5	0.27	E0	5.2	169	2.0	0.34	E0	-	-	-	-	-

P;available P in mg/kg; K † exchangeable K in Cmol$_c$/kg; a; Agro ecological Zonation in Kenya (Jaetzold and Schmidt, 1983) ; b; Agro ecological Zonation in Tanzania*

Soil –critical values (Mehlich et al 1964): P (ppm)= 20 ppm: K = 0.2 %: SOC = 2%

Table 8. Linkages between land cover/land use and soil fertility in sites in Uganda.

Country	Major land use types	Major Soil Chemical Properties: Ntungamo				Ntungamo				Lake Mburo			
		pH (H_2O)	*P**	*OC%*	*K†*	*pH (H_2O)*	*P**	*OC%*	*K†*	*pH (H_2O)*	*P**	*OC%*	*K†*
Uganda	Forestry	4.0	6	6.5	0.22	-	-	-	-	-	-	-	-
	Woodland					-	-	-	-	8.0	049	3.29	2.98
	Bushland					-	-	-	-	6.6	0.6	0.66	0.26
	Grassland	4.7	38.7	3.73	0.8	5.2	5.2	1.78	0.14				
	Woodlots												
	Pasture												
	Fallow									5.1	4.3	1.38	0.2
	Cultivation					5.5	5.9	0.9	0.18				
	• Coffee	5.4	3.7	1.89	0.09	7.0	7.0	1.17	0.14	6.0	6.0	1.68	1.10
	• Maize/beans	5.3	9.6	0.79	0.78	5.7	5.4	1.88	0.18	5.6	3.2	1.56	0.78
	• Coffee/banana	6.0	18.2	1.06	0.03	5.6	2.6	2.5	0.03	6.3	7.8	1.5	0.65

There have been changes in land use/cover associated with expansion and intensification of agricultural activities to the semi-arid areas and even in high rainfall areas (Mugisha, Misana 2004, Olson 2004, 2003, Nyathi *et al.* 2003, O'Kting'ati and Kessy 1991). These changes have a significant impact on soil chemical degradation. Clearing the natural forest in most parts of the upper zones for cultivation has contributed significantly to reduced levels of SOC, N, P, and K in the soil. Reduction in soil nutrients and acidification has forced farmers to abandon their fields and have converted them into woodlots dominated with Eucalyptus spp., usually planted for the purpose of demarcating field plot boundaries and to provide shade to coffee plants. The effects of individual land use/cover types on soil degradation in East Africa is presented in Tables 7 and 8 for Kenyan, Uganda and Tanzanian soils. Indicators of land degradation used to assess land degradation include soil nutrient levels and evidence of observed soil erosion features and crop performance assessment by farmers (Rowell 1993, Majule *et al.* 1997, FAO 1983). An assessment of the few key chemical soil fertility indicators (soil pH, SOC%, available P and exchangeable K) revealed a variation associated with different land use categories. There is a marked decrease in soil fertility levels in cultivated fields compared with non-cultivated forest, woodlot, grassland etc.

Soil pH increases from the upper high land zones of East Africa to the lower zones and ranged from extremely acid to near basic. Low pH as in the upper zone restricts availability of plant nutrients and thus crop choices as shown in Table 7 from tea, maize, beans and coffee in Kenya. In the middle zones the soil pH is near neutral, which is optimal for wide range of crop growth. In the lower zone, extreme soil acidity was only observed in the soil in wetlands or paddy cultivation; otherwise, the other areas experienced near neutral pH value. Low soil pH in this case is probably due to nitrogen transformation associated with flooding of rice fields (Rowell 1993). Phosphorous (P) is low in upper and middle zones and high in lower zones and its amount varies with land use and length of use. Severe degradation in woodlots (middle and low zones) as well as in rice fields in Tanzania and pasture land are good examples of phosphorus depletion. Potassium is not a major limiting factor in East Africa soils due to inherent soil properties.

The amount of soil organic carbon (%) in the upper zones in Kenya is adequate in agronomic terms (Mehlic *et al.* 1964) and inadequate in other regions of Tanzania and Uganda. It is high in soils under tea, coffee, bananas, woodlots and pastureland due to prevailing management practices. Type of soil, coupled with moderate temperatures and available moisture in the upper zones, allows slow decomposition/mineralization of organic matter. Organic carbon contents in similar land use types found in the middle and lower zones declined where environmental factors favours fast decomposition of organic carbon. In the lower zone of slopes of Mount Kilimanjaro in Tanzania, there is a marked regeneration in soil organic carbon in soils under pasture and maize/bean cropping, respectively, due to application of animal manures and crop residues, prevention of leaching through mulch application and terracing to prevent soil erosion.

All soils across East Africa have inherently good soil fertility. However, in many areas, they do not receive adequate nutrient replenishment to compensate for continuous nutrient mining through grazing, crop harvesting or erosion. This replenishment could come in the form of organic manures, inorganic fertilizers or biomass transfer through agro-forestry or short fallow or an integration of these technologies. The ability of farmers to combine livestock raising with cropping activities is important to increase manure availability. In order to increase farm incomes, intensification and diversification of crop enterprises is important due to small land holdings in some of these areas.

5.2.1 Effects of grazing on soil properties

Grazing increases the bulk density and moisture content through compaction and exposure of the soil to the sun, but reduces most soil nutrients through feeding and subsequent erosion due to the reduced ground cover. The soil analysis results are presented in the Table 9 below compares soil chemical properties in a grazed area (open) and ungrazed area (enclosed). Grazed sites were higher in soil pH and lower in bulk density, nitrogen, moisture content, percent organic matter and organic carbon than un-grazed sites (P<0.05).

Table 9. Physical and chemical properties of soil between grazed and un-grazed sites (t-test). (from Kamau 2004)

Variables	Grazed	Un-grazed	p-value
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

5.2.2 Effects of irrigation on the salinisation of soils

Most of the irrigated areas in East Africa show signs of soil salinity. Most of the farmers in cultivated lands are realizing a drop in productivity as a result of increased salinity of the soil (Ntiati 2002, Githaiga *et al*. 2003). These areas are likely to be abandoned in the next 5-10 years or farmers will change to other crops. This is confirmed by a study of soils in cultivated lands indicating a high exchangeable sodium percentage (ESP) of strongly sodic' soils and a sodicity hazard (Touber *et al.* 1983). The swamps acts as sinks for salts (pollutants) washed out of higher elevation soils by rainfall and irrigation water. Despite some outflows from swamps, solutes accumulates in the 'sumps' of the hydrological systems rendering the water, and soils on swamp margin, unsuitable for cultivation (Southgate and Hulme 1996).

In irrigation schemes, farmers need to increase their protection of crops using pesticides, because permanent water bodies tend to favour the proliferation of pests such as insects, snails and birds. In Kenya, there is liberal application of pesticides with the farmers blending several pesticides in the hope of maximizing protection for the crops. The applied chemicals are finally washed into the water bodies after water application in the fields, contaminating downstream water bodies and ecosystems.

5.3 Effects of land cover and land use on soil erosion

Land use/cover, soil type, slope, slope length and rainfall amount and intensity influences the rate of soil erosion in an area. Classes for identifying the severity of observed erosion in an area have been established by FAO (1983). Erosion intensity was assessed in different zones and land uses within the study area (Table 10). Erosion classes are as follows: E0= no visible evidence of soil erosion or slight sheet erosion, E1= slight to moderate sheet erosion (or shallow rills), E2 = moderate to severe sheet wash soil erosion, and E3 = severe erosion with gully development. Soil erosion in Kenya and Tanzania was common in the three major agro-ecological zones but varied with land use type and in severity. In the upper zones, despite high rainfall amounts and intensity, soil erosion varied from slight to severe in forest, woodlots and cropped land. This is due to high rainfall amounts and steep slopes and some use of soil conservation structures. In the middle zone, there was slight visible erosion in Tanzania and moderate sheet wash in Kenya. There is increased evidence of gullies in the lower zone than in the upper zones with sheet wash being dominant. Observed soil erosion in the lower zone particularly in the land under bushland, grassland, fallow and maize/beans is probably due to soil physical properties. The soils vary from sandy to sandy loam and there are no appropriate soil and water conservation measures (Thomas *et al.* 2003). Variable levels of soil erosion observed in different land uses is due to different levels of conservation management practices implemented by individual farmers especially in cropland. Farmers need to create favourable conditions to prevent soil erosion (e.g. terracing, trash lines etc).

Table 10. Percent erosion classes within AEZ's along the Embu-Mbeere transect (from Gachimbi 200 2002 a)

Zone No.	AEZ	E0	E1	E2	E3
1.	TA	10	0	0	0
2.	LH1	40	25.7	22.8	11.4
3.	UM1	57.7	23.1	11.5	7.7
4.	UM2+3+4	45.4	30.15	13.4	21.9
5.	LM3	35.7	57.1	7.1	0
6.	LM4	23	30.7	7.7	38.5
7.	LM5	14.3	35.7	14.3	35.7
Class					
EO	No visible evidence of erosion or very slight sheet wash.				
E1	Slight- moderate sheetwash. Shallow rills affecting less than 10% of plot.				
E2	Moderate- severe sheetwash. Rills affecting 10-25% of plot.				
E3	Moderate- severe sheetwash. Gullies or rills affecting 25-50% of plot.				

5.4 Effects of land use on water quality

Changes in land use strongly reduced the quality and availability of water in the Amboseli swamps of Kenya (Githaiga *et al.* 2003). The study results show (Appendix 5) that land use has negatively impacted water quality and water is less available. Indicators of various water quality parameters from the different land use systems in Loitokitok were studied to investigate the changes in water quality associated with land use types.

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 uses types.

There was an increment in nitrogen nutrient concentrations from irrigated farms and from livestock as well as 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.

5.5 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 community structure, loss of communities dependent on water and establishment of salinity tolerant plant species. Water diversion and abstraction are already impacting on water availability and plant community structure especially in Kenya.

