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

Linkages between Changes in Land Use, Biodiversity and Land Degradation on the Slopes of Mount Kilimanjaro, Tanzania

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1.0 INTRODUCTION

The development of mankind over the past decades has gone through a number of historical stages. The process of development entails exploitation of natural resource with the purpose of converting it into usable form. For example, human activities such as land tillage, forest clearing, and irrigation are all aimed to increase food production in order to feed the people, who are ever increasing. In many cases, most of development activities conducted in unplanned way have resulted into serious land degradation. Land degradation means a reduction or loss, in 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. These processes include those arising from human activities and habitation patterns, such as soil erosion caused by wind and or water, deterioration of the physical, chemical and biological properties of soils as well as loss of natural vegetation and biodiversity. A number of studies have been conducted to assess the various kind of land degradation in Tanzania (see for examples Dejene *et al.,* 1997; Majule *et al.*, 1997; Boesen *et al.,* 1999; Majule and Mwalyosi, 2003). Kilimanjaro being one of the potential areas in Tanzania in terms of natural resources and agricultural production, studies on land degradation, and their implications on biodiversity and the livelihood of the people in the area are inevitable in order to have sustainable management of resources.

Kilimanjaro region is endowed with a number of natural resources such as fresh water, fertile volcanic soils, wildlife, forests and pastures. Smallholder agriculture under a typical Chagga system known as *kihamba*, dominates in the highlands in areas that formerly supported natural forests. This system, however, favors land fragmentation because of the kinship and land inheritance system that prevails even today. The land is intensively used due very high population density, which exceeds 500 people per km^2 in some places. The lowland zone, which in the past was sparsely populated due to low and unreliable rainfall, poor soil fertility and poor physical environment such as high temperatures, was mainly used for grazing livestock. Over time, however, this zone is increasingly becoming settled and cultivated due to high population pressure in the highlands. Land scarcity in the highlands has forced people to move down to the lowlands. This has increased pressure on the land leading to changes in patterns of land use and land degradation in some parts.

Cultivation on Mount Kilimanjaro is believed to have taken place as long as people have inhabited the slopes of the mountain probably more than 2000 years back in time (Masao, 1974). Over time, however, changing land use patterns across ecological gradients, particularly over the last 150-200 years, driven by a variety of social, economic, political and natural processes have become characteristic of the mountain slopes. These changes have resulted in land cover changes that affect biodiversity, water, land productivity and other factors, that cumulatively affect the biosphere. Understanding the effects of land use and cover changes on the degradation of natural resources particularly soils and biodiversity is very important in the planning for the sustainable management of natural resources. This paper, therefore, explores the impact of land use and cover changes on land degradation, particularly deterioration of chemical, physical and biological properties and their linkage to biodiversity loss.

2.0 METHODOLOGY

A survey was carried out along two transects traversing through three different agro-ecological zones on the southern slopes of Mount Kilimanjaro (Figure 1). The overall objective was to find out how different land use practices affect plant biodiversity and consequently land degradation. The two transects ran from the forest belt to the lowlands where people are engaged in irrigation agriculture. Of the two transects, one transect along Machame route started at an altitude of 1840 metres above the sea level down to Kikafu Chini which lies at an altitude of 770 metres. The Mbokomu transect started from the forest belt at around 1830 metres down to Mabogini at an elevation of 686 metres. Comparatively, the Machame transect was much longer and it crossed several land use types than the Mbokomu transect. Topographically, Mbokomu transect traversed very steep and rugged hillslopes, such that it was in some cases impossible to lay quadrats where the sub-transects fell.

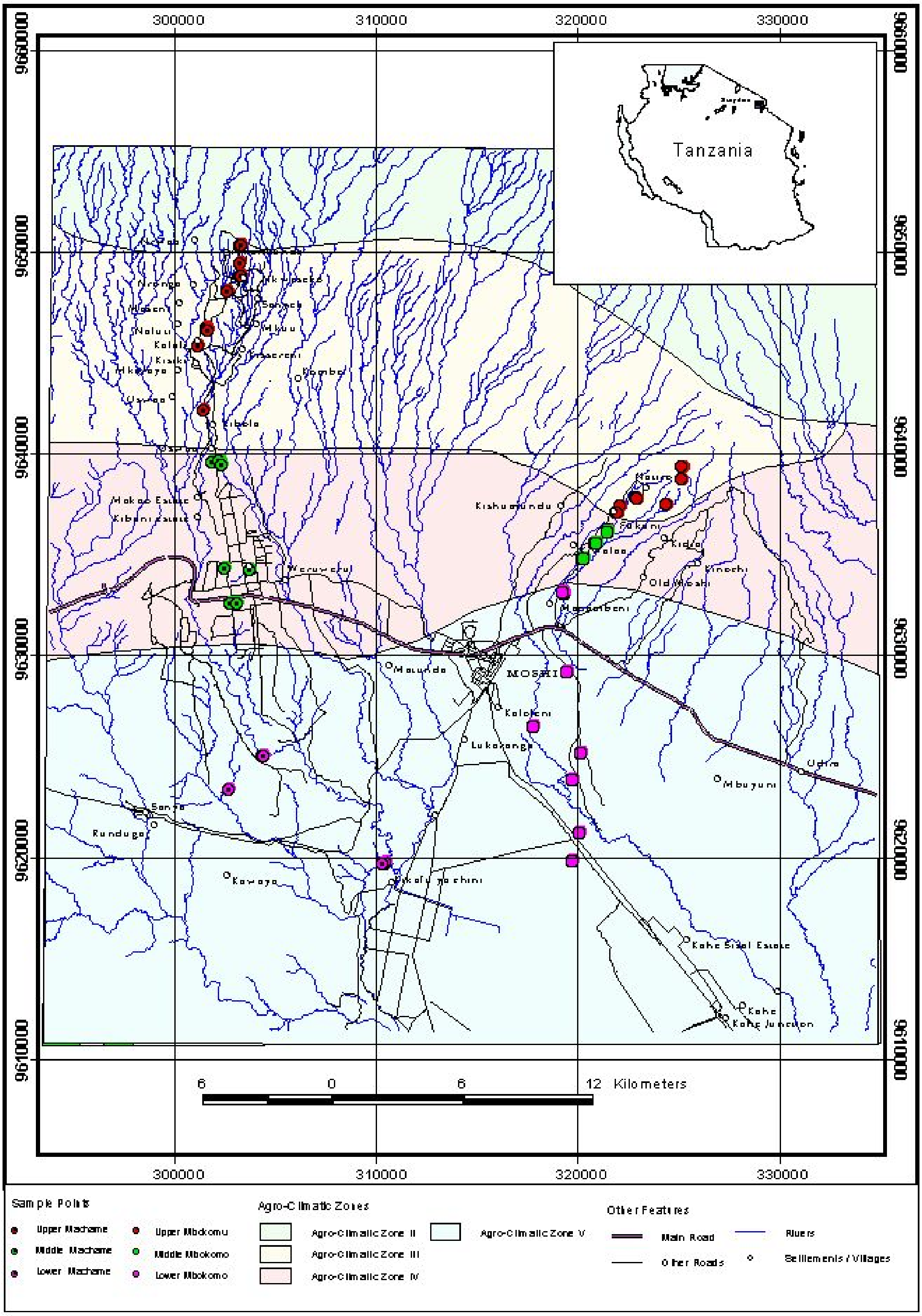


Figure 1: Sampling Points along the Agro-Climatic Zone Gradient Machame - Mbokomu Study Area

Along each transect, 12 sub-transects which ran perpendicular to the main transect were established such that for each major agro-ecological zone there were 4 sub-transects. The major agro-ecological zones encountered included the upper coffee/banana highland zone, the middle highland zone and the lowlands where the main activity was pastoralism and irrigation agriculture (Table 1). The mountain zone, which lies above 1800 metres was not included in the sample. The lengths of sub-transects were variable depending on how close different land use categories were found, but generally sub-transects covered 500 metres on either side of the main transect.

During the sampling exercise, a minimum of two quadrats representing each land use category were sampled, and in some cases up to 3 different land use categories could be found in one sub-transect. In case where there was only one site representing a specific land use category, the site was also sampled in order to capture maximum variability of biodiversity in each sub-transect. Data on land use and cover types, soils and plant species were recorded in each quadrat.

Table 1. Agro-ecological zones and major land use and cover types

Attribute	**Mountain**	**Highlands**		**Lowlands**
		Upper	**Middle**	
Altitude range (masl)	> 1800	1800 – 1500	1500 – 1000	1000 –700
Altitudinal Zone	Lower montane to sub-alpine	Sub-montane to Lower montane	Sub-montane	colline
Agro-ecological zone	Humid to alpine desert	Humid	Humid to Sub-humid	Sub-humid to arid
Slope	>30°	<4° - 30°	0° - 9°	0°- 4°
Annual rainfall (mm)	>2000-200	2000	2000-1500	1500-400
Potential evaporation (mm)	<700	700-1000	1000-1800	1800-2000
Predominant land uses	Forest reserve, National Park	Intensive cultivation of coffee, bananas, fruits and shade trees (agro-forestry), maize, planting of fodder, settlements, Eucalyptus plantation (woodlots) forests, zero and open grazing, pastureland	Intensive cultivation of coffee, bananas, fruits and shade trees (Agroforestry), maize, beans, vegetables and horticultural crops, zero and open grazing, pastureland and settlements	Intensive and mechanized cultivation (rainfed) of maize, beans, sorghum, cotton, sunflower, cassava, millet; Irrigation agriculture (bananas, rice, vegetables); livestock grazing
Natural vegetation	Moist and dry forest, sub-alpine moorland and heath, tussock grassland	Moist and dry forest	Moist and dry forest, bushland, grassland	Woodland, scrub, *Acacia* thorn bushland, grassland

2.1 Soils fertility evaluation

Composite soil samples were collected from the different land use/cover plots and were later analysed in the laboratory using the standard procedures for cation exchange capacity, pH, organic carbon, exchangeable bases and total nitrogen by following methods outlined in Majule (2003). Soils were also described in terms of their physical properties, such as soil color, moisture, erodibility and textural class, by finger feel method. Field observations of different plants on a particular soil was also undertaken in order to explain relationships between soil fertility and crop growth.

The proportions of different land se and cover types along the transects per zone were all listed and their proportions calculated in-terms of their occurrences. Their proportions were plotted in graphs, with a detailed description of representative land use and cover types presented in a tabular form. Soil degradation particularly soil erosion per land use/cover type was assessed by classifying into different erodibility classes such as 0=E0, 1=E1 and 2=E2 meaning no visible evidence of erosion, slight moderate sheet wash and moderate-severe sheet wash respectively. Major nutrients (C, N, P, K) in soils and soil pH were compared with the national standards (NSS, 1993) in order to get different fertility ratings per transect and per land use/cover types.

2.2. Vegetation survey

In accordance with the sampling protocol outlined in the LUCID cookbook, different sizes of quadrats were used depending on the type of the vegetation, the criteria being the vegetation height. For example woodlots were sampled in 20 x 20 square metre plots, whereas coffee/banana plots were sampled in 10 x 10 square metre quadrats. Monocultural crops such as maize at different stages of development, as well as herbs and grasses were sampled using quadrats ranging from 1 x 1 square metres to 4 x 4 square metre plots. A total of 40 quadrats were sampled along Mbokomu transect with eleven land use categories and with coffee/banana as the major land use type. The information obtained by calculating species diversity (H'), evenness (E) and species richness (S) of the plots sampled along Mbokomu transect was later on used to plot graphs on effects of land use change on biodiversity. For Machame transect where there were more land use categories, a total of 81 quadrats were sampled with an indication that maize and coffee/banana were the major land use categories of this area.