In the Mt. Kilimanjaro area of Loitokitok, the diversion of virtually the entire Nolturesh River flow to Kitengela horticulture farms 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* trees and Acacia had dried due to the water diversion (Githaiga *et al.* 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*.

5.6 Effects of land degradation on farmer crop choices

In Tanzania and Kenya, there has been an expansion of pastureland in areas where soils are very poor (Majule 2003, Gachimbi 2002, Nyathi *et al.* 2003). As a result of decreased soil fertility, one of the coping strategies adopted by farmers includes the introduction of new crops adapted to degraded soils. The farmers also institute integrated nutrient management strategies in rainfed agricultural areas including introduction of salt-tolerant crops, e.g., cowpeas, pigeon peas or onions in irrigated systems due to problems of salinization. Further, there have been some changes in settlement patterns in the study areas so that people are moving from high to low potential areas replacing grazing land with cultivation (Herlocker, 1999).

6. LINKAGES BETWEEN BIODIVERSITY AND LAND DEGRADATION

6.1 Effects of soil chemical and physical properties on plant diversity and cover

6.1.1 Effects of soil erosion on plant species numbers

Analysis on the effects of soil erodibility has shown a strong negative correlation between soil erosion severity and plant species numbers (Figure 7). Soil erosion tends to alter the natural habitat of certain species leading to their loss. Farms with more erosion are poorer in plant species in Tanzania. Soil erosion reduces soil fertility and water availability to the plants due to removal of the fertile topsoil that is vital for the growth of different plants species. Removal of vegetation on land through various factors such as tree harvesting for timber and building poles and conversion of natural vegetation to farmland, has a significant impact on the number and distribution of species available. On the other hand, the introduction of exotic woodlots and expansion of farmland has contributed significantly to accelerated soil erosion and loss of species.

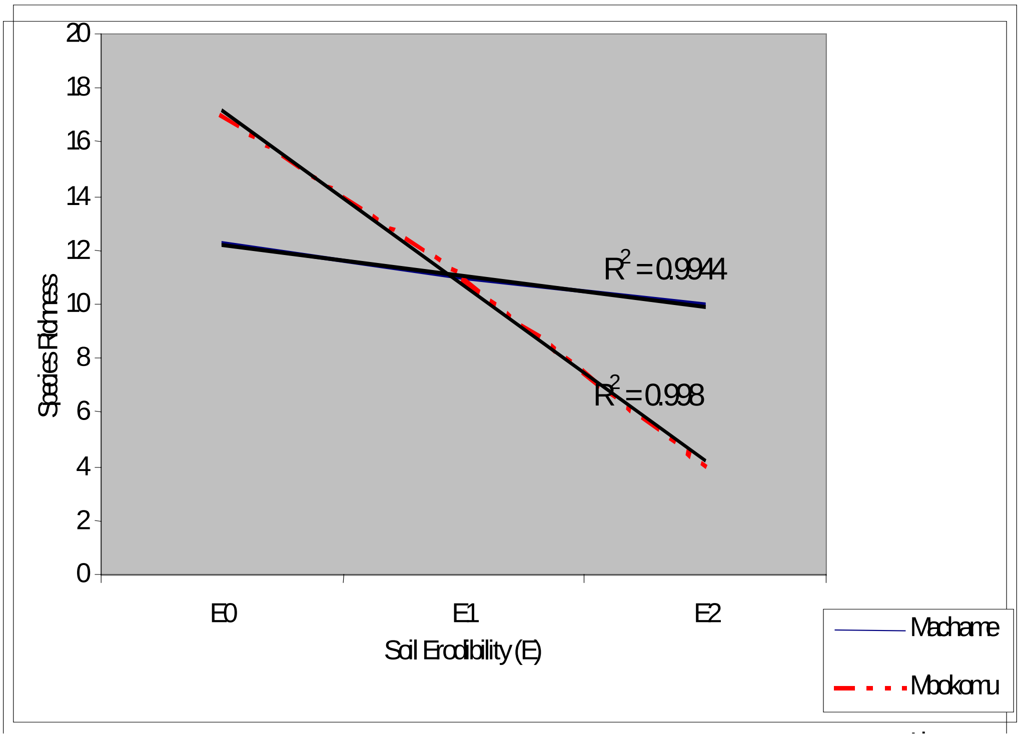

Figure 7. The effects of soil erodibility on species numbers in Tanzania (Majule 2003).

6.1.2 Effects of changes in vegetation cover on soil fertility in different land uses

Reduction in vegetation cover reduces the amount of soil organic carbon in the soil (Figure 8 and 9). 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.

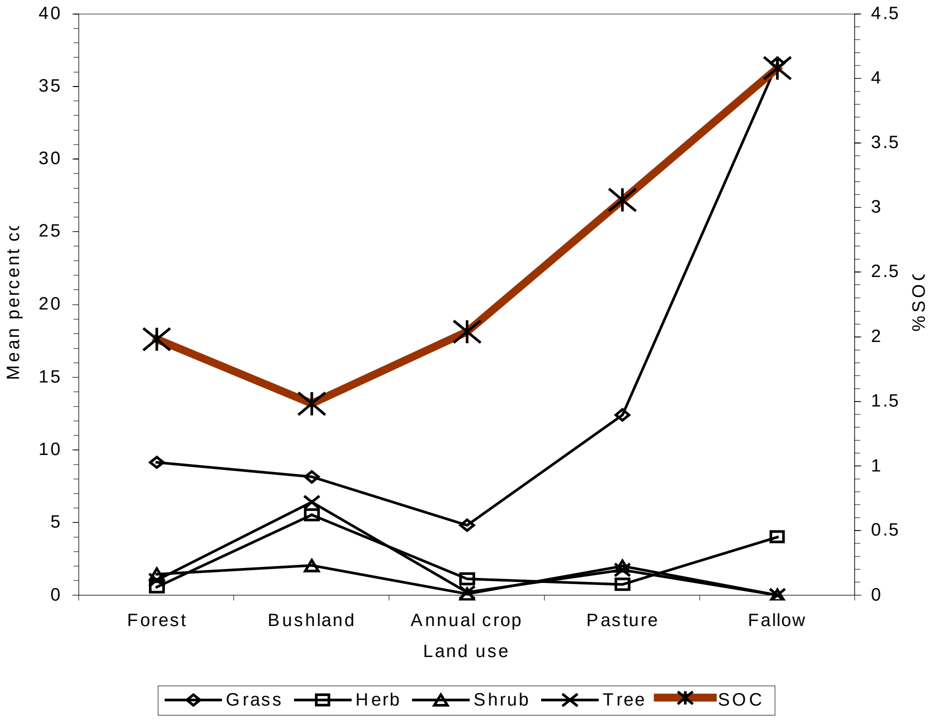

Figure 8. The relationship between soil organic carbon and mean percent cover of different vegetation categories in different land uses in the upper zones of the study sites in Tanzania.[2] (from Majule 2003)

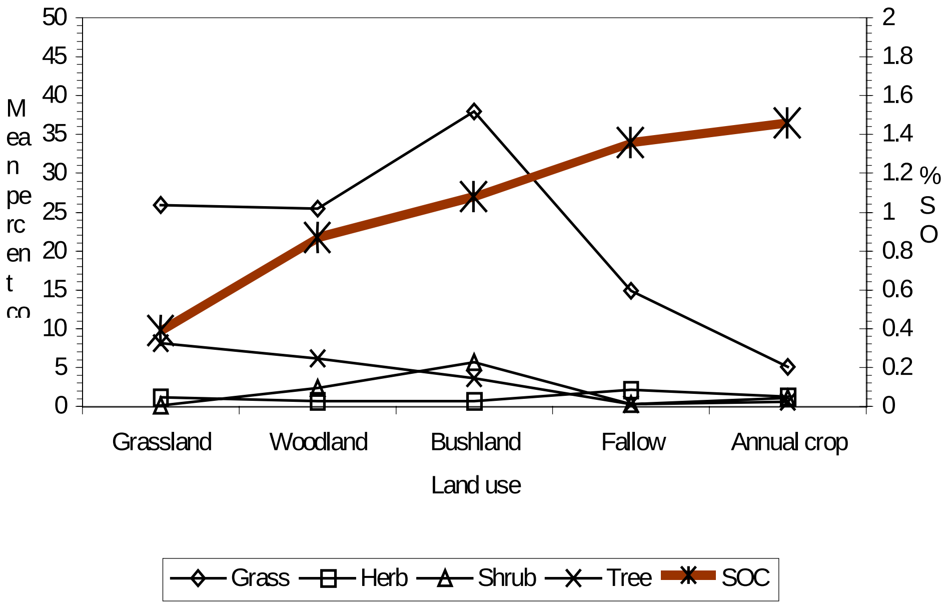

Figure 9. The relationship between soil organic carbon and the mean percent cover of different vegetation categories in different land uses in the lower zones of the study sites in Tanzania (from Majule 2003).

---

[2] Note the variation in vegetation cover between the upper and lower zones and the corresponding changes in soil carbon content.

6.1.3 Effects of soil nutrients on plant species composition
Soil characteristics affect the distribution of plant species. The relationship between soil characteristics and plant species composition can be used as an indicator of soil productivity. Poor soils tend to have certain specific plant species. For example, in the coffee/banana zones of Tanzania, the low plant species diversity and the poor soil conditions due to intensive land management favours *Oxalis corniculata*, *Bidens pilosa*, *Senecio abyssinica*, *Setaria homonyma*, *Digitaria scalarum* and *Launea cornuta*. Also common are some cultivated crops such as *Ananas comosus* (pineapple), *Helianthus annuus* (sunflower) and *Carica papaya* (pawpaw).

7. LINKAGES BETWEEN LAND DEGRADATION AND POVERTY

7.1 Effects of poverty on soil fertility
Our studies have shown that areas with poor soils have higher poverty levels. Generally, within the regions, better houses are located in the upper and middle land zones where as we have shown in this report that soils have higher levels of nutrients. More assets including good houses, good schools, churches, vehicles are owned by people living in the upper zones than people in the lower zones. In the lower zones, poor farmers are not able to purchase farm inputs like fertilizers that would help to restore soil fertility. Despite the inability to purchase fertilizers, the poor farmers offer for sale crop residues and manure produced by their livestock in order to generate cash. The problem of nutrient transfer in the form of residue particularly maize from the low potential area (lower zone) in Kilimanjaro is a serious problem. Most of the fields located in the lowland area are rented to people living in the upper or middle zones. Soon after harvests of maize, beans and sunflower, nearly 80% of residue is harvested and transferred to the upper zones for the purpose of feeding livestock. Those without livestock tend to sell residues to cattle owners whose animals are grazed. The rest of residue in most farms is grazed in the farms by the livestock. The situation is the same in Kenya.

There is a lot of debate going on in Tanzania with regard to soil fertility degradation over time. A number of studies conducted in the country at farm level have indicated that there is a serious problem of declining soil fertility and this affects rural crop productivity (Majule 1999, URT 2000). Major causes of soil fertility decline are many ranging from political factors such as changes in agricultural policies such as removal of subsidies from fertilizers in late 1980's(www.fao.org/ag/agl/swlwpnr/reports). Constant removal of soil nutrients through crop harvests, organic residue transfers, vegetation clearing and poor agronomic practices. Other factors are natural such as poor inherent soil fertility of most soils. In the slopes of Mount Kilimanjaro, declining soil fertility has also been reported to be a problem despite having naturally fertile Andosols.

7.2 Conversion of dry season grazing areas to farming and lack of access for pastoralists
In the recent past, there have been adequate water resources in the Amboseli area in Kenya for domestic consumption, livestock watering and for wildlife. The associated riparian areas and swamps were favoured as dry season grazing areas for the pastoral community and refuge for wildlife during drought periods. However, land use in the area has undergone rapid changes with an increased tendency towards sedentarization of the pastoral community and the introduction of irrigated horticultural agriculture along the rivers and within former swamps. Due to poverty, fertile plains around the swamps have been targeted for cultivation and water availability has provided ideal opportunities for irrigated agriculture. Large areas of the swamps have been cleared, reclaimed and converted to irrigation fields, growing onions, tomatoes, maize and other horticultural crops. The high value crops grown require intensive use of pesticides, which eventually find their way into the streams affecting water quality. The competing demands for water resources, and the incidental human wildlife conflict for the highly nutritious crops has led to the erection of solar powered electric fences around agricultural to exclude wildlife from watering points.

7.3 Sand mining on Kilimanjaro by smallholder miners

Sand mining is a major non-agricultural income generating activity in Kilimanjaro and Mbeere area in Tanzania and Kenya respectively. Based on field observation, there has been an expansion of sand mining activities particularly in the middle zones. Sand mining takes place along the rivers causing land degradation particularly soil erosion. Mining of stones particularly volcanic tuff , which is very common in the middle and lower zones. This provides materials for construction in the better cash endowed upper zone and the ever expanding urban centres. Major reason for engaging in mining activities includes income generation especially due to the fact that returns from agriculture is low (Mbonile, 2003; Gachimbi *et al* 2003).

8. IMPLICATIONS OF LAND DEGRADATION AND CHANGING BIODIVERSITY FOR THE FUTURE VIABILITY OF LAND USE SYSTEMS

The livelihoods of the people living in East Africa depends largely on agriculture for food production and income generation (GOK 2002). Other economic activities include exploitation of forestry products and tourism and employment in available agro based industries. Due to endowment of fertile soils, high rainfall and suitable climatic conditions for cropping and livestock keeping, there has been development of agriculture in the three countries and around Mt. Kilimanjaro over the past 150 years (Misana 1991). The rising population has contributed to the subdivision of land to uneconomically small units, the reduction of fallow periods and continuous cultivation, leading to the rapid depletion of soil nutrients, declining yields and environmental degradation. For example in Kenya, lower agricultural zones with poor rainfall are sparsely populated with an average of 90 people per square km while highland zones are densely populated with 600 people per square km (CBS, 2000). Increase in population in many agricultural areas and the declining access to land for many will bring profound changes in the farming systems in East Africa. Some of the areas where change might occur include: -

Increase in irrigated agriculture:

This will include commercial enterprise type of technology in drier areas and wetlands in the region and use of ground water system. Common soil degradation problems associated with irrigated agriculture include salinization, water logging, nutrient constraints under multiple cropping associated with imperfect marketing infrastructure and supply of production inputs and finally biological degradation due to blanket excessive use of agro-chemicals.

Increased livestock production in mixed farming and pastoral areas e.g. Loitokitok and Embu area in Kenya.

Livestock management is a major activity in the study area with 93.0% of the respondents in Tanzania keeping livestock (URT 2002). The number of cattle kept differs from one household to another ranging from 1-5 tropical livestock units (Gachimbi *et al.* 2003). The dominant livestock keeping practices in the upper and middle slopes is zero grazing or semi zero grazing. The major reason for such practice is land scarcity, which doesn't allow free range grazing. Most of the livestock kept in the upper zones are crossbreed cattle while in the lower zones are traditional stocks. Common degradation problems in the system issues in the areas include: - soil erosion; slow and low soil nutrient depletion; removal of natural vegetation perennials from landscape; soil compaction, physical degradation from cultivation and acidification

8.1 Implications of wildlife policy on land and biodiversity conservation

8.1.1 Wildlife policy

Wildlife is the property of the Kenya government and the same applies in the other East African countries. 65-80% of Kenya's wildlife is outside the National parks on communal land reserves and in private land (Elliot and Mwangi 1997). Kenya wildlife service (KWS) is charged with the management of wildlife, which includes protection and regulation of how it is used. Current wildlife utilization policy allows for non-consummative use i.e. tourism and ecotourism except for birds where game bird hunting is allowed. The policy also assumes natural regulation of wildlife populations. There is no programme for population control in Kenya.

Due to lack of a defined fence between national parks and communal land resources, land use conflicts between national parks, private and communal farmers are common as wildlife disperses into their lands (Western 1976). Farmers derive no or very low benefits (Muthiani 2001) from wildlife in most cases. Wildlife also makes it difficult to the farmers to allocate resources optimally because he can only control his livestock and wildlife has no real economic benefit. Wildlife has in most cases led to overstocking in grazing fields leading to vegetation degradation. On the other hand, the landowner can decide to deliberately clear/remove wildlife from his land, and this eventually may lead in the long run to reducing species diversity. The scenario is almost similar in fenced/isolated national parks or reserves. Wildlife build up without population control may lead o overstocking as has been observed in Nakuru National park. This in the long run leads to change in the vegetation composition and structure (Mwangi 1994). Soil compaction, soil erosion and nutrient mining through gazing and bush or weed encroachment also accompany overstocking. In other cases some wildlife species are suppressed and if not checked may lead to local extinction of the species.

8.2 Implications of linkages for policy

8.2.1 Land management policy

In Uganda and in the other countries in the 1900s, a series of land agreements between the British Government and various local kings and chiefs created new systems of tenure based on landowners and tenants (Egulu and Ebanyat 2000). In 1950s land was placed under the state management. This put customary tenants in a very insecure position as they were now regarded as occupiers of crown land from which they could be evicted. Many farmers were indeed forced off their land, as it was common for politicians and government officials to grant themselves leases of large tracts of land regardless of its occupants' customary rights. This decree was reversed in Uganda by the 1995 constitution, which vested all land in the citizens of Uganda and recognized customary tenure rights to land (Walaga *et al.* 2000). In 1998 a new land act was approved decentralizing the administration of land and offering better protection for tenants (Republic of Uganda 1998). The aim of the 1998 Land Act is to strengthen security of tenure for tenants and customary landholders, whose legal ownership is to be recognized by the issue of land certificates. The 1998 Act in Uganda is also intended to bring into production some of the agricultural land that is presently not being used.

Land administration and planning policies and legal instruments in Kenya have had a bearing not only on the management and development of the land resource but also on the productivity of the agricultural sector. However, the policies have not been clear and had problems with implementation according to the Government of Kenya (GoK, 2004). There is no comprehensive land policy covering use and administration, tenure and security and delivery systems of land in Kenya. This has resulted in low investment in the development of land leading to environmental degradation. To enhance proper management, development and production of the land resource, the Government's land policy pursued the following measures:

- prepared and implemented a national land use policy; prepared and implement land use plans for all urban and rural areas;
- revised land rates and rent of urban properties; developed land management information systems; accelerate the Land adjudication process;
- carried out revision and mapping at the basic scale of 1:500,000 for effective planning and resource allocation; established a National Spatial Data Infrastructure (NSID) for efficient management of Geo-Spatial information; and acquire land for establishment of settlement schemes.

8.2.2 Agricultural policy

Agricultural policies in the three countries aims at producing what it requires to feed its population and to produce excess for export while at the same time conserving its natural resources (soil and water) for use by its future generation. Considerable progress in food production was achieved during late 1960's and early 1970's. However, this declined in the 1980's through to date due to introduction of structural adjustment programmes. Much of the expansion of Agricultural output has come from an increase in smallholder production as new land has been incorporated into smallholdings and large farms subdivided especially in Kenya.

In 1981 in Kenya, 1993 in Uganda and 1997 in Tanzania national Food policy were or agriculture and livestock policy, which sets the guidelines for decision-making on all major issues related to food production and distribution. The primary objective of the agricultural policy in Kenya (GoK 2004) is to provide institutional environment that is conducive to increasing agricultural productivity, promoting investment, and encouraging private sector involvement in agricultural enterprises and agribusiness. Key to this environment is the creation of the legal and regulatory frameworks that are fair and just to all farmers, producers, processors, and marketers of agro-products; the availability of efficient agricultural advisory and extension services that are pluralistic, responsive to farmers' need and dynamic enough to cope with the changing environment; an efficient agricultural research system that consistently provides appropriate technology, knowledge and information to sustain improved agricultural productivity and competitive and cost efficient agricultural production systems; and a working, pluralistic agricultural inputs system that is amenable to farmers.