In the sampling procedure, individual plants were identified to species level, counted and recorded, and contribution of each species to percentage cover was estimated and recorded. Specimens that were difficult to identify in the field were collected, pressed and transported to Dar es Salaam for confirmation of their identity. Such unidentified specimens were properly determined at the University of Dar es Salaam Herbarium by matching with preserved herbarium specimens or by keying using floras and manuals.

A questionnaire was administered to a number of people along each transect in order to obtain information on the economically important plant species found in the area and their current status, to indicate whether they were declining or increasing over time. Information was also sought about species that have become extinct in the study area, their possible cause of the extinction and habitats where such species were found.

The vegetation data were combined with the soil analysis results in multivariate analysis in order to reveal the indicator species of different soil conditions. Calculation of species diversity was done using the Shannon & Wiener Diversity Index (as in Magurran, 1988) from the relationship $\mathbf{H' = -\sum p_i \ln p_I}$, where p_i is the relative proportion of the **i**th species in the sample. Evenness (**E**) or equitability which is a measure of how individuals are distributed for each species was calculated from the relationship $\mathbf{E = H'/\ln S}$, where **S** is the species richness. Similarity between samples of the same land use category was calculated based on Sørensen's (1948) Similarity index from the relationship

$$\mathbf{SI = 2C/A + B},$$

Where, **C** are species common to samples **A** and **B**, **A** and **B** are total number of species found in sample **A** and **B** respectively.

Multivariate analysis of the data was performed using the programme PC-ORD Version 4.20 (McCune & Mefford 2000). The data were analysed using Canonical Correspondence Analysis (CCA), Detrended Correspondence Analysis (DCA) and Two Way Indicator Species

Analysis (TWINSPAN). The data matrices used were the species/plots data x soil/altitude/plots data that served as the environmental variables.

The nomenclature used in this study follows that of Turrill & Milne-Redhead (1952-) in Flora of Tropical East Africa and that of Exell & Wild (1960-) in Flora Zambesiaca.

Limitation of the results

Although sampling technique that employs square quadrats is becoming obsolete nowadays (see account by Stohlgren *et al*., 1995), the team adopted square quadrats in order to obtain comparable data with the Kenyan counterparts, who did their field- work much earlier. The use of different size quadrats suggested in the LUCID cookbook, however, was a serious problem to data interpretation. Effective comparison of the data could not be done for different land use categories because each vegetation type was sampled using quadrats of different sizes. For example it was possible to compare graze land, fallow land, maize fields, paddy fields and fodder since these entities were sampled in 2 x 2 m^2 quadrats.

3.0 RESULTS AND DISCUSSION

3.1 The Impact of Land Use Change on Biodiversity and Land Degradation

Human activities have increasingly modified the environment over time and space. In fact, their role in environmental change overrides natural changes to ecosystems brought by climate variations of the past few thousand years (Turner, *et al.,* 1990). These activities include cultivation in various forms, livestock grazing, settlement and construction, reserves and protected lands and timber extraction, among others. These and other land uses have cumulatively transformed land cover at the local and global scales, with significant consequences for land cover, biodiversity, soil condition and water and sediment flows (Turner, *et al.,* 1994).

3.2 Patterns of land use and cover change

The patterns of land use and cover change along the Machame and Mbokomu transects are presented in Tables 2 and 3.

Much of the present day cultivated land (the home gardens and shambas) in the highlands, an area referred to by Allan (1965) as Chagga land proper, was initially forestland. With the establishment of settlements in the areas, the forests were cleared for cultivation of bananas. Settlement started in the middle zone up to 1400 m (Iliffe, 1979). However, according to Holland (1996) and Illife (1979), there was still plenty of cultivable land on Mount Kilimanjaro during the 19th and beginning of the 20th centuries. There was enough room to extend the area where banana, the staple food, was grown as the population increased. Thus with population increase, settlements coupled with cultivation extended to the upper zone. Historically, grazing of livestock and the collection of fodder was more extensively practiced in the upper zone (O'Kting'ati and Kessy, 1991). As human numbers in the middle zone expanded, increasing numbers of people moved into this zone to cultivate.

Table 2. Major land use changes and environmental problems along the Machame transect

Attribute	Upper	Middle	Lowlands
Present land use and cover	Forest, Eucalyptus woodlots, agrculture (home gardens), agroforestry, pasture land, fodder	Settlements, agriculture (home gardens, shambas) agroforestry, fallow, horticulture, fodder, grazing, eucalyptus trees, grassland	Bushland, rainfed and irrigated agriculture, grazing, fallow land
Major crops	Coffee/bananas, maize, napppier grass	Coffee/bananas, maize, cabbages, onions, tomatoes, nappier grass	Maize, cotton, beans, groundnuts, cassava, bananas, rice along rivers and swamps, tomatoes, sisal
Land use and cover change	Natural forest to settlement and crop land (agroforestry), natural forest to eucalyptus plantations and woodlots, forest to grazing land, crops/ Eucalyptus trees to nappier grass	Natural forest to settlement and crop land (agroforestry), forest to grassland/ grazing land, coffee to maize, beans vegetables, horticultural crops and floriculture	Bushland to cultivation, grazing land to cultivation, increased intensity of irrigated agriculture
Major problems	Fire, soil erosion, low fertility	Low fertility, erosion on foothills and river banks	Medium to low fertility, soil erosion, salinity, severe degradation in some places, poor plant growth
Response to problems	Terracing (step terraces), manure, contour farming, mulching	Contour ridging, step terraces, farm residues, manure, chemical fertilizers	Crop residues, chemical fertilizers, trash line cultivation, manure

Table 3. Major land use changes and environmental problems along the Mbokomu transect

Attribute	Upper	Middle	Lowlands
Present land use	Agriculture (home gardens) agroforestry, Eucalyptus wood lots	Agriculture (home gardens and shambas) agroforestry, horti-culture, pasture land, woodlots/ nappier grass	Rainfed and irrigated agriculture, forest reserve, grassland
Major crops	Coffee, maize, beans	Coffee/bananas, maize, beans, cocoyams, lettuce, cabbage, tomatoes, cassava	Coffee, maize, bananas, cassava, rice in along rivers and swamps
Land use and cover change	Natural forest to Eucalyptus woodlots, settlement and coffee/bananas (agroforestry), coffee to maize	Forest to settlement and cultivation, grazing land to settlement, cropland to pasture land, cropland to woodlots, bush and severely degraded land to trees and nappier grass	Forest to cultivation (rice, bananas, maize), grazing land to cultivation, maize to rice during excessive rains, rice to maize, Forest to maize to grazing
Major problems	Soil erosion, degradation of soil structure, low fertility	Erosion, poor soil	Water, very heavy soils with flooding
Response to problems	Terracing	Terraces, trash lines, crop residues, manure	Animal and chemical fertilizers, crop residues

Two different types of land use emerged, the Kihamba or home gardens where houses were built and multi-purpose trees were intercropped with food crops, mainly bananas, and later with coffee, introduced during the German colonial period (1886-1916) and the shamba land (small fields in-between the different vihamba) where food crops like maize, beans, yams, finger millet and grass for livestock were cultivated (Anderson, 1982). This farming system was supported by a sophisticated irrigation system using traditional fallows. According to Soini (2002), in 1961 there was still space in the home garden area for small fields of sweet potatoes, other vegetables and small patches of grazing lands. With increased population, however, the small fields were converted to Kihamba. There was also establishment of European estates mainly for coffee, although many of these were established in woodland and bushland zones in the upper lowlands. Some of these estates have now been converted to maize farms.

With the emergence of Kihamba system and introduction of coffee, many indigenous trees were replaced with exotic tree species, such as *Grevillea robusta, Eucalyptus spp., Persea americana*, which were planted for various purposes, such as timber, shade, fruit and animal fodder. *Eucalyptus* was mainly planted for fuelwood supply and poles. Some indigenous species, such as *Albizia schimperiana* and *Newtonia buchananii* were, purposely retained in the farms for soil conservation. These are leguminous plants, which fix atmospheric nitrogen and therefore add nutrients to the soil. A total of 111 plant species, ranging from trees, food crops, fodder and medicinal plants, were recorded in home gardens in Hai District on the southern slopes of Mount Kilimanjaro (O'Kting'ati *et al*., 1984). This is an indication of prevalence of high diversity of plants in the Chagga home gardens.

There has been continuity of land use on the mountain in time and space. The two types of land use, the home gardens (Plate 1) and shamba, have remained a characteristic way of Chagga farming until today (Holland 1996) although many of the small fields in the highlands have been converted to kihamba. For example, by 1982, as the population pressure increased on the upper slopes, most of the open spaces had been taken for building new home gardens (Soini, 2002) The upper slopes became more uniformly covered by home gardens while in the lowlands, more bush land was opened up for food production at the same time period.

Until the 1980s, the Chagga home gardens covered about 1200 km^2 on the southern and eastern slopes of Mount Kilimanjaro (Fernandez *et al*., 1984). Because of sub-division between the sons of the family, home gardens have, however, become increasingly fragmented. Today, land in the upper and middle zones is so fragmented that there is no further room for expansion. The home gardens have become so fragmented that they are now too small to sustain a family (Soini, 2002). The average size of holdings ranges between 0.5 ha to 2 ha, with some households having less than 0.25 ha (0.5 acres) while others have over 2.2 ha (4 acres) (Oyan, 2000). Because of land scarcity and the limited opportunity to expand agriculture in the upper and middle zones, farmers have opted to diversify their crop production. Thus cropping patterns have changed over time. In some areas, coffee is being replaced with maize, vegetables, horticultural crops like tomatoes and onions and flowers. In other areas, cropland has been converted to pasture land. The shamba system has now, been extended to the lowlands due to scarcity of land in the highlands.

Plate 1. A typical Chagga home garden (Kihamba) in Materuni village, consisting of a mixture of coffee, bananas, yams, trees (*Grevillea robusta* and *Albizia gummifera) Draceana usambarensis* and fodder grass.

The past decades have also been characterized by an expansion of farmland towards the rivers. Deforestation arising from such expansion seems to have taken place before 1962 because as reported by Holland (1996), in 1962 there were large areas in the river valleys in Mwasi Juu and Mwasi Chini between Uru East and Mbokomu without woody vegetation. From 1962 to 1992, however, the open areas along the rivers decreased more than 50%. This may be due to the agroforestry system practiced in river valleys where the farmers cultivate perennial and seasonal crops in-between the trees. They also collect fodder and harvest and plant trees (Holland, 1996).

Although grazing was taking place in open areas on the slopes of the mountain, it has now become very restricted because of the increase in population and expansion of cultivation in the former grazing areas. Consequently, the number of livestock has gone down tremendously and the open grazing system has been replaced by zero grazing. Changes in land use and subsequent decline in access to pasture and shortage of fodder are believed to have led to decline in livestock numbers (Moore, 1986). Holland (1996), for example, believes that the decrease in the number of cattle may be attributed to the introduction of coffee trees. Although cattle used to be the main source of wealth and the main symbol of high status, the increase in income from coffee production made ownership of land to become more important than the ownership of cattle. The shortage of pasture in the highlands has subsequently led to the emergence of sale of fodder, something that was, according to O'Kting'ati and Kessy (1991) virtually non-existent in the 1960s. In the past, women used to carry bundles of grass from the lowlands to the Kihamba. Today, however, pick-up trucks are seen carrying loads of grass from the lower areas. This has resulted in transfer of nutrients from the lowlands to the highlands, with wider implications on land management.

The lower slopes that bordered settled areas and the plains were mostly covered by woodland and bushland (Holland, 1996). The major crops grown in the lowlands were maize, beans, finger millet and vegetables. Cotton was also being produced in some areas of Moshi District as a cash crop on a smallholder basis. Because of the drastic drop of the price of cotton since the 1980s, however, many people turned to the production of coffee (Sevaldsen, 1997). But due to the increased scarcity of water and the fact that many people did not have the required shady environment to make the coffee trees thrive, many farmers have been forced to turn to new crops such as tomatoes, other vegetables and sunflower. Since the mid-1980s, tomatoes have gained significance as a cash crop and have even become the number one cash crop for people in Makuyuni ward (Sevaldsen, 1997). However, because of the perishability of the crop and the limited market as many people have become involved in the production of the crop, the prices are no longer favorable, although they are still much better than the coffee and cotton prices.

In the dry low-lying areas (rainfall less than 700mm), pastoralism has always been the main land use type, which is practiced mainly by the Masai herdsmen. Near the rivers, irrigated agriculture for crops such as rice and vegetables is common. Over the years, there has been a lot of encroachment on the grazing areas by agriculture particularly by people who are migrating from the densely populated highland areas. This has led to expansion of areas under agriculture and a decrease in grazing areas and has been a major source of conflict in these areas.

3.3 Impact of land use changes on ecosystems and floristic diversity

3.3.1 Status of Economically Useful Plants along the Transects

Information from questionnaires revealed that a number of plants are very useful and are used in various ways. A number of people cited among the uses as medicinal plants, timber trees, fodder, shade trees for coffee and others have great cultural significance among the Chagga. Among the ailments treated using herbal medicine were stomach upsets, persistent coughs, ethno-veterinary use for both livestock and chicken, treating wounds, fever, fungicidals and many others. A total of 15 species were cited from Mbokomu transect as being economically useful, whereas in Machame about 24 species were enumerated. A complete list of plants, their uses, their level of abundance and their common species names are provided as Tables 4 & 5 below. These species and their uses compare well with those identified by O'Kting'ati *et al*. (1984) on the slopes of Mount Kilimanjaro.

The interviews further revealed that there has been a tremendous loss of biodiversity of economically useful plants due to habitat fragmentation in the recent years and the practice is still going on to date. This trend of loss in biodiversity can be explained by the existing land tenure system among the Chagga, which results into fragmentation of the land. By this it implies that the traditional system of distributing part of the family shamba (locally known as Kihamba) to every boy born in the family, results into less land available for cultivation in favor of building houses, and consequently results into fragmentation of the natural vegetation. Fragmentation of land is more pronounced in the lowlands that in the high altitudes. This is partly due to the reason that not all land is suitable for agriculture due to ruggedness and very poor skeletal soils. Such fragmented habitats, that are very common along the Machame transect are only used for grazing of livestock.

Table 4. Economically Useful Plants Cited by Informants along Mbokomu Transect

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 steudneri	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	Declining in abundance
Cordia africana	Mringaringa	Timber, fodder, coffee shade tree, fuel wood	Declining in abundance due to overexploitation
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.

Table 5. Economically Useful Plants Cited by Informants along Machame Transect

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, dysentry	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	Stomach 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 dysentry	Very common
Sansevieria conspicua	Katani pori	Ethno-veterinary 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

3.3.2 Species of High Conservation Value

In the context of this work, we consider species of conservation concern as any of the species, which fall in any one of the categories: endemic species, overexploited species for timber, species with narrow range of distribution, medicinal plants of which their harvesting mode was not sustainable, species difficult to propagate and keystone species. An example of keystone species are the figs, which have, fruits all year round and so are the cultivated fruit crops. Among the timber trees, *Olea welwitschii*, *Cordia Africana*, *Albizia schimperiana* and *Albizia gummifera* were species subjected to overexploitation in the range where they occur. Although two of the cited trees are coffee shade trees, they are declining in number due to timber production. Such species tend to decrease in number as one moves from the high altitudes to the lowlands.

On the issue of sustainability of harvesting medicinal plants, at least for four species cited, the harvesting mode is not sustainable because harvesting involves total de-barking of the individual plants or by obtaining the roots. This in fact has an effect of killing the trees and could be disastrous where only few individuals of the species are present. It was noted that *Erythrina abyssinica*, *Grewia burtii*, *Lannea stuhlmannii* and *Terminalia sericea* were species most affected by this unsustainable mode of 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 country and their amount remaining in the natural habitats is not ascertained.

Generally, the diversity of medicinal plants was highest in the uncultivated land than in the cultivated land, specifically with scrubland having the highest density. Elsewhere in Tanzania, the species cited above are already on the verge of extinction and therefore there is an urgent need to promote the conservation of their populations wherever they occur.

In view of this study, it is recommended to carry out intensive studies for all those species that are likely to disappear in the near future. Such studies should include their ecological and silvicultural aspects, and also to find out the distribution pattern of their populations wherever they occur in Tanzania. Such useful data could be used in future to update CITES appendices.

3.3.3 Impact on floristic diversity

Each land use category was characterized by certain group of plants, which served to indicate the prevailing soil conditions of the area. As an example, the maize fallows seemed to be of very poor soil fertility and showed a decreased species diversity. The fallows were dominated by a number of weed species to include *Trichodesma zeylanicum*, *Argemone mexicana*, *Physalis peruviana*, *Euphorbia hirta* and *Solanum incanum*. In areas, which were used for pastoral activities, a number of annual grass species were encountered such as *Eragrostis superba*, *Pennisetum polystachion*, *Heteropogon contortus* and *Eragrostis aethiopica* were common. Presence of the annual grasses and a number of unpalatable shrubs is a reflection of high grazing pressure exhibited in the area.

In the coffee/banana zone, the species diversity was also very low and this is accounted by land management practices. A number of species were common as indicators of cultivation and of humid soils such as *Oxalis corniculata*, *Bidens pilosa*, *Senecio abyssinica*, *Setaria homonyma*, *Digitaria scalarum* and *Launea cornuta*. Together with such weeds, were some cultivated crops such as *Ananas comosus* (pineapple), *Helianthus annuus* (sunflower) and *Carica papaya* (pawpaw).

The relationship between soil factors and species diversity for both Machame and Mbokomu transects is rather complex in that all four axes of the ordination space accounted for the observed relationship. However, axes I and II explain more than 60% of the observed variance, and so only these two axes will be considered in the discussion. The most influential variables, which accounted for the observed relationship are pH, altitude and organic carbon.

The first axis of the ordination space explains the observed variance by ca. 36.2%, and it depicts decrease in altitude from the forest belt through the coffee/banana zone to the lowlands where irrigation agriculture is practiced (Figures 2 & 3).

Generally, at agro-ecological zone level, species diversity and richness were observed to increase with decrease in altitude and also increase in the soil pH. This implies that the undisturbed lowlands, including the scrubland and the shrubland, which were used as pastureland were much more diverse having a number of grass species and shrubs which were not encountered anywhere in the highlands. The notable shrubs included *Commiphora africana*, *Boscia angustifolia*, *Croton pseudopluchellus*, *Grewia burtii*, *Solanum incanum*, *Hyptis suavelons* and *Ocimum suave*. Such species may serve to indicate overgrazing in the area. A number of palatable annual grasses in this vegetation type include *Eragrostis superba*, *Pennisetum polystachion*, *Heteropogon contortus* and *Eragrostis aethiopica*. Thus, with a decrease in altitude, the lowlands were favorable for grazing activities and to some extent cultivation of cereal cash crops such as maize, rice and a number of vegetables.

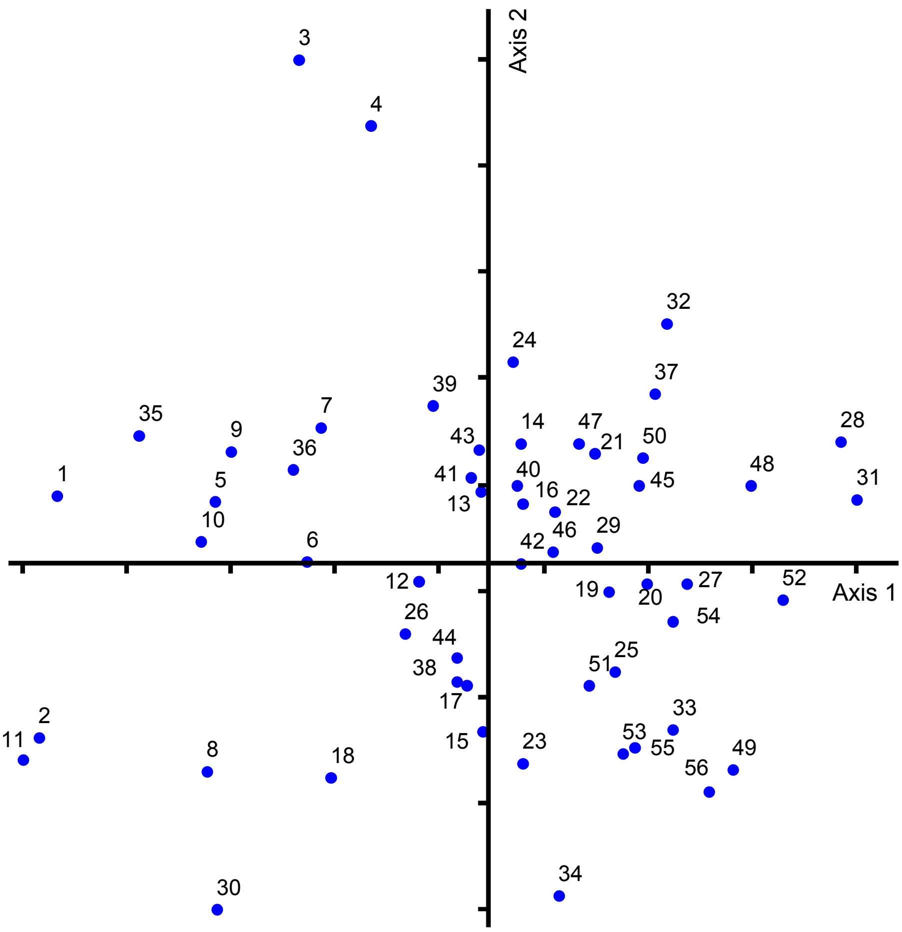


Figure 2. Scatter Diagram Depicted from Detrended Correspondence Analysis of Plots Under Different Land Use Systems in Machame and Mbokomu transects