8.2.3 Livestock policy

The need for such a policy arises from the fact that an analysis of the Present and projected situation for the major livestock products indicates large and possibly continuing deficits over domestic supplies (GOK 1981). The main objective is to avoid any shortfalls in livestock production. Such shortfalls would either be expensive to satisfy from the imports. Secondly, achieved self-sufficiency in both milk and meat. In its operation the Kenya Government encouraged the formulation of the policy so as to generate employment at all levels of livestock production. Thirdly, the production of sufficient animal products to ensure adequate nutrition for our people, production of the necessary raw materials for our agro-industries-intensification in use of high potential land to ensure higher land and other resource productivity (URT 1997). In Uganda, like in Kenya and Tanzania livestock is food and source of income for many people, but grazers and cultivators compete for land and some times result in conflicts over the rights to use the land. In Uganda grazing of animals in communal land amounts to 43 %, against grazing in confinement that amounts to 37% of the total grazing systems.

8.2.4 Forest policy

The three countries in East Africa have two main sources of forest related raw materials. These are the plantations, and the farmlands and settlements. The Ministry of Environment and Natural Resources (MENR) in Kenya and in the other countries is entrusted with forestry policy through the Department of Forestry. The policy is to contribute to the growth of the natural resource sector by enhancing development, conservation and management of all forest resources in the country. This entails ensuring and increasing supply of forest products and services for meeting the basic needs of the present and future generations. The Kenya Government and Tanzania (URT 1998) drafted a Forestry Act based on the Forestry Master Plan that enable the Department of Forestry to come up with strategies to tackle the shortcomings on the raw material front as well as to provide it with legal muscle to enforce forestry decisions. Kenya Forestry Research Institute (KEFRI) in Kenya has promoted farm forestry for smallholder farmers with the target of accelerating the rate of acreage growth. The same policies apply in Tanzania and Uganda. Uganda has long had detailed policies on forestry and now has a Forest Authority. However, biodiversity surveys in Ugandan forests are the most detailed in Tropical Africa and they inform policy decisions.

8.2.5 Environmental policy

As Kenya undergoes transformation into a Newly Industrialised Country, one of the major challenges it faces is to promote industrialization without compromising the ability of the resource base to meet the needs of future generations. In the past, inadequacies, especially those governing management of the resource base, have resulted in widespread environmental problems, which include land degradation, alarming rate of forest destruction, pollution of our lakes and rivers and accumulation of garbage in our cities and towns.

Environmental and development issues are integral and the Ministry of Environment and Natural Resources (MENR 1996) through National Environmental Management Authority coordinates the development of strategies aimed at the sustainable utilisation of resources, taking into account the need to manage and conserve them on a sustainable basis as the country moves towards higher levels of industrialisation. The MENR involves NGOs, international agencies, and other stakeholders in its implementation arrangements. Serious involvement by the three East African countries in environmental issues came into effect after the Rio UN conference on environment. The National Environmental policy of Tanzania (URT 1997) recognizes that the state of the environment has limiting implications to social and economic development and the human welfare is ultimately based upon the products and services that nature provides. The state of the environmental wealth, that is the stock of natural assets such as forest biodiversity, soil and minerals, freshwater and marine resources constitute the limiting factor for human existence.This imply that humankind is completely dependent on nature, from breathing to producing.

Strategies to achieve successful environmental management includes: Enhancing harmonisation, implementation and enforcement of laws for the management, sustainable use and protection of the environment. In Uganda for example, the National policy for the conservation and management of wetland resources was established in 1995 to set out principles by which wetland resources can be optimally utilized to enhance productivity, maintain biodiversity in wetlands and integrate wetland concerns into the planning and decision making of other sectors (Republic of Uganda; Ministry of Natural Resources 1995).

8.2.6 Policy on poverty (Poverty reduction strategy papers - PRSP's)

Poverty manifests itself in the form of hunger; illiteracy; and lack of access to basic needs e.g. education, drinking water, minimum health facilities and shelter. According to the 1992 Welfare monitoring and evaluation survey (WMES), the level of absolute poverty in rural areas in Kenya was 46.4% while in urban areas the rate was 29.3%. A number of national policies in Tanzania, Kenya and Uganda National Development Plans clearly state a need for sustainable poverty alleviation strategies. After experiencing economic crises in the 1980s and implementing a series of Structural Adjustment Programmes (SAPs) in the 1990s, the Governments, in collaboration with development partners formulated long-term targets for poverty reduction (Republic of Uganda 1993, CBS 1996, URT, 2002). From 1997-2001, in Tanzania and Kenya the long terms strategy for alleviation of poverty is to achieve high rates of sustainable economic growth as a means of generating earned incomes. This is expected to lead a rejuvenation of economic growth, improved per capita income and a reduction of poverty levels. In the year 2000, the Poverty Reduction Strategy Paper (PRSP) was formulated to guide poverty reduction in the medium term (up to 2010) as progression towards achieving the 2025 national visions. The strategy rests on three main considerations. First, the strategy is viewed as an instrument for channeling national efforts towards broadly agreed objectives and specific inputs and outputs. Secondly, it is an integral part of ongoing macro-economic and structural reforms supported by multilateral and bilateral partners. Thirdly, the strategy concentrates its efforts on reducing poverty, increasing incomes, improving human capabilities, survival and social well-being, and limiting the vulnerability of the poor. Observed soil degradation in the study areas which corresponds to loss of diversity clearly indicates that poverty alleviation strategies will rarely be achieved if this degradation will continue due to the fact that the majority of people who live in the area depends on agriculture for their livelihood.

9. CONCLUSIONS

Land use in East Africa is changing at a very high rate. Based on land change analysis done by the LUCID group (Mugisha 2003, Misana 2004, Olson 2004, and Campbell 2002) land use has changed to more cultivated area and less bush, forests and grasslands. These changes have tremendously reduced areas with natural vegetation where in some sites there is hardly any natural vegetation.

After the primary land cover conversion from natural vegetation to cultivation or grazing, land use becomes more complicated due to intensification and diversification as land for conversion becomes less and less available and farm sizes become smaller and smaller as a result of subdivision. The causes for these land use changes are well documented in several reports in the LUCID working paper series.

Conversion of primary land cover to cultivation replaces natural vegetation cover with crops either planted as mixed cropping or planted and maintained as monoculture. In addition to planting food-crops there are fields planted with pastures for livestock grazing, woodlots for shade and fencing and homesteads. Within the cropped areas there are many types of crops planted and each type could have different management practices and therefore will affect the land differently.

Changes in land use are here reported to reduce plant species numbers and percentage cover for all vegetation categories and all land use types. Land use in monocultural cropping system results to more loss on species numbers than mixed cropping system.

Understanding of plant species responses to grazing pressure and seasonality needs to consider multiple scale effects and the dogmatic notions about degradation of the arid zones at the course scales should be reconsidered Land degradation assessments in the arid zones should focus at the fine scale (Lusigi, 1980,1984; Oba et. al. 2002).

Land use change causes habitat fragmentation thereby reducing habitat for wildlife. This has created restrictions on wildlife movements and their access to key resources like water, dry season grazing areas and in general the spatial grazing range. As a result especially the increased contact with humans the animal numbers and the species diversity has reduced in the affected regions. In all the study sites wildlife is reported to decline.

We have observed remarkable decline in soil nutrients (also described as a decline in soil productivity in terms of crop yields) due to deterioration of chemical, physical and biological properties. The main reasons for the decline besides soil erosion are decline in organic matter (soil organic carbon), degradation of soil structure and reduction in availability of major nutrients (N, P, K) and micro elements and increase in toxicity due to acidification and salinisation especially in irrigated farming systems.

Land use change increases herbaceous vegetation cover without increasing species diversity

10. ACKNOWLEDMENTS

The authors acknowledge with gratitude UNEP/GEF for granting financial resources (GF/1030-01-01) that enabled these multidisciplinary investigations at the sites and the regional synthesis of the site results. We also extend our thanks to all the institutions that supported us by providing time for the investigators to participate in all aspects this research. The institutions include, the International Livestock Research Institute, Michigan State University, University of Dar Es Salaam, Makerere University, Kenya Agricultural Research Institute, National Museums of Kenya and Bordeaux University in France for contribution to the greater effort in LUCID goals. Finally we would like to thank many individuals who provided technical skills and material resources to enable completion of this work. We especially want to thank the members of the LUCID team, who have been a source of inspiration to each of us over the last 5 years.

11. REFERENCES

Braun, H.M.H. 1975. “The soils In R.F van der Weg, J.P. Mbuvi (Eds); Soil of the Kandoruma area.” Reconnaissance soil survey Report No. R1. Ministry of Agriculture/National Agricultural Laboratories Kenya Soil Survey/Republic of Kenya, Nairobi.

Campbell, D., Lusch, D. P.; Smucker, T.; Wangui, E.E. 2003. “Root Causes of Land use change in the Loitokitok Area, Kajiado.” LUCID Working paper Number 19. International Livestock Research Institute. Nairobi

Campbell, D. (b) Gichohi , H.; Reid R.; Mwangi, A., Chege, L., and Sawin, T. 2003. “Interactions between People and Wildlife in Southeast Kajiado District, Kenya.” LUCID Working paper Number 18. International Livestock Research Institute. Nairobi

Campbell, D.J., and J.M. Olson. 1991. “Environment and development in Kenya: Flying the Kite in Kajiado District.” The Centennial Review, XXXV,2, pp.295-314.

CBS (Central Bureau of Statistics), 1996. “Welfare monitoring survey II.” Ministry of planning and National Development, Nairobi. Kenya.

CBS (Central Bureau of Statistics) 2000. “Kenya population Census.” Ministry of Planning and National Development. Government of Kenya, Government Printer, Nairobi.