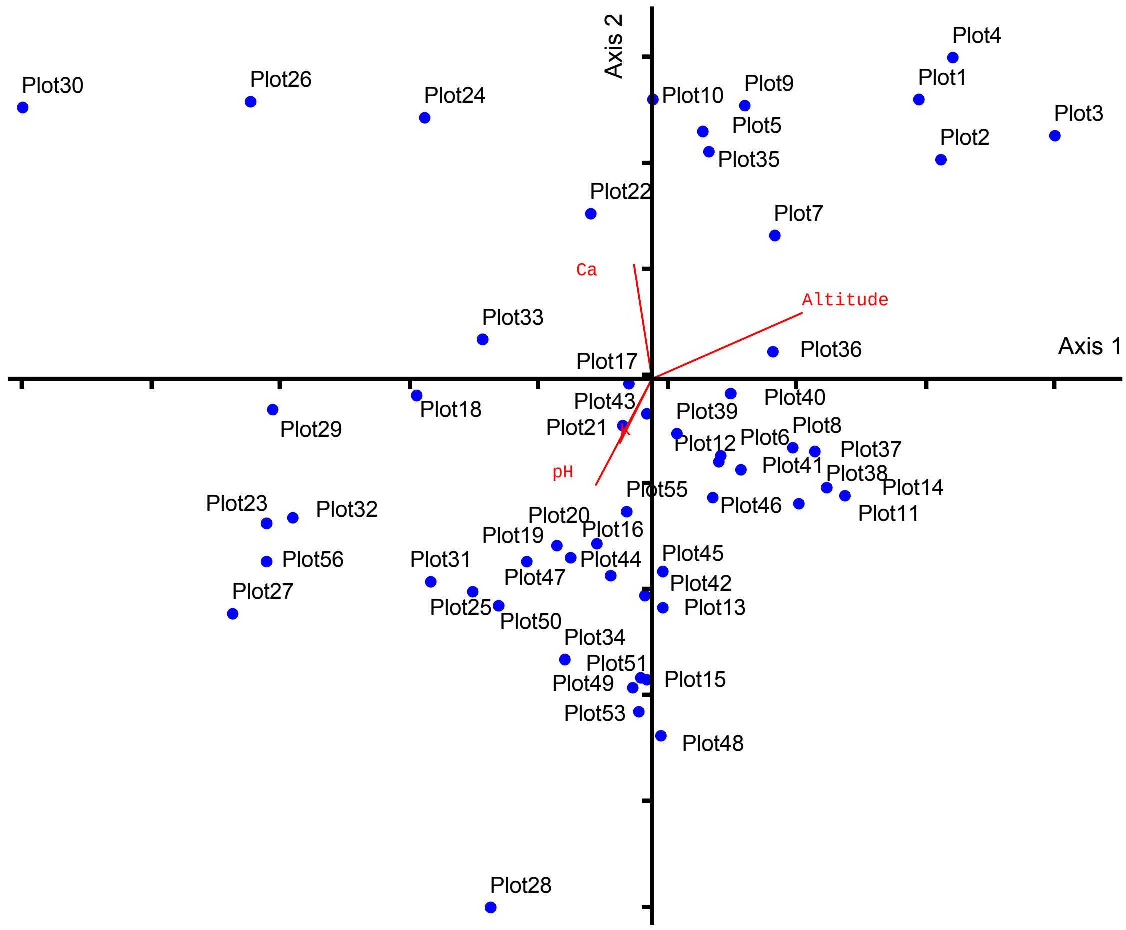


Figure 3. Scatter Diagram of the Plots Under Different Land Use Systems in Machame and Mbokomu transects as Depicted from Canonical Correspondence Analysis (CCA) results

At the transect level, there was no any definitive pattern of change in biodiversity and similarity of sites exhibiting the same land use along a gradient from high altitude to the irrigable lowlands at lower altitudes. This may lead to a suggestion that diversity observed along transects is dictated by factors such as soil conditions, amount of precipitation and land management system rather than altitude.

There was a tendency of decreasing species richness and diversity from uncultivated land to cultivated land along transects (Figures 4 and 5). At sub-transect level, the variation was not noticeable. This discrepancy can be explained by the management practices in cultivation of weeding which eliminates unwanted species and partly can be explained the use of agricultural inputs such as fertilizers and pesticides which modify the soil conditions, thereby favoring selectively specific species.

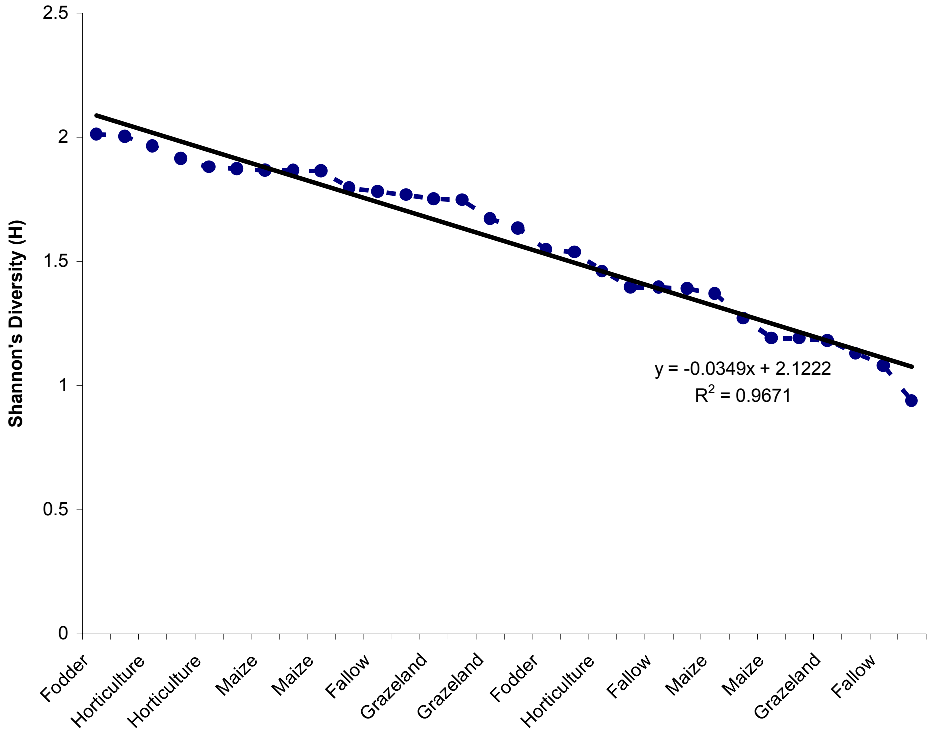


Figure 4. The Effect of Land Use Change on Biodiversity (Machame Transect).

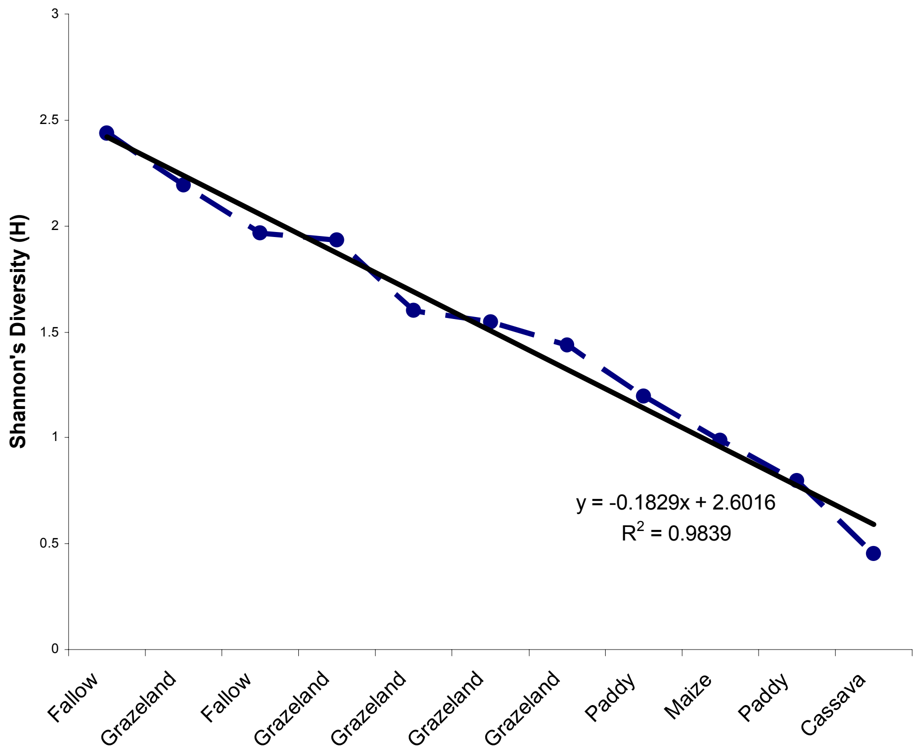


Figure 5. The Effect of Land Use Change on Biodiversity (Mbokomu Transect).

Machame transect (Figure 4) is much more diverse in terms of land use categories, species diversity and species richness compared to Mbokomu transect (Figure 5). Precipitation among other factors dictates the type of vegetation to be found in an area. The Machame transect is presumably wetter than the eastern side of the mountain hence can support high diversity of plants. In line with this it is possible that the coffee/banana zone can further be extended down the lowland depending on the availability of water. Prior to the commencement of the Lower Moshi irrigation scheme, there were neither banana nor coffee crops in the lowland, but now they are common.

Along Machame transect below 1000 metre altitude, there is very arid degraded vegetation confined to shallow skeletal soils, which may be termed as scrubland. This is an important zone where people practice agro-pastoralism. The unique feature of this land use type is a very high diversity of palatable annual grasses such as *Eragrostis superba, Pennisetum polystachion, Eragrostis aethiopica* and *Heteropogon contortus*. Research has shown elsewhere that intensive grazing has an effect of increasing the diversity of annual grasses in a rangeland (see O'Çonnor & Pickett, 1991), increasing seed influx passively into the area (Lyaruu, 1999) as well as reducing the perennial grasses which are obligate seed producers.

Another important feature of the scrubland is the presence of spiny, unpalatable woody herbs and shrubs that are left deliberately by the grazing ungulates. As for ecosystem integrity, overgrazed areas tend to loose palatable grass species that are overgrazed and gain unpalatable species that of not much economic use. Such species include *Hyptis suavelons* (Lamiaceae), *Ocimum suave* (Lamiaceae), *Solanum incanum* (Solanaceae), *Ocimum basilicum* (Lamiaceae), *Argemone mexicana* (Papaveraceae), to mention a few. These species, particularly *Argemone mexicana* and *Solanum incanum* wherever they occur are indicators of skeletal and very unfertile soils. Moreover, *Argemone mexicana* is a weed known to have a persistent seed bank and is a very inferior competitor with agricultural crops. This is a probable explanation as to why such species surface in farms after harvest of the crops.

The agricultural practice of tilling the land selectively favors certain groups of plants that feature as weeds. Secondly the practice of turning the soil exposes seeds to optimum germination conditions, thereby increasing the short-lived ephemerals. This is the reason why cultivated land contained much higher species diversity of weedy species.

3.3.4 Effect of Monoculture on Plant Species Diversity

Figures 6 and 7 illustrate the effect of monoculture and poly-culture on plant species diversity along Machame and Mbokomu transects, respectively. In both cases, species diversity is low in monoculture and high in poly-culture systems. Possible explanation to the observed loss of biodiversity in monoculture can partly be to changes in the land use practices in Kilimanjaro. To cite an example, horticulture is now a lucrative business when compared to traditional coffee farming system due to the high market price of horticultural crops. People are clearing coffee farms and replacing them with tomatoes, onions, cabbages, sweet potatoes *etc*. Generally, vegetable farming requires a lot of agricultural inputs such as fertilizers and pesticides that consequently have detrimental effect to the plants 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. Probably the domination of the weed *Oxalis corniculata* throughout the Coffee/Banana zone could explain the acidic conditions of the soil.

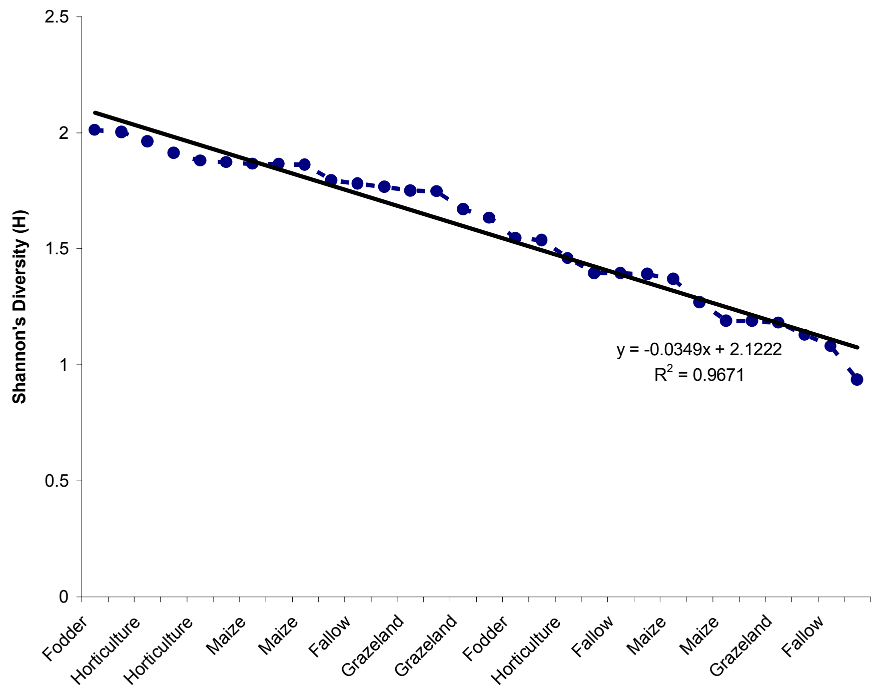


Figure 6. The Effect of Poly-vs Monoculture on Biodiversity along the Machame Transect.

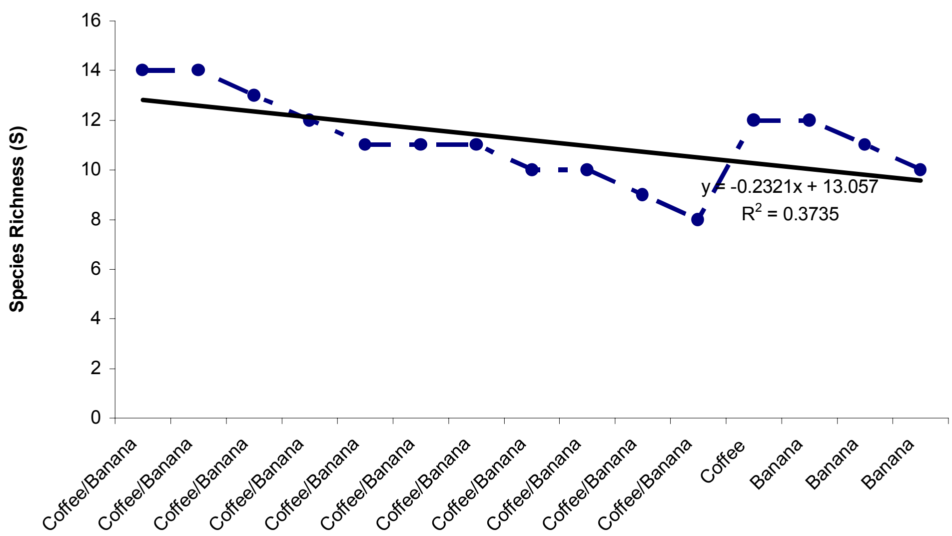


Figure 7. The Effects of Poly-vs Monoculture on Biodiversity along the Mbokomu Transect

3.4 Patterns of Fauna Change Related to Land Use Change

3.4.1 Impact on livestock numbers

Available records show that there has been a general decline of livestock numbers during the last three to four decades. A study by O'Kting'ati and Kessy (1991) showed a decline in the number of cattle, sheep and goats per farmer between 1960's and 1980's. They attributed this to the conversion of open pasture areas to agricultural production. Accordingly, in the middle zone, women and children were forced to travel up to 10 km in search of fodder. Moore (1986) also attributed this decline to changes in land use and subsequent decline in access to pasture and shortage of fodder. As observed by Moore (1986:130-131),

> "…*Cattle keeping seems to have substantially declined over the century. Cattle are expensive, and the absence of pasture in the banana belt, land shortage, and the increasing distance woman must go to obtain fodder have made the maintenance of cattle much more difficult that it used to be.…The large herds of hundreds of cattle said to have been held by some chiefs in the pre-1919 period have not been held by anyone, chief or not, for many decades. All evidence suggests that the number of beasts per capita has continuously decreased*…."

The decrease in the number of cattle has also been attributed to the introduction of coffee, which replaced cattle as a source of wealth. Today, farmers in the middle zone keep about 2-3 cattle per household, on the average, which are stall-fed. Poor farmers have a tendency of keeping more goats and sheep, presumably because these are less expensive to buy and less demanding on fodder resources than cattle (Oyan, 2000).

A similar situation has been observed in the Kitendeni corridor, where the average number of livestock per person at present is reportedly low compared to previous years (Noe, 2002). Majority of the people own between 1-5 cattle while only a few own between 5-20 cattle. The decline in livestock production over the years has been attributed to limited pastures following the expansion of agriculture into grazing areas, long periods of droughts and outbreak of disease in 1970s (Noe, 2002).

3.4.2 Impact on diversity of wildlife

Although there is paucity of data on the impact of land use changes on wild animal numbers and their distribution, the probability of local extinction and displacement of wild animals is high because of loss of forest, conversion of bush land into farms and settlements and blockage of migratory routes, which in turn lead to isolation of animals. As remarked by Newmark *et al*. (1991), forest loss and conversion have adversely affected the distribution of montane fauna and the size of these species, and thus in the near future the rare montane forest species could be seriously threatened by these activities. They, for example, report of the local extinction of the klipspringer (*Oreotragus oreotragus* and the mountain reedbuck (*Redunca fulvorufula)* during the last 45 years due to increasing isolation of Kilimanjaro National Park/Forest reserve. The Black Rhinoceros has become extinct on Mt. Kilimanjaro. The forest zone, however, is home to the largest known population of abbot's duiker, which is globally threatened.

Apart from loss of fauna, Newmark *et al*. (1991) also note that seven species of large mammals – the *Lepus crawshayi* (Crawshay's hare), *Papio cynocephalus* (baboon), *Crocuta crocuta* (spotted hyena), *Canis mesomelas* (black-backed jackal), *Canis adustus* (side-striped jackal), *Ichneumia albicauda* (white-tailored mongoose) and *Phacochoerus aethiopicus* (warthog) had been added to the mammal species checklist for Kilimanjaro National Park and Forest Reserve. This may be explained by tree falling and fires at the lower elevations of the forest, which have converted the habitat in some places into a secondary disturbed bush land

and have thus permitted these species, which were formerly not found in the national park and forest reserve to enter the reserve.

Available literature also indicates that wildlife was quite abundant on the lower southern, eastern and western slopes of Mount Kilimanjaro until about the 1930's (Newmark *et al*., 1991). Large mammals, including elephants, baboons, impala, spotted hyaena, white-tailored mongoose and warthog, among others, have, historically, been recorded in these areas. However, the heavy disturbance of and encroachment on forests for agriculture, logging and other human activities, have led to loss of fauna. Elephants, leopards, impala and baboons that were found in the lowland zone on the eastern, southern and western sides of Mount Kilimanjaro had by mid-1970's virtually disappeared (O'Kting'ati and Kessy, 1991). Today, these animals are found only on the northern side of Mount Kilimanjaro. The expansion of agricultural activities and human settlements over time, have, largely, been responsible for the disappearance of wildlife formerly found on the slopes of Mount Kilimanjaro and particularly in the lowlands.

Other studies, such as Millard (1954) and Child (1965) have shown that in the 1950's, the elephant population in the Kilimanjaro-Amboseli Ecosytem in the north-western part of Mount Kilimanjaro was in the order of 1,500. Millard (1954) also noted the existence of rhinoceros in the forest and around Kitendeni. Over the years, however, there was a drastic decline in elephant numbers, particularly since the late 1960's. Grimshaw and Foley (1990), for example, reported a decline in the Kilimanjaro elephants between 1970 and 1980. Recent records, however, suggest a recovery and steady increase in elephant population (MNRT, 2001)

A recent study by Noe (2002) in the corridor that links Kilimanjaro and Amboseli National Parks has also shown an increasing trend for such animals like elephants, buffaloes, velvet monkeys, zebra, eland, giraffe, warthogs, antelopes and rodents. This was confirmed by 81% of the respondents, who, during her survey, commented about the increase of some wild animal species while others were extinct. New species of antelopes, described as gerenuks, are reported to have been coming into the farms and eating crops, especially beans. Species like leopards, lions and ostrich, however, are reported to have decreased in the area while the rhinoceros had become extinct.

Although land use changes have contributed to increase, decline or loss of faunal species diversity, the impact of land use changes on the animal populations is not very distinct and straight - forward. This is because many other factors, like poaching and hunting, operated in the area during the same period when land use changes were taking place. As such it is difficult to attribute loss of faunal diversity sorely to land use changes. The increase in species diversity, however, can be said to result from habitat changes arising from changing land use and its impact on forests.

3.5 Impact of land use change on land degradation

3.5.1 The influence of land use and cover changes on soil fertility

An assessment of soil chemical fertility in the study area (Machame and Mbokomu) is shown in Figure 8a and b. Three major nutrients (nitrogen, phosphorus organic carbon contents) and pH have been used to describe chemical properties across the different agroecological zones per transect.