Campbell, K. and H. Hofer (1995). :People and wildlife: spatial dynamics and zones of interaction." Serengeti: Dynamics, Management and Conservation of an Ecosystem. A. R. E. Sinclair and P. Arcese. Chicago, Illinois, USA, University of Chicago Press**:** 534-570.

Campbell, David J., Helen Gichohi, Robin Reid, Albert Mwangi, Lucy Chege and Thor Sawin. 2002. "Competition and Conflict between People and Wildlife in S.E. Kajiado District, Kenya."

Conelly, W. T. (1994). "Population pressure, labour availability, and agricultural disintensification: The decline of farming on Rusinga Island, Kenya." Human Ecology **22**: 145-170.

Dublin, H. T. (1995). "Vegetation dynamics in the Serengeti-Mara ecosystem: the role of elephants, fire and other factors." Serengeti II: Dynamics, Management and Conservation of an Ecosystem. A. R. E. Sinclair and P. Arcese. Chicago, Illinois, USA, University of Chicago Press**:** 71-90.

Egulu, B. and Ebanyat, P. 2000. "Policy processes in Uganda and their Impacts on Soil Fertility." Managing Africa's Soils No. 16. IIED

Elliot, J. and Mwangi, M.M. 1997. "Making wildlife “Pay” in Laikipia, Kenya." Laikipia Wildlife Economic Study Discussion Paper CEC-DP-1. AWF (African Wildlife Foundation), Conservation, Economics and Commerce Program, Nairobi, Kenya.

Fairhead, J. and M. Leach (1996). "Misreading the African Landscape." Cambridge, UK, Cambridge University Press.

Gachimbi, Louis N.. 2002a. Technical report on soil survey and sampling: Embu - Mbeere Districts, Kenya.

Gachimbi, Louis N., 2002. "Technical report on soil survey and sampling: Loitokitok Division, Kajiado District, Kenya." LUCID Working paper Number 10. International Livestock Research Institute. Nairobi.

Gathara, G.N. 1999. "Aerial survey of the destruction of Mt. Kenya, Imenti and Ngare Ndare forest reserve." Kenya Wildlife Service, Nairobi.

Githaiga, John M., Robin Reid, Andrew N. Muchiru and Sandra van Dijk**.** 2004. Survey of Water Quality Changes with Land Use Type in the Loitokitok Area, Kajiado District, Kenya.

Government of Kenya (GOK), 1981. "National food policy Sessional paper No. 4." Government printer.

Government of Kenya (GOK) 2002. "National development Plan 2002-2008. Effective management for sustainable economic growth and poverty reduction." Government Printer.

Herlocker, D. 1999. "Rangeland Resources in Eastern Africa. Their Ecology and Development." German Technical Co-operation (GTZ), Nairobi.

Hoare, R. (1999). Conservation Biology.

Lambin, E.F.; Geist, H.J.; Lepers, E. 2003: "Dynamics of land use and land cover change in tropical regions." *Annual review of Environmental Resources* 28: 206-241

Lamprey, R. H. and F. Mitchelmore (1996). "Survey of wildlife in protected areas of Uganda. Kampala, Uganda, Ugandan Wildlife Authority."

Lusigi, J. W. 1980. The integrated – ecosystem approach to research on the arid lands of northern Kenya. In *IPAL Tech. Report No. A-3 Proceedings of a scientific seminar, Nairobi Nov. 1980.*

Lusigi, J.W. 1984. Integrated resource assessment and management Plan for western Marsabit District, northern Kenya. *IPAL Tech. Report, A-6, Marsabit, Kenya.*

Lyaruu, Herbert V. 2002. Plant Biodiversity Component of the Land Use Change, Impacts and Dynamics Project, Mt. Kilimanjaro, Tanzania

Kaihura Fidelis and Michael stoking. (2003) "Agricultural biodiversity in smallholder farmers of East Africa." United Nations University Press.

Kamau, Peris. 2004. "Forage Diversity and Impact of Grazing Management on Rangeland Ecosystems in Mbeere District, Kenya." LUCID Working paper Number 36. International Livestock Research Institute. Nairobi.

Majule, A.E. 2003. A study on land use types, soils and linkage between soils and biodiversity along the slopes of Mt. Kilimanjaro, Tanzania.

Mbugua, Simon M. 2002. Influence of land use patterns on diversity, distribution and abundance of small mammals in Gachoka Division of Mbeere District, Kenya

Mehlich A., E. Bellis and J.K. Gitau. 1964. "Fertilizing and liming in relation to soil chemical properties." Scott Laboratories, Department of Agriculture: Nairobi.

Ministry of Environment and Natural Resources (MENR), 1996. "National Environment Action Plan." Republic of Uganda, Kampala.

Misana, Salome B., A.E. Majule and Herbert V. Lyaruu. 2003. "Linkages between Changes in Land Use, Biodiversity and Land Degradation on the Slopes of Mount Kilimanjaro, Tanzania." LUCID Working paper Number 38. International Livestock Research Institute. Nairobi.

Mwangi, E.M 1994. "The structure and dynamics of large insularized herbivores community on Lake Nakuru National Park, Kenya." PH.D Thesis. University of Nairobi.

Mugisha, Samuel. 2002. "Root causes of land cover/use change in Uganda: An account of the past 100 years." LUCID Working paper Number 14. International Livestock Research Institute. Nairobi.

Muthiani E. N. 2001. "Wildlife utilization for community benefit: an assessment of ecological and socio-economic viability of community wildlife utilization." A joint Kenya Agricultural Research Institute and International Livestock Research Institute Report, 55 pp.

Nanyunja, Robinah K. 2003. "Human Perceptions of Biodiversity Losss in Uganda: Case Studies of Sango Bay, Lake Mburo National Park and Rubaale Grasslands." LUCID Working paper Number 29. International Livestock Research Institute. Nairobi

Noe, Christine. 2003. "The Dynamics of land use changes and their impacts on the wildlife corridor between Mt. Kilimanjaro and Amboseli National Parks." LUCID Working paper Number 31. International Livestock Research Institute. Nairobi

Ntiati Paul, February 2002**.** "Group Ranches Subdivision Study in Loitokitok Division of Kajiado District Kenya." LUCID Working paper Number 7. International Livestock Research Institute. Nairobi

Nyathi, P., Kimani, S.K., Jama, B., Mapfumo, P., Murwira, H.K., Okalebo, J.K. and Bationo, A. 2003. "Soil fertility management in semi-arid areas of East and Southern Africa." In (ed.) Gichuru, M.P., Bationo, A., Bekunda, M.A., Goma, H.L., Mafongonya, P.L. Mugendi, D.N., Murwira, H.M., Nandwa, S.M., Nyathi Pand M.J. Swift. Soil Fertility Management in Africa*: A Regional Perspective*. TSBF-CIAT, Academy Science Publishers (ASP). Nairobi.

Oba, G., Weladji, R.B., Lisigi, W.J., Stenseth , N.C.2002. Scale dependent effects of grazing in rangeland degradation in northern Kenya: a test of equilibrium and non equilibrium hypotheses. *Land Degradation and development Vol. 14 (1) 83-94*

Okigibo, B.N and Lal, R. 1979. "Soil fertility maintenance and conservation for improved agro forestry systems in agro forestry." ICRAF, Nairobi, Kenya.

O'Kting'ati, A. and Kessy, J.F. 1991. "The Farming Systems on Mount Kilimanjaro." In Newmark, W.D. Ed. The Conservation of Mount Kilimanjaro. IUCN, Gland and Cambridge.

Olson, Jennifer M., Salome B. Misana, David J. Campbell, Milline J. Mbonile, and S. Mugisha. 2004. The Spatial Pattern and Root Causes of Land Use Change in East Africa. LUCID Working Paper Number 47. Nairobi: International Livestock Research Institute.

Olson, Jennifer M. , Bilal Butt, Fred Atieno, Joseph Maitima, Thomas A. Smucker, Eric Muchugu, George Murimi and Hong Xu**.** 2003. "Multi-scale analysis of the root causes of land use and cover change in Embu and Mbeere Districts, Kenya." LUCID Working Paper Number 20. International Livestock Research Institute. Nairobi

Ottichilo, W. K., J. de Leeuw, et al. (2000). "Population trends of large non-migratory ild herbivores and livestock in the Masai Mara ecosystem, Kenya, between 1977 and 1997." African Journal of Ecology **38**: 202-216.

Pomeroy, Derek, Joy Tukahirwa, Samuel Mugisha, Robinah Nanyunja, Mary Namaganda and Nathan Chelimo. 2003. Linkages between changes in land use land degradation and biodiversity in S.W. Uganda.

Reid, R. S., M. E. Rainy, et al. (2001)."Wildlife cluster around pastoral settlements in Africa." Nairobi, Kenya, PLE Science Series, International Livestock Research Institute.

Republic of Uganda, 1993. "Poverty Eradication Plan." Ministry of Finance Planning and Development, Kampala.

Republic of Uganda (1995) "National Policy for the conservation and management of wetland resources." Ministry of Natural resources. Uganda

Republic of Uganda 1998. The land Act 1998 Government Printer, Entebbe.

Sanchez, P.A., Shepherd, K.D., Soule, M.J., Place, F.M., Buresh, R.J., and Izac, A.M.N. 1997. "Soil fertility replenishment in Africa: An investment in natural resource capital." In: *Replenishing Soil Fertility in Africa.* F.E. Buresh *et al.* (ed.). ASA, CSSA, SSSA, Madison, WI., USA, P. 1-46.

Serneels, S. and E. F. Lambin (2001). "Impact of land use changes on the wildebeest migration in the northern part of the Serengeti-Mara ecosystem." Journal of Biogeography **28**: 391-407.

Southgate, C and Hulmes, D 1996. "Land, Water and Local Governance in Kenya wetlands in Dryland: Kimana Group Ranch and its Environs;" Working Paper No. 4; University of Manchester, United, Kingdom.

Tiffen, M., M. Mortimore, et al. (1994). "More People, Less Erosion." Nairobi, Kenya, ACTS Press.