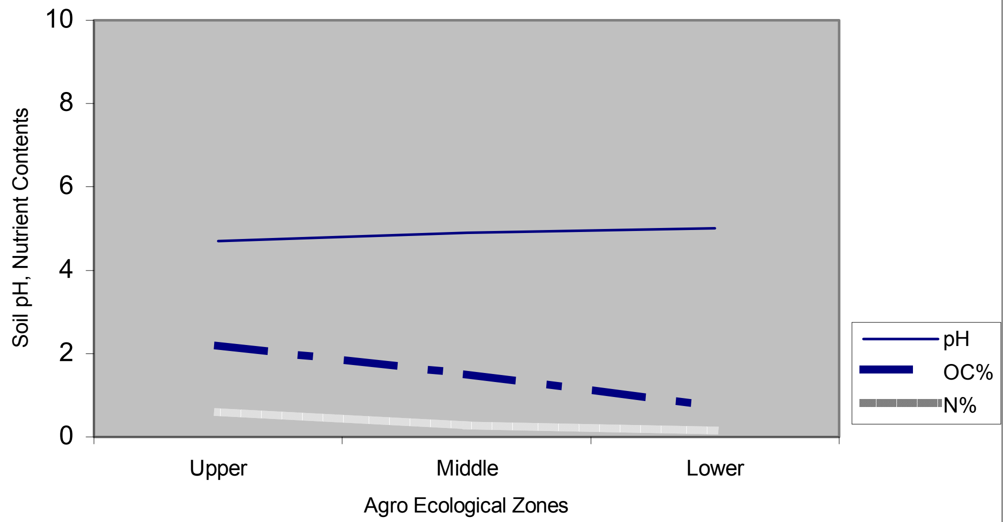


Figure 8a. Soil pH and Nutrient Variation Across Zones (Machame)

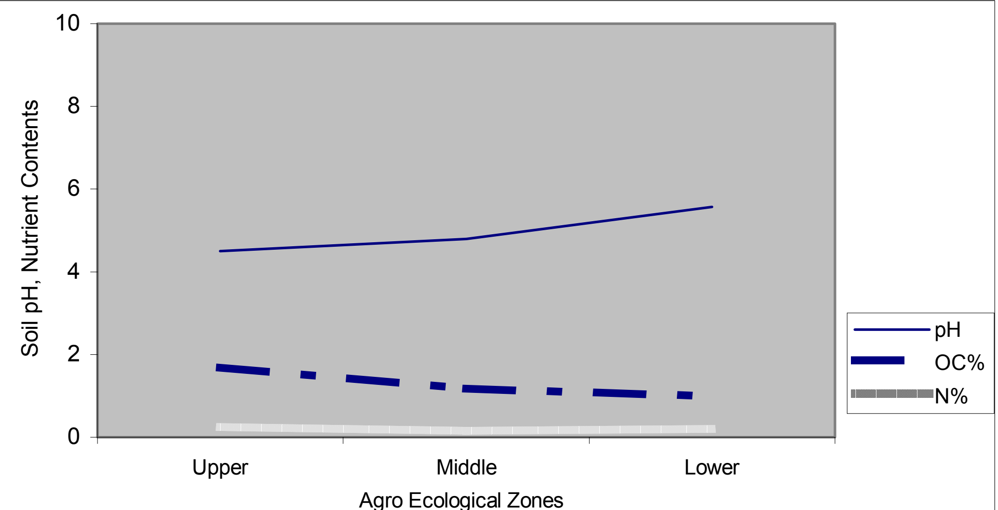


Figure 8b. Soil Nutrient Variations Across Zones (Mbokomu)

According to developed soil fertility ratings for Tanzanian soils (NSS, 1993), soil pH slightly increased from 4.7 in the upper zone to 5.0 across the Machame transect (Figure 8a). The soil pH range is classified as very strongly acid. A slight increase in soil pH is probably due to deposition of basic cations associated with erosion and irrigation. Soil organic carbon declined across the zone from medium range in the highland to very low range in the lower zone. A decline in organic carbon is due to vegetation clearing; burning and transfer of organic materials particularly crop residues to the upland areas. Under extreme acid conditions, most of soil nutrients such as N, P, Ca, Mg and K became unavailable and other toxic elements like Al, Mn and Cu became more available to toxic levels. Total nitrogen content ranged from high to low in the upper and low zones, respectively. This can be linked with decline in soil organic matter, which is a major source of nitrogen (Reuss and Johnson, 1986; Rowell, 1993).

Soil pH along the Mbokomu transect increased from very strongly acid to strongly acid in the Upper and lower zones respectively (Figure 8b). A slight increase is probably due to basic cation (Ca, Mg and K) accumulation in the lower zone due to erosion and irrigation. The variation in soil pH is largely influenced by the land use and cover types within zones across transects. Organic carbon along the Mbokomu transect is generally lower than in Machame transect (Figures 8a and 3b). It decreased from medium range (1.68%) in the upper zone to low range (0.99) in the lower zone. A decrease in soil organic matter is negatively related with soil erosion across the zone. Soil total N% is much lower in Mbokomu than in Machame transect. Available nitrogen is released to the soil through the process of organic nitrogen mineralization (Sakala, 1998; Majule, 1999).

Available phosphorus declined across the Machame transect compared to the Mbokomu transect (Figure 9). However, the available phosphorus is well above the high level (> 20 mgP/kg). Along the Mbokomu transect, soil available phosphorus declined in the upper and middle zones. An increase in the amount of available phosphorus in the lower zone is probably due to high levels of phosphorus application, particularly in crop fields.

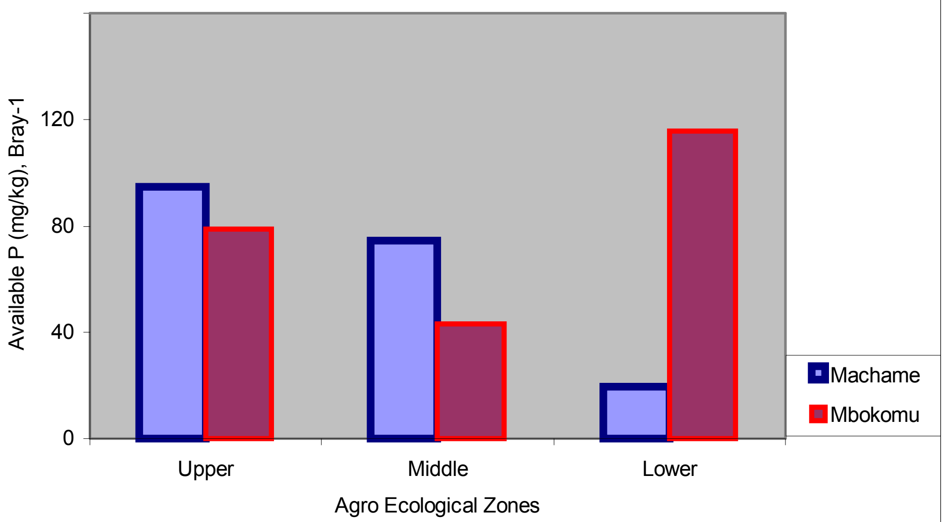


Figure 9. Soil Available phosphorus (mgP/kg) across Machame and Mbokomu Transects

a) Machame transect

Over the past few decades there has been a number of landuse changes in the region associated with changes in agricultural practices (O'Kting'ati and Kessy, 1991). The effects of individual landuse/cover types on soil degradation along the Machame transect are presented in Figures 10a through 10c). One of the indicators of land degradation is declining soil fertility (Rowell, 1993; Majule *et al.,* 1997). An assessment of the few key chemical soil fertility indicators (soil pH, OC% and total N%) reveled a variation in soil chemical characteristics associated with different landuse categories.

According to NSS (1993), soil pH in upper Machame is extremely acidity (<4.5) in pastureland and this restricts annual crop cultivation. Soil pH in other landuse types is very strongly acid (pH 4.5-5.0). The amount of soil organic carbon (%) is within the medium range. Soil nitrogen is very low in pastureland and woodlots increasing slowly to medium range in forest and grazing land.

In middle Machame (Figure 10b), the soil is extremely acid in woodlots. However, it is a bit high in other landuse types. Organic carbon also followed a similar pattern while soil total N is low in all landuse types. Broadly, soil degradation is marked in woodlots followed with grazing land.

In the lower Machame (Figure 10c), extremely soil acidity was observed in the soil under paddy cultivation. Low soil pH is probably due to nitrogen transformation associated with flooding of rice fields (Rowell, 1993). There is a marked regeneration in soil organic carbon in soils with the exception of the grazing land.

Organic carbon contents, soil pH and total N% in the land under coffee/banana is relatively stable due to the following reasons;

- Application of animal manures and crop residues
- Prevention of leaching processes through mulch application
- Proper agronomic practices such restricting burning

The practice of using organic manure resulting from zero grazing and mulches which was very common along Machame transect should, therefore, be encouraged as a means to improving soil quality as well as increasing soil pH and consequently productivity and species diversity. Organic fertilization not only increases soil fertility and soil water holding capacity, but it also buffers the soil against pH changes. Soil fertility also can be regenerated as the land is being converted from agriculture to controlled grazing (zero grazing), which is restricted near Chagga home gardens.

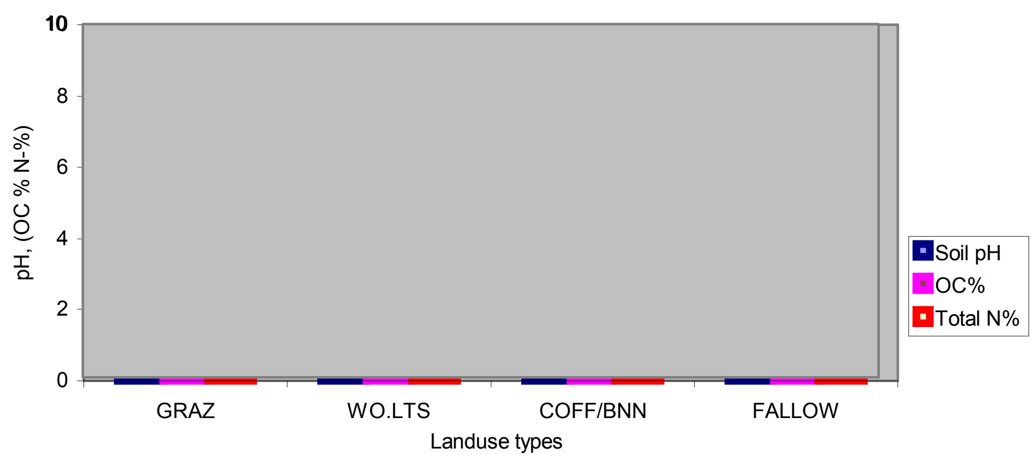


Figure 10b. Soil Fertility in Different Landuse/cover types (Mid Machame)

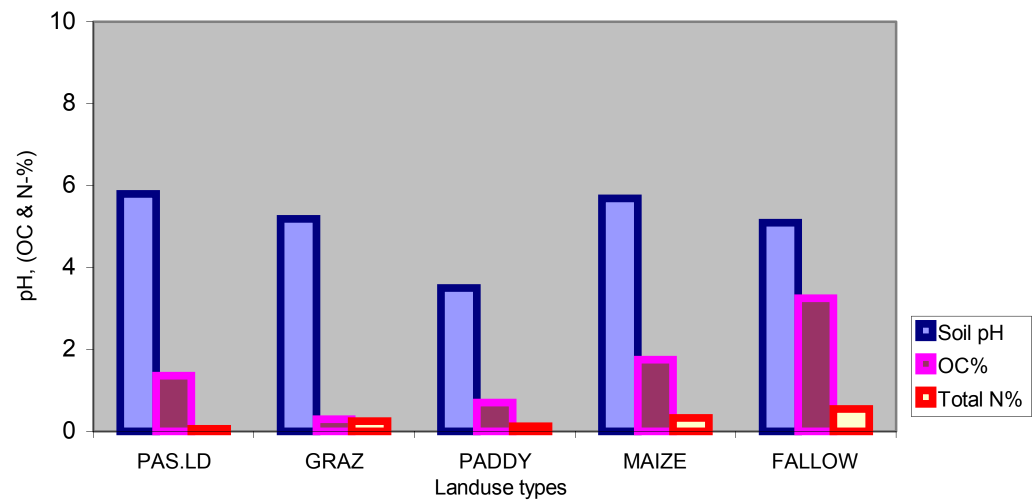


Figure 10c. Soil Fertility in Different Landuse/cover types (Lower Machame)

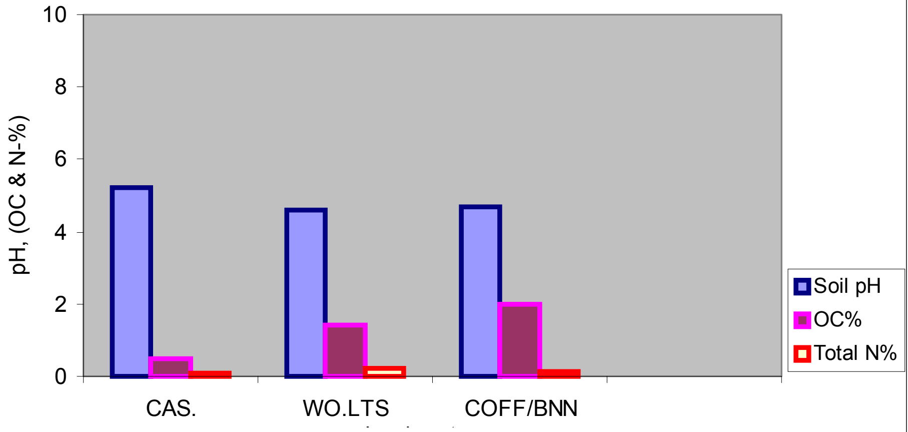


Figure 10e. Soil Fertility in Different Land use/cover types (Mid Mbokumu)

Declining soil fertility in the lower Machame is probably due to intensive land utilization associated with overgrazing and transfer of organic matter to the upper potential areas. There are no remnants of natural forest, which could serve as a mean of regenerating soil fertility

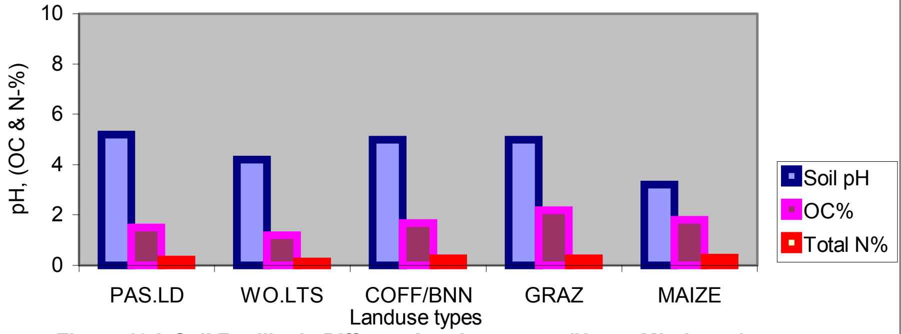


Figure 10d. Soil Fertility in Different Landuse types (Upper Mbokomu)

through cycling of organic matter.

b) *Mbokomu transect*

Field observations indicated that land degradation is a serious problem along the Mbokomu transect as compared to Machame transect. Historically, after clearing the natural forest in most parts of the upper Mbokomu, the land was cultivated with different crops. Depletion in soil nutrients and acidification forced farmers to abandon their fields and converted them into woodlots dominated with *Eucalyptus* spp. or *Grevillea* sp planted for the purpose of demarcating field plot boundaries and to provide shade to coffee plants. Soils in upper Mbokomu (Figure 10d) under woodlots are extremely acid (pH < 4.5). Soils under other land use types are strongly acid (pH 5.1-5.6). The availability of other nutrients is also high in similar soils (Table 4).

Soil organic carbon (%) is low (<0.6%) in the soil under *Eucalyptus* woodlot and medium range in other landuse types (Figure 10d). Total nitrogen is low but is lowest in the land use under Eucalyptus woodlots.

In the middle zone (Figure 10e), there is an improvement in soil pH in most land use types (strongly acid). An improvement in soil pH is probably due intensive management of soils through increased organic matter applications. Organic matter is low in the soil under cassava indicating degradation of nutrients and it is in the medium level in soils under woodlots and in mixed farming (coffee and banana).

In the lower zone (Figure 10f), soil pH is very strongly acid in the land under coffee and maize alone. Other land use types have their soil pH slightly large within the strongly acid range. The acidity in the coffee/maize farming systems is probably due to the application of artificial fertilizers and copper fungicides in treating coffee berry disease. Field observation also indicated low organic matter content in the lowland and this is validated by laboratory test, which revealed very low soil organic carbon in all land use types (Figure 10f). Total soil nitrogen is low in all land use type categories.

3.6 A linkage between land use types and soil erosion

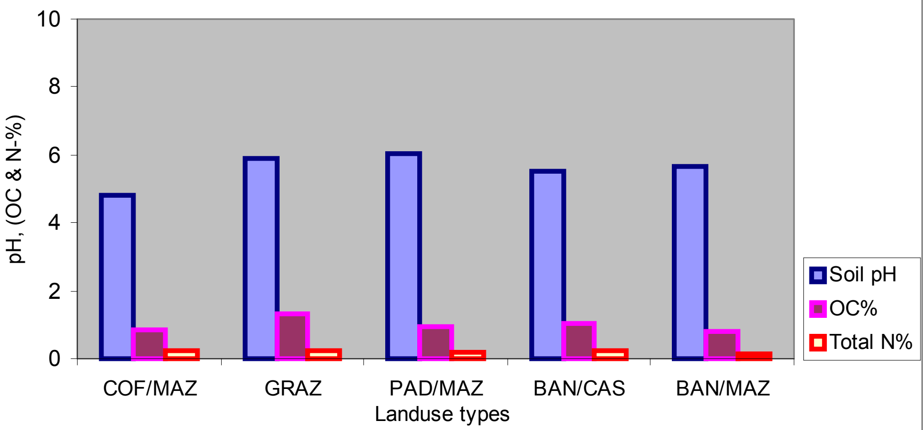


Figure 10f. Soil Fertility in Different Land use/cover types (Lower Mbokumu)

In order to assess the magnitude of soil erosion in different zones and land use types, a criterion was set based on field observation (Table 6). In this case E0 means no visible evidence of soil erosion, E1 means slight erosion, E2 means moderate soil erosion and E3 severe soil erosion.

Table 6. Soil erosion classes in the different land use and cover types

Transect	Upper	Middle	Lower
Machame	Pasture land (E0) Coffee banana (E0) Maize (E1) Woodlots (E2) Banana (E2)	Pasture land (E0) Coffee banana (E0) Woodlots (E0) Banana (E0) Maize (E1) Fallow (E1)	Paddy (rice) (E0) Maize (E1) Cassava (E0) Fallow (E1)
Mbokomu	Pasture land (E0) Coffee banana (E0) Maize (E1) Woodlots (E2) Banana (E2)	Coffee banana (E0) Woodlots (E1) Cassava (E1)	Grazing land (E0) Coffee/maize (E0) Paddy/maize (E0) Banana/cassava (E1) Banana/maize (E1)

Soil erosion prevalence in Machame transect was common in all three major agro-ecological zones. The magnitude of soil erosion that is mainly due to water movement toward the slope direction varies with land use types. Based on field observations, soil erosion in Machame transect varied with land use types. In the upper Machame soil erosion was moderate in woodlots and banana fields. It was not visible in the pasture and in coffee/banana land use types.

In the mid Machame, there is no visible soil erosion in most land use types with the exception of land under maize and fallow land use types, where erosion is slight (E1). In the lower Machame a similar pattern was observed.

High soil erosion in the upper zone was probably due to high slope and destruction of soil structure by woodlots particularly *Eucalyptus* spp. Field observation indicated that there is evidence of some gullies developing in the land under woodlots. Poor cycling of organic matter was also observed and this can be linked with soil structure deterioration. Poor soil structure in the land under pure maize and banana farming also contributed to soil erosion. On the other hand, land covered with grasses and field densely populated by coffee and banana had no marked soil erosion.

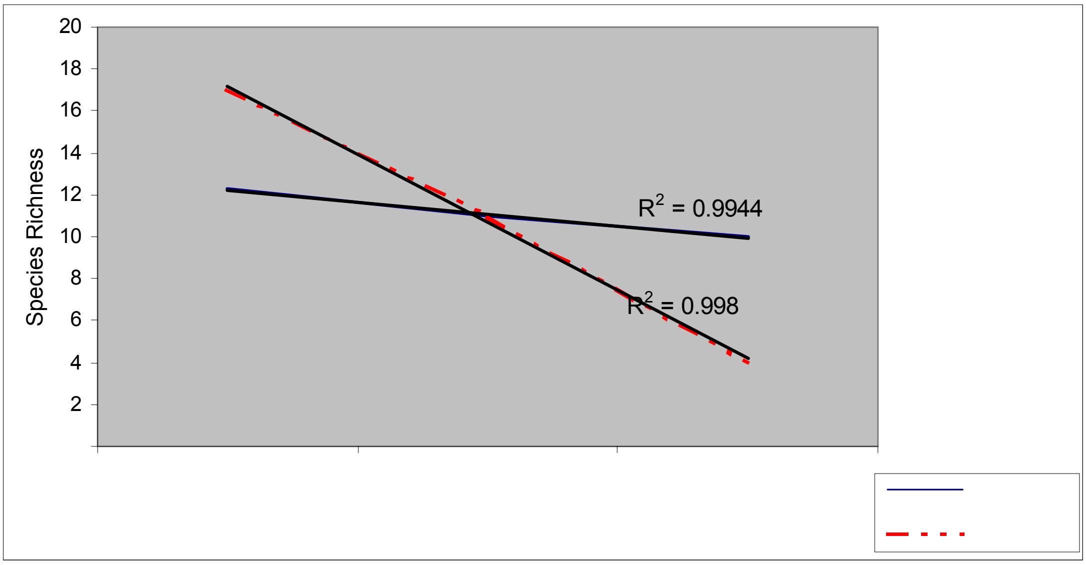
Observed soil erosion in the lower zone particularly in the land under pure maize is probably due to land preparation practices such as use of tractors, which tends to loosen soils and thus creating chances for both water and wind caused soil erosion to take place. Soil erosion in fallow land is probably due to severe degradation following intensive cultivation of the land and overgrazing.

The magnitude of soil erosion also varied across zones and land use types along the Mbokomu transect. Soil erosion in the upper zone was almost similar to that of Machame In mid Mbokomu, there is no evidence of erosion in the soil under pasture and coffee/banana. Erosion increased in pure mono-cropping (maize, banana) as well as in woodlots. In the mid and lower Mbokomu, soil erosion followed a similar pattern like that of Machame. In view of the number of land use types assessed in the field, broadly soil erosion increased along the transect from E0 to E2 values probably due to remove of vegetation cover and overgrazing particularly in the lower zones. Soil erosion was much on the higher side in the Mbokomu transect as compared to Machame transect.

3.7 The linkages between land degradation and Changes in Biodiversity

3.7.1 Relationship between soil erosion and species richness

A linkage between species richness and soil erodibility is presented in Figure 11 Values of species richness used to construct the linkage are those reported in section 2.2 and were obtained during the fieldwork. Generally, there are more species in Mbokomu than in Machame transect particularly in the upper zone. Results indicate a negative correlation (Figure 11) between species richness and soil erosion in both transects. Soil erosion being a form of land degradation, it manifest soil fertility and water availability to the plants. An increase in soil erosion tends to remove 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, have a significant impact on the number and distribution of species available. Changes in species richness (decrease by 14) along the Mbokomu transect seem to be much high as compared to Machame. This is probably due to soil stability and water availability in the Machame transect.