Tiffen, M. 2003. Transition in Sub-Saharn Africa: “Agriculture, Urbanization and Income growth.” World Development Vol. 31, No. 8. pp 1343-1366. Elsevier. Great Britain.

Thomas. D.B; K.Mutonga and J.K. Mburu 2003. “Soil and water conservation in Kenya.” Regional Land Management Unit (RELMA). Working Paper No. 19. Nairobi, Kenya.

Touber, L. B.J.A van der Pouw and V.W.P. van Engelen (Eds). 1983. “Soils and vegetation of the Amboseli, Kibwezi area.” Report No. R6, Kenya Soil Survey, Nairobi, Kenya.

United Republic of Tanzania (2002). “Poverty and Human Development Report.” Dar es Salaam.

United Republic of Tanzania (1998). “National Forestry Policy.” Dar es Salaam, Ministry of Natural Resources and Tourism.

United Republic of Tanzania (1997). “National Environmental Policy.” Dar es Salaam, Vice Presidents Office.

United Republic of Tanzania (1997). “National Agricultural and Livestock Policy.” Dar es Salaam, Ministry of Agriculture and Food Security.

US. Salinity Laboratory Staff. 1954. “Diagnosis and improvement of saline and alkaline soils.” Agriculture Handbook No. 60. USDA, Washington, D.C.

Walaga C; Egulu B, Bekunda M and Ebanyat, P., 2000. “Impact of policy change on soil fertility management in Uganda. In: Hilhorst T and Muchena, F.M. (Eds) Nutrients on the Move-Soil fertility dynamics in African farming systems.” IIED, London, United Kingdom.

Wangui, Elizabeth E. 2003. “Links between Gendered Division of Labour and Land Uses in Kajiado District, Kenya.” LUCID Working paper Number 23. International Livestock Research Institute. Nairobi

Wells, M. and Brandon, K. 1992. “People and Parks: Linking Protected Area Management and Local Communities.” Washington, D.C.; The World Bank.

Western, D. 1976. “Amboseli; Integration of people, land and wildlife seeks to end the conflicts which threaten this national park.” *Parks*, 1, 2:1-4.\

Wilson, C.J. Reid, R. Stanton, N.L. Perry, B.D. 1997. “Effects of land use and tsetse fly control on bird species richness in southwestern Ethiopia.” Conservation Biology Vol. 11 pp 435-447

Worden, J. Reid, R. and Gichohi, H. 2003. “Land Use Impacts on Large Wildlife and Livestock in the Swamps of the Greater Amboseli Ecosystem, Kajiado District, Kenya.” LUCID Working Paper Series Number 27. ILRI, Nairobi, Kenya.

WWW.fao.org/ag/ugl/swlwpnr/reports

WWW.Lucideastafrica.org

12. APPENDICES

Appendix 1. Economically useful plants identified by informants along Mbokomu Transect on Mt Kilimanjaro, Tanzania (from Misana *et. al* **. 2003).**

Species Name	**Local Name (Chagga)**	**Use**	**Abundance Level**
Rumex abyssinicus	Ilimilimi	Medicinal (stomach disorders)	Very common along water courses
Rauvolfia caffra	Msesewe	Anthelmintic, catalyst in fermentation process	Very common
Todallia asiatica	Mkananga	Stomachache, cancer, fodder, boundaries	Declining in abundance
Tabenaemontana pachysiphon	Irahacha	Anti-thrombin, wound healing	Very common
Dracaena studneri	Isale	Stomachache, rituals, boundary markers	Very common
Solanum incanum	Ndulele	Stomachache	Widespread ruderal of disturbed land
Vernonia adoensis	-	Persistent coughs	Widespread ruderal
Cassia didymobotrya	Latangao	Ethno-veterinary for treating constipation	Very common
Albizia gummifera	Mfuruanje	Timber, coffee shade trees	Common
Cordia Africana	Mringaringa	Timber, fodder, coffee shade tree, fuel wood	Common
Olea welwitschii	Loliondo	Timber, poles	Declining due to overexploitation
Grevillea robusta	Mwerezi	Coffee shade tree, timber	Exotic species naturalized in many parts of Tanzania
Eucalyptus saligna	Mikaratusi	Timber, poles, fuelwood	Introduced species from Australia
Eucalyptus globulus	Mikaratusi	Timber, poles, fuelwood	As above
Cuppressus lusitanica	-	Timber, fuel wood, poles	Exotic species naturalized in Tanzania.

Appendix 2. Economically useful plants identified by informants along Machame Transect, Mt Kilimanjaro, Tanzania (from Misana *et. al.* 2003).

Species Name	**Local Name (Chagga)**	**Use**	**Abundance Level**
Grewia burtii	Seseti	Ethno-veterinary, fungicidal	Declining due to clearance of farms
Euphorbia cuniata	Mlangari pori	Ethno-veterinary (chicken)	Very common
Lannea stuhlmannii	-	Fever, anaemia	Declining due to unsustainable mode of harvesting
Terminalia sericea	Mbugwe	Ethno-veterinary, persistent coughs, dysentery	Declining due to unsustainable mode of harvesting
Agauria salicifolia	-	Treatment of open wounds	Declining due to clearance of farms
Azadirachta indica	Mwarobaini	Fever, pesticide	Planted and very common around homesteads
Plecranthus kilimandscharica	Wombo	Stomache upset, appetizer	Very common
Rauvolfia caffra	Msesewe	Anthelmintic, catalyst of fermentation process of mbege	Very common, planted and along water courses
Cordia Africana	Mringaringa	Coffee shade, ethno-veterinary, timber	Declining due to over harvesting
Albizia gummifera	Mruka, mfuruanje	Stomach disorder, timber, fuel wood, coffee shade tree	Declining, most preferred species for timber
Psidium guajava	Mpera	Stomachache	Very common as a cultivated crop
Persea americana	Parachichi	Toothache	As above for *Psidium guajava*
Solanum incanum	Ndulele	Stomachache	Very common as a weed of disturbed land and cultivation
Erythrina abyssinica	-	Ethno-veterinary as a treatment of mastitis	Overexploited indigenous species on the verge of extinction
Ricinus communis	Mbarika	Painkiller, purgative	Very common weed of cultivated or disturbed land
Dracaena steudneri	Isale	Stomachache, cultural significance, boundary markers	Very common
Cassia didymobotrya	-	Amoebic dysentery	Very common
Sansevieria conspicua	Katani pori	Ethnoveterinary for chicken	Very common on skeletal soils in scrubland
Setaria homonyma	Ilale	Stomachache	Very common as a weed of cultivated land
Grevillea robusta	Mwerezi	Coffee shade tree, timber	Exotic species naturalized in many parts of Tanzania
Eucalyptus saligna	Mikaratusi	Timber, poles, fuelwood	Introduced species from Australia
Eucalyptus globulus	Mikaratusi	Timber, poles, fuelwood	as above

Appendix 3. Effects of land use type on the number of plant species and the mean for plant % cover by agro-ecological zone across the three countries in East Africa. See the definitions of the agro-ecological zones listed under each country name. (in all the sites trees, shrubs and herbs were sampled in 20x20; 10x10 and 1x1 m quadrat sizes respectively)

Country	Major land-cover/use types[1]	Agro-ecological zone					
		Upper zone		Middle zone		Lower zone	
		Total spp #	Total % cover[3]	Total spp #	Total % cover[2]	Total spp #	Total % cover[2]
Tanzania*	**Forest**	**-**	**-**	**33**	**80.9**	**-**	**-**
Machame	**Woodland**	**-**	**-**	**-**	**-**	**-**	**-**
Upper zone =	**Bushland**	**-**	**-**	**13**	**82**	**27**	**60.0**
1500-1800m	**Grassland**	**-**	**-**	**13**	**45.3**	**-**	**-**
Middle zone =	**Woodlots**	**64**	**56.2**	**-**	**-**	**31**	**79.0**
1000-1500 m	**Pasture**	**12**	**94.9**	**20**	**69.6**	**14**	**31.2**
Lower zone =	**Fallow**	**-**	**-**	**11**	**36.0**	**4**	**36**
700-1000 m	**Cultivation**						
	• **Annual mono-crop**	**46**	**77.0**	**31**	**0**	**44**	**29.9**
	• **Perennial mono-crop**	**-**	**-**	**29**	**38.6**	**12**	**45.0**
	• **Annual mixed crop**	**13**	**70.1**	**26**	**45.9**	**-**	**-**
	• **Perennial mixed crop**	**19**	**10.3**	**41**	**48.7**	**-**	**-**
	Settlements	**11**	**5.0**	**-**	**-**	**-**	**-**

[1] Wetlands were not sampled for plant species in this study and are thus excluded from this table.
[3] Total percent cover obtained by summing up of all average % cover of samples in individual land use types that make up the major land use.

Tanzania*	**Forest**	**-**	**-**	**-**	**-**	**30**	**100**
Mbokomu	**Woodland**	**-**	**-**	**-**	**-**	**-**	**-**
Upper zone =	**Bushland**	**-**	**-**	**-**	**-**	**-**	**-**
1500-1800m	**Grassland**	**17**	**59.6**	**16**	**100**	**-**	**-**
Middle zone =	**Woodlots**	**15**	**59.1**	**12**	**18**	**-**	**-**
1000-1500 m	**Pasture**	**-**	**-**	**17**	**56.1**	**4**	**89.2**
Lower zone =	**Fallow**	**24**	**100**	**-**	**-**	**-**	**-**
700-1000 m	**Cultivation**						
	• **Annual mono-crop**	**5**	**50.8**	**2**	**4**	**20**	**33.8**
	• **Perennial mono-crop**	**-**	**-**	**-**	**-**	**59**	**55.1**
	• **Annual mixed crop**	**-**	**-**	**4**	**73**	**-**	**-**
	• **Perennial mixed crop**	**21**	**63.4**	**48**	**63.7**	**-**	**-**
	Settlements	**-**	**-**	**3**	**4.4**	**-**	**-**
Kenya - Embu	**Forest**	**15**	**11.7**	**-**	**-**	**-**	**-**
Upper zone =	**Woodland**	**-**	**-**	**12**	**5.2**	**36**	**18.0**
LH	**Bushland**	**-**	**-**	**-**	**-**	**-**	**-**
Middle zone =	**Grassland**	**-**	**-**	**-**	**-**	**2**	**0.9**
UM	**Woodlots**	**-**	**-**	**32**	**24.3**	**-**	**-**
Lower zone =	**Pasture**	**10**	**19.5**	**60**	**67.9**	**35**	**80.7**
LM	**Fallow**	**29**	**18.3**	**71**	**33.5**	**46**	**95.2**
	Cultivation						
	• **Annual mono-crop**	**10**	**0.7**	**80.2**	**78.6**	**92**	**48.4**
	• **Perennial mono-crop**	**43**	**67.0**	**55.1**	**52.5**	**23**	**10.2**
	• **Annual mixed crop**	**29**	**26.0**	**99**	**49.9**	**55.4**	**40.0**
	• **Perennial mixed crop**	**20**	**22.3**	**89.6**	**52.0**	**15**	**11.4**
	Settlements	**-**	**-**	**21**	**60.2**	**4**	**2.0**

Kenya - Loitokitok Upper zone = LH3 Middle zone = UM4 Lower zone = LM5,LM6	**Forest**	**-**	**-**	**32**	**12.1**	**-**	**-**
	Woodland	**-**	**-**	**-**	**-**	**174**	**71.4**
	Bushland	**-**	**-**	**26**	**22.1**	**135**	**28.6**
	Grassland	**-**	**-**	**19**	**24.1**	**24**	**35.3**
	Woodlots	**-**	**-**	**-**	**-**	**-**	**-**
	Pasture	**14**	**27.2**	**21**	**16.9**	**81**	**6.5**
	Fallow	**-**	**-**	**29**	**10.1**	**50**	**71.7**
	Cultivation						
	• **Annual mono-crop**	**-**	**-**	**30**	**33.9**	**87**	**90.6**
	• **Perennial mono-crop**	**-**	**-**	**-**	**-**	**-**	**-**
	• **Annual mixed crop**	**13**	**8.5**	**80.8**	**53.7**	**87**	**95.5**
	• **Perennial mixed crop**	**-**	**-**	**11**	**13.1**	**-**	**-**
	Settlements	**-**	**-**	**22**	**31.2**	**-**	**-**
		High rainfall (1500 mm)		**Moderate rainfall (900 mm)**		**Moderate rainfall (850 mm)**	
Uganda Sango Bay = higher rainfall at 1500 mm Rubaale = moderate rainfall at 900 mm Lake Mburo = moderate rainfall at 850 mm	**Forest**	**-**	**-**	**-**	**-**	**-**	**-**
	Woodland	**-**	**-**	**17**	**13.7**	**20**	**10.0**
	Bushland	**-**	**-**	**-**	**-**	**-**	**-**
	Grassland	**13**	**9.9**	**9**	**14.5**	**11**	**9.3**
	Woodlots	**-**	**-**	**-**	**-**	**-**	**-**
	Pasture	**-**	**-**	**-**	**-**	**-**	**-**
	Fallow	**12**	**12.8**	**7**	**17.1**	**-**	**-**
	Cultivation						
	• **Annual mono-crop**	**-**	**-**	**-**	**-**	**-**	**-**
	• **Perennial mono-crop**	**10**	**14.4**	**9**	**16.9**	**11**	**13.9**
	• **Annual mixed crop**	**-**	**-**	**-**	**-**	**-**	**-**
	• **Perennial mixed crop**	**-**	**-**	**-**	**-**	**-**	**-**
	Settlements	**-**	**-**	**-**	**-**	**-**	**-**

Appendix 4. Effects of land use type on the presence of weeds and dominant species by agro-ecological zone across the three countries in East Africa. See the definitions of the agro-ecological zones listed under each country name.

Country	Major land-cover/use types	Agro-ecological zone					
		Upper zone		Middle zone		Lower zone	
		% weeds	Dominants	% weeds	Dominants	% weeds	Dominants
Tanzania* Machame **Upper zone = 1500-1800m** **Middle zone = 1000-1500 m** **Lower zone = 700-1000 m**	**Forest**	-	-	80.9	Oxa. Corniculata	-	-
	Woodland	-	-	-	-	-	-
	Bushland	-	-	60	Lantana camara	0	None
	Grassland	72.7	C. asiatica	-	-	50	Boer. Diff
	Woodlots	56.2	P. acquil.	-	-	79	Dig. Macro
	Pasture	75.2	Oxa. Corniculata	45.3	Bulb. Burch	-	-
	Fallow	-	-	51.1	Trid. Proc	36	Trich. Zeyl
	Cultivation						
	• **Annual mono-crop**	38	Oxa. Corniculata	75.7	Altn. Pung	79	Chlo. Virg
	• **Perennial mono-crop**	79	Trich. Zey	38.6	C. benghalensis	45	Euph. Het
	• **Annual mixed crop**	70.1	Ag. conyz.	45.7	Gal. Parviflora	-	-
	• **Perennial mixed crop**	16.1	Ag. conyz.	51.7	P. acquil	-	-
	Settlements	5	C. asiatica	-	-	-	-
Tanzania* Mbokomu **Upper zone = 1500-1800m** **Middle zone = 1000-1500 m** **Lower zone = 700-1000 m**	**Forest**	-	-	-	-	0	None
	Woodland	-	-	-	-	-	-
	Bushland	-	-	-	-	-	-
	Grassland	-	-	0	None	-	-
	Woodlots	55.1	Bulb bur	79.1	K.alata	-	-
	Pasture	59.6	Bulb bur	56.1	C. asiatica	9.2	C. rotundus
	Fallow	100	Trich zeyl	-	-	-	-
	Cultivation						
	• **Annual mono-crop**	50.8	Dig scal	20.5	S. nigrum	59.5	Ag conyz
	• **Perennial mono-crop**	-	-	70	A. lanata	73.4	Trid proc
	• **Annual mixed crop**	-	-	-	-	-	-
	• **Perennial mixed crop**	63.4	Ag conyz	63.7	Euph het	-	-
	Settlements	-	-	4.4	C. asiatica	-	-

Kenya - Embu Upper zone = LH Middle zone = UM Lower zone = LM	**Forest**	**26.70**	**Con. Bonariensis**	**-**	**-**	**-**	**-**
	Woodland	**-**	**-**	**41.70**	**Tri. Rhomboidea**	**69.40**	**Lantana camara**
	Bushland	**-**	**-**	**-**	**-**	**-**	
	Grassland	**-**	**-**	**-**	**-**	**50.00**	**-**
	Woodlots	**-**	**-**	**31.30**	**Ric.braziliensis**	**-**	**Melhania ovata**
	Pasture	**70.00**	**T.bergiana**	**85.70**	**Oxa. Corniculata**	**88.40**	**-**
	Fallow	**86.20**	**Bidens pilosa**	**91.50**	**Fla. Australasica**	**93.40**	**Lantana camara**
	Cultivation						
	• **Annual mono-crop**	**100.00**	**Gal. Parviflora**	**93.90**	**C. benghalensis**	**94.60**	**C. benghalensis**
	• **Perennial mono-crop**	**93.00**	**Gal. Parviflora**	**96.10**	**Oxa. Corniculata**	**95.70**	
	• **Annual mixed crop**	**82.80**	**Gal. Parviflora**	**92.90**	**Oxa. Corniculata**	**95.10**	**Scl. Africanus**
	• **Perennial mixed crop**	**85.00**	**Oxa. Corniculata**	**94.70**	**Bidens pilosa**	**86.70**	**Gal. Parviflora**
	Settlements	**-**	**-**	**68.30**	**Rhy. repens**	**100.00**	**Oxy. Sinuatum Gal. Parviflora C. benghalensis**
Kenya - Loitokitok Upper zone = LH3 Middle zone = UM4 Lower zone = LM5,LM6	**Forest**	**-**	**-**	**34.40**	**Tag. minuta**	**-**	**-**
	Woodland	**-**	**-**	**-**	**-**	**29.30**	**Ach. aspera**
	Bushland	**-**	**-**	**30.80**	**Tag. minuta**	**45.60**	**Tri. cistoides**
	Grassland	**-**	**-**	**47.40**	**Tag. Minuta**	**50.00**	**Da. aegyptium**
	Woodlots	**-**	**-**	**-**	**-**	**-**	**-**
	Pasture	**57.10**	**Gal. parviflora**	**33.30**	**Lactuca capense**	**42.00**	**Ric. communis**
	Fallow	**-**	**-**	**69.00**	**Tag. minuta**	**70.00**	**Bidens pilosa**
	Cultivation						
	• **Annual mono-crop**	**-**	**-**	**70.00**	**Ama. hybridus**	**77.00**	**Ama. hybridus**
	• **Perennial mono-crop**	**-**	**-**	**-**	**-**	**-**	**-**
	• **Annual mixed crop**	**38.50**	**Gal. parviflora**	**73.10**	**Da. aegyptium**	**73.60**	**Bidens pilosa**
	• **Perennial mixed crop**	**-**	**-**	**90.90**	**Da. aegyptium**	**-**	**-**
	Settlements	**-**	**-**	**68.20**	**Ama. hybridus**	**-**	**-**