4.0 GENERAL CONCLUSIONS

From the findings of this study, it is evident that the slopes of mount Kilimanjaro have undergone significant land use changes over the past decades, and that these changes have had significant impacts on both floral and faunal diversity and on land degradation. It has been shown that the previously forested areas in the middle and upper zones have been transformed into cultivated areas, with the Chagga agroforestry system characteristic of the home gardens characterizing much of the landscape. This is a mixture of trees (both planted and indigenous) interplanted with crops and fodder grass. The exotic plant species have in many cases replaced indigenous species except where the latter were purposefully left standing in the fields either for shade, timber, fodder, fuelwood or for soil and water conservation. In the lowlands, bushland has given way to agriculture, which has expanded at the expense of grazing land.

Changes from natural vegetation to cultivated land have, however, led to decrease in indigenous plant species richness and diversity and an increase in exotic plant species. At the same time, there has been an increase in crop diversity following the diversification of crops by the farmers. It has been shown that some farmers were uprooting coffee trees and planting tomatoes, onions and other vegetables instead because of favorable prices. Where there is monoculture, the tendency has been for species diversity to decrease compared to polyculture system.

Although it is not possible to link directly the decrease in animal numbers to land use changes because of the interplay of other factors such as poaching and hunting, available data indicate that while some animals have decreased in number or even disappeared, others such as antelopes, warthogs and monkeys seem to have increased, particularly in the wildlife corridor. In the lowlands, however, all wild animals that were previously recorded there have disappeared completely because of increased human activities such as agriculture and settlements. Records also indicate a decrease in number of domesticated livestock, particularly cattle in the middle and lowland zones.

With regard to land degradation, it is evident that soil erosion incidences are common in both transects and in the three major ecological zones. Although soil erosion is a function of slope whereby it decreases with slope, much soil erosion in the lower zone is due to poor agronomic practices, overgrazing in marginal land and burning. Land under Eucalyptus woodlots and pure mono-cropping, particularly maize and banana are vulnerable to erosion due to poor soil physical conditions. This is a reflection of poor land management. Therefore, soil erosion can significantly be reduced by proper incorporation of organic residues, sustainable agronomic practices such conservation tillage and controlled grazing.

A negative correlation between species richness and soil erosion, a form of land degradation, has been established in both transects. This implies that there is more plant species in the land with low soil erosion probably due to suitable soils and water availability. Increased soil erosion from E0 to E2 ratings, however, tends to decrease species richness. Bare soils associated with vegetation clearing are one of the major causes of species loss.

From the above, it can be concluded that land use changes and associated land cover changes have led to changes in biodiversity of both floral and fauna with the number and diversity of some species having increased while others have become lost or even extinct. Land use changes have also been associated with land degradation reflected in the loss of soil fertility and increased soil erosion. These have in turn negatively affected species richness.

5.0 References

Allan, W. 1965. *The African Husbandman.* Oliver and Boyd, Edinburgh

Anderson, G.D. 1982. *The Soils and Land Use Potential of the Southern and Eastern Slopes of Kilimanjaro, Tanzania.* Resource Management paper No. 1, IRA and International Development Program, Clarke University, Worcester, Massachusets.

Boesen, N,J., Kikula, I.S. and Maganga, F.P. 1999. *Sustainable Agriculture in Semi Arid Tanzania*. Dar es Salaam University Press, Dar es Salaam.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science* 59: 39 - 45.

Bremner, J.M. and Mulvaney, C.S. 1982. Total nitrogen. In: *Method of Soil Analysis Part 2. Agronomy Monograph No. 9. (Edited by Page, A.L., Miller, R.H. and Keeney, P.R.)* American Society of Agrnomy Inc., Madison, Wisconsin. Pp. 149 - 157.

Child, G.S. 1965. Some notes on the mammals of Kilimanjaro. *Tanganyika Notes and Records* 64:77-89.

Dejene, A., Shishira, E.K., Yanda, P.Z. and Johnsen, F.P. 1997. *Land Degradation in Tanzania. Perception from the village*.

Exell, AW and Wild, H (eds) 1960. *Flora Zambesiaca*. Crown Agents for Overseas Governments and Administration. Flora Zambesiaca Managing Committee.

Fernandez, E.C.M., O'Kting'ati, A. and Maghembe, J. 1984. The Chagga homegardens: a multistoried agroforestry cropping system on Mt. Kilimanjaro (Northern Tanzania). *Agroforestry Systems* 2:73-86.

Grimshaw, J. & C. Forley 1990. *Kilimanjaro Elephant Project*. Final report to Friends of Conservation. Nairobi, Kenya

Holand, I.S. 1996. *More People, More Trees: population Growth, the Chagga Irrigation System, and the Expansion of a sustainable Agroforestry System on Mount Kilimanjaro*. Msc Thesis, Norwegian University of Science and Technology, Trondheim.

Iliffe, J. 1979. *A modern History of Tanganyika*. Cambridge University Press, Cambridge.

JICA. 1977a. *The Kilimanjaro Region Integrated Development Plan Summary Report*. Vol. 1. Overseas Technical Cooperation. Japan International Cooperation Agency, Japan.

JICA. 1977b. *The Kilimanjaro Region Integrated Development Plan Summary Report*. Vol. 11. Overseas Technical Cooperation. Japan International Cooperation Agency, Japan.

JICA. 1977c. *Water Master Plan, Kilimanjaro Region*, Vol. V. Technical Report: Irrigation. Ministry of Water, Energy and Minerals, Dar es Salaam.

Kangalawe, RYM 2001. *Changing Land-Use Patterns in the Irangi Hills, central Tanzania. A study of soil degradation and adaptive farming strategies.* PhD dissertation, Stockholm University, Sweden.

Lyaruu, HVM 1999. Seed rain and its role in the recolonization of degraded hill slopes in semi-arid central Tanzania. *Afr. J. Ecol*. **37**: 137-148.

Magurran, AE 1988. *Ecological Diversity and its Measurements*. Chapman & Hall, London.

Majule, A.E. (2003). *Impacts of Land Use/Land Cover Changes on Soil Degradation and Biodiversity on the Slopes of Mount Kilimanjaro, Tanzania.* LUCID Working Paper Series Number 26.

Majule, A.E. 1999. *The Effects of Organic Residues and Elemental Sulphur Additions to Soils of Southern Tanzania*. PhD Thesis. Reading University. UK. 238pp.

Majule, A.E., Toper, C.P. and Nortcliff, S. 1997. The environmental effect of dusting cashew (*Anarcadium occidentale* L) trees with sulphur in southern Tanzania. *Tropical Agriculture Journal (Trinidad)* 74: 25 - 33.

Maro, P.S. 1974. *Population and land resources in the northern Tanzania:the dynamics of change 1920-1970*.Ph.D thesis, University of Minessota.

Masao, F.T. 1974. The irrigation system in Uchagga: An Ethno-historical approach. *Tanzania Notes and Records* 75:

Millard, J. 1954: The Fauna of Kilimanjaro: *Tanganyika Notes and Records* 36: 47-53

Ministry of Natural Resources and Tourism 2001. *Management Plan for the African Elephant in Tanzania.* Unpublished.

Misana, S.B. 1991. *The Importance of Mount Kilimanjaro and the needs for its integrated management and conservation*. In. Newmark. W.D. Ed. *The Conservation of Mount Kilimanjaro*. IUCN, Gland and Cambridge Pp 103-110

Moore, S.F. 1986. *Social Facts and Fabrications: "Customary" Law on Kilimanjaro, 1880-1980.* Cambridge University Press, Cambridge.

Murphy, J. and Rilley, J.P. 1962. A modified single solution method for determination of phosphate in natural water. *Analytica Chemica Acta* 27: 31 - 36.

Nelson, D.W. and Sommers, L.W. 1982. Organic carbon In: *Method of Soil Analysis Part 2. Agronomy Monograph No. 9. (Edited by Page, A.L., Miller, R.H. and Keeney, P.R.)* American Society of Agrnomy Inc., Madison, Wisconsin. Pp. 561 - 573.

Newmark, W. D, Forley, C.A.H, Grimshaw J.M, Chambegga, D.R and Rutazaa, A.G. 1991: Local extinction of large mammals within Kilimanjaro National Park and Forest Reserve and implications of increasing isolation and forest conversion. In Newmark, W.D. Ed. *The Conservation of Mount Kilimanjaro*. IUCN, Gland and Cambridge Pp. 35-46.

Noe. C 2002: *Impacts of land use changes on the wildlife. A case of Kilimanjaro-Amboseli wildlife corridor, Tanzania.* M.A Dissertation, University of Dar es Salaam, Tanzania.

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. Pp 71-80

O'Kting'ati, A., Maghembe, J.A., Fernandes, E.C.M. and Weaver, G.H. 1984. Plant species in the Kilimanjaro agroforestry system. *Agroforestry Systems* 2:177-186.

O'Connor T.G. and Pickett, G.A. 1991. The influence of grazing on seed production and seed banks of some African savanna grasslands. *J. Appl. Ecol*. **29**:247-260.

Oyan, T. 2000. *Catchment Management on Mount Kilimanjaro*. Msc Thesis, Norwegian University of Science and Technology, Trondheim.

Reuss, J.O. and Johnson, D.W. 1986. Acid deposition and the acidification of soils and waters. *Ecological Studies* 59: 25 - 31.

Rowell, D.L. 1994. *Soil Sciences: Methods and Applications*. Longman, London. England. pp. 153 - 173.

Sakala, M.G. 1998. *The Effect of Incorporating Plant Residues on Soil Acidity in The Management of Tropical Soils.* PhD Thesis, Reading University, UK. 220pp.

Sevaldsen, K. 1997. *Competing Interests and Growing Demand for Water. Irrigation in the Lowlands of Kilimanjaro: The Case of Makuyuni Ward.* Msc Thesis, Norwegian University of Science and Technology, Trondheim.

Soini, E. 2002. *Changing Landscapes on the Southern Slopes of Mt. Kilimanjaro, Tanzania: An Aerial Photo Interpretation Between 1961 and 2000.* World Agroforestry Centre (ICRAF) Working Paper no. 2002-1.

Sørensen, TA 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analyses of vegetation of Danish commons. *Biol. Skr., Kongl. Danske Vidensk. Selsk*. **5**: 1-34.

Stohlgren, TJ; Falker, MB and Schell, LD 1995. A Modified Whittaker Nested Vegetation Sampling Method. *Vegetatio* **17**: 113-121.

Tan, K.H. 1996. *Soil Sampling, Preparation and Analysis*. Marcel Dekker Inc., New York.

Turner II, B.L., Clark, W.C., Kates, R.W., Richards, J.F., Mathews, J.T. and Meyer, W.B. eds. 1990. *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere Over the Past 300 Years.* Cambridge University Press, Cambridge.

Turner II, B.L., Meyer, W.B. and Skole, D.L. 1994. Global land-use/land cover change: towards an integrated Program of Study. *Ambio* 23(1): 91-95

Turrill, W and Milne-Redhead, E (eds) 1952. *Flora of Tropical East Africa*. Balkema, Roterdam.