		High rainfall (1500 mm)		Moderate rainfall (900 mm)		Moderate rainfall (850 mm)	
Uganda	**Forest**	-	-	-	-	-	-
Sango Bay = higher rainfall at 1500 mm	**Woodland**	-	-	**20**	**Asy. gangetica**	**10.71**	**Bot. Insculpta**
Rubaale = moderate rainfall at 900 mm	**Bushland**	-	-	-	-	-	-
Lake Mburo = moderate rainfall at 850 mm	**Grassland**	**5.06**	**Asy. gangetica**	**3**	**Dig. abyssinica**	**4.17**	**None**
	Woodlots	-	-	-	-	-	-
	Pasture	-	-	-	-	-	-
	Fallow	**100**	**Dig. ternate**	**22.2**	**Dig. abyssinica**	-	-
	Cultivation						
	• **Annual mono-crop**[4]	-	-	-	-	-	-
	• **Perennial mono-crop**	**78.67**	***Bidens pilosa***	**85.4**	**Gal. parviflora**	**79.17**	***Bidens pilosa***
	• **Annual mixed crop**	-	-	-	-	-	-
	• **Perennial mixed crop**	-	-	-	-	-	-
	Settlements	-	-	-	-	-	-

[4] This type is irrigated rice or maize or horticulture (cabbages, tomatoes, onions) in Tanzania, and irrigated horticulture or maize in Loitokitok, irrigated vegetables or rainfed horticulture

Key to species names: (goes with appendix 4)

A. lanata= *Aerva lanata*
Ach. aspera = *Achyranthes aspera*

Ag. Conyz = *Ageratum conyzoides*
Altn pung= *Altenanthera pungens*
Ama. Hybridus = *Amaranthus hybridus*

Asy. gangetica = *Asystasia gangetica*
Boer diff = *Boerhavia diffusa*
Bot. Insculpta = *Bothriochloa insculpta*
Bulb burch =*Bulbostylis burchelli*
C. asiatica = *Centella asiatica*
C. benghalensis = ***Commelina benghalensis***

C. rotundus = *Cyperus rotundus*
Chlo virg= *Chloris virgata*
Con. bonariensis = *Conyza bonariensis*

Da. Aegyptium = *Dactyloctenium aegyptium*

Dig macro= *Digitaria macroblephara*
Dig scal= *Digitaria scalarum*
Dig. abyssinica = *Digitaria abyssinica*
Dig. ternate = *Digitaria ternate*
Euph het= *Euphorbia heterophylla*
Fla. australasica = ***Flaveria australasica***

Gal. Parviflora = *Galisonga parviflora*

K. alata= *Kylinga alata*
Oxa. corniculata = ***Oxalis corniculata***

Oxy. sinuatum = ***Oxygonum sinuatum***

P. acquil= *Pteridium acquilinum*
Rhy. repens = ***Rhynchelytrum repens***

Ric. communis = *Ricinus communis*

S. nigrum= Solanum nigrum
Scl. africanus = Sclerocarpus africanus
Tag. Minuta = *Tagetes minuta*

Thel. Bergiana = ***Thelypteris bergiana***

Tri. cistoides = *Tribulus cistoides*

Trich zeyl= *Trichodesma zeylanicum*
Trid proc= *Tridax procumbens*

Definitions:
Native: - non-exotic to East Africa excluding those that are naturalized
Endemic: – Endemic to East Africa or to specific area like Kenya, specify area.
Weeds: - Weeds of cultivation. Robin to check on a definition.

Summary notes for the data in appendix 4
Dominant weed species in the sites.

The weeds grow rapidly and have capacity to establish and persist in disturbed sites.

- Within the forests that occurred in the middle zones, *Oxalis corniculata* (80.9%) was the dominant weed species in Machame Tanzania, while *Tagetes minuta* (34.4) dominated Loitokitok in Kenya. *Coniculata bonariensis* (26.7%) dominated the forest in the upper Embu.
- Within the cultivated sites, *Ageratum conyzoides* is one of the commonest weed species in Tanzania, and was found to occur predominantly both in Machame and Mbokomu. In Embu Kenya, *Galisonga parviflora, Oxalis corniculata* and *Commelina benghalensis* were prevalent, while *Amaranthus hybridus* and *Dactyloctenium aegyptium* were the common weed species in Loitokitok. In Uganda, *Bidens pilosa* prevailed.
- *Amaranthus hubridus* was the only weed species that could be associated with annual mono cropping, although it was confined in Loitokitok. On the other hand, the weed species that could be associated with the annual mixed cropping is *Galisonga parviflora*. This species was dominant in the upper zones of Embu and Loitokitok in Kenya, and the middle zone of Machame in Tanzania. It was also a typical weed for perennial mono-cropped areas, both in the Lower zone in Embu Kenya and the Middle zone in Uganda.
- The weed species of perennial mixed cropping was *ageratum conyzoides* despite being confined in the upper zones of Machame and Mbokomu in Tanzania.
- No particular weed was found to occur in common across all the cultivated sites of the EA countries.
- The typical weed for the settled land was *Centella asiatica,* only found in the two Tanzanian sites.
- *Lantana camara,* and *Tagetes minuta* were common weeds of the wooded and bush land in Tanzania and Kenyan sites.

SPECIES NUMBERS AND COVER

- Much of the vegetation cover of the three EA countries indicates that forests have been removed in the upper zones, apart from the Embu Mbeere in Kenya. Even in the Embu region, the total percent cover remains very low (below 15%) indicating signs of serious disruption.
- Machame in Tanzania and Loitokitok in Kenya are the only two sites where forest has been recorded in the middle zone. The total percentage cover for Machame is nevertheless much higher (654%) compared to that of Loitokitok (13%).
- On the other hand, the species numbers in the forest regions was very comparable in all zones across the EA sites with the total species of 30, 32 and 33, in Mbokomu, Loitokitok and Machame respectively with the exception of Embu where a total of 15 species was sampled. However, very low species numbers characterise these sites.
- Besides the forest, woodland, bush land and the woodlots are some of the other few land use cover types that were recorded in the three EA countries. This perhaps indicates the extent to which woody vegetation is affected when the landscape is converted into agrarian one. It also suggests that agro forestry and silvicultural values of vegetation has not been properly integrated with agricultural production and conservation.
- Pasture, the annual mixed crop and the perennial mixed crop are the most common form of land use cover types encountered in the three EA countries. The activities here are therefore likely to be the key determinants of the vegetation dynamics in terms of composition and numbers of species within the landscapes that they occur. Pasture was however not recorded in the three zones covered in Uganda.
- Within the cultivated areas, a relatively higher number of species were on average recorded in the middle zone compared to both the upper and the lower zones of similar land use types in many of the EA sites. Nevertheless, a gradual increase in the total number of species and the total percentage cover as the altitude decreased was evident.

Appendix 5: Comparison of water quality parameters with WHO and KEBS standards levels (from Githaiga *et. al.* 2004).

Parameter	Springs	IR/A	Exits	WHO	KEBS
COD (mgO_2/lt)	124**	325**	244**	10	10
BOD (mgO_2/lt)	129**	169**	110.4**	6	6
TDS	129.6	253.5	230.4	1500	1000
SS	369.6**	283**	523**	Nil	Nil
NO_3-N	4.8*	14.5**	8.68*	1.0	10
NO_2-N	0.012	0.031	0.022		
PO_4-P	5.44**	4.6**	8.8**	0.1	0.1
PH	7.2	7.82	7.48	5.5-9	
EC (S/cm)					
Fe	0.17	0.766**	1.1**	0.3	0.3
Mn	-	0.011	0.03	0.1	0.05

*** Values beyond both WHO and KEBS limits, * values beyond WHO safe limits.*

Appendix 6: i) The effects of land use-cover on the numbers of plant species recorded from quadrats in various sites: upper boxes labelled PC, PG, PW (Note b); and numbers of bird species at 17 sites (data from Appendices 1 and 2, respectively) From Pomeroy *et. al*. 2003.

	SANGO BAY AREA					LMNP AREA			RUBAALE			MEANS
	Woody veg[a] : Most → Least					Most → Least			Most → Least			
CULTIVATIONS (including fallow)	PC[b] 47						PC 30		PC 53			PC 43
	S4 58 (68)	S5 44 (55)					L6 59 (70)		R2 53 (63)	R3 40 (50)	R6 49 (59)	B 51 (61)
PASTORAL (woodlands and grasslands			PW 36	PG 39		PW 89		PG 40	PG 71			PW 63 / PG 50
			S3 82 (112)	S1 75 (102)	S2 51 (66)	L4 77 (94)		L2 60 (89)	R1 39 (46)	R4 49 (66)	R5 43 (54)	BW 80 (103) / BG 54 (71)
NATURAL						P all[c] (322)						P (322)
						L5 70 (92)	L3 70 (89)	L1 43 (60)				B 61 (80)

NOTES a woody vegetation is the sum of the estimated % cover in height bonds 3-8 and >8 mc the LMNP list (MUIENR 2002)

b PC, PG, PW = Plants of cultivation, grasslands, woodlands.

ii) The effects of land use-cover on the numbers of plant species, as in Table 4 and numbers of those which are woody (trees and shrubs, in parentheses) compared to numbers of birds species associated with trees (FF, F and f-species, see text). Data from Appendix 2.

	SANGO BAY AREA					LMNP AREA			RUBAALE				MEANS
	Woody veg: Most → Least					Most → Least			Most → Least				
CULTIVATIONS (including fallow)	PC 47 (9)						PC 30 (6)		PC 53 (8)				PC 43 (8)
	S4 29	S5 26					L6 20		R2 22	R3 17	R6 17		B 22
PASTORAL (woodlands and grasslands			PW 36 (16)	PG 39 (9)		PW 89 (25)		PG 40 (1)	PG 71 (0)				PW 63 (21) PG 50 (3)
			S3 49	S1 29	S2 14	L4 31		L2 25	R1 12		R4 11	R5 7	BW 40 BG 16
NATURAL						P all (NP list) (322)							P (322)
						L5 30	L3 28	L1 14					B 24

PC, PG, PW = Plants of cultivation, grasslands, woodlands. The latter comprise species actually recorded (and estimated by Jack 1 – see text). Bird sites are prefixed S, L and R – see Appendix 1 for key. Where there is more than one site in a particular area, they are arranged in order of decreasing woody vegetation cover from left to right: e.g., S3 > S1 > S2 in terms of trees and shrubs**.**