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

# Plant Biodiversity Component of the Land Use Change, Impacts and Dynamics Project, Mt. Kilimanjaro, Tanzania

LUCID Working Paper Number: 40

By

Herbert Valentine Lyaruu

Department of Botany
University of Dar es Salaam
P.O. Box 35060
Dar es Salaam, Tanzania
lyaruu@botany.udsm.ac.tz

November 2002

**Address Correspondence to:**
LUCID Project
International Livestock Research Institute
P.O. Box 30709
Nairobi, Kenya
E-mail: lucid@cgiar.org
Tel. +254-20-630743
Fax. +254-20-631481/ 631499

# Plant Biodiversity Component of the Land Use Change, Impacts and Dynamics Project, Mt. Kilimanjaro, Tanzania

The Land Use Change, Impacts and Dynamics Project
Working Paper Number: 40

By

Herbert Valentine Lyaruu

Department of Botany
University of Dar es Salaam
P.O. Box 35060
Dar es Salaam, Tanzania
lyaruu@botany.udsm.ac.tz

November 2002

**Address Correspondence to:**
LUCID Project
International Livestock Research Institute
P.O. Box 30709
Nairobi, Kenya
E-mail: lucid@cgiar.org
Tel. +254-20-630743
Fax. +254-20-631481/ 631499

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.

## TABLE OF CONTENTS



## TABLES



## FIGURES

## A. INTRODUCTION

Tropical drylands are generally nutrient-poor ecosystems with a potentially low productivity due to insufficient and erratic rainfall, and are highly susceptible to vegetation and soil degradation. Whereas soil degradation results from wind and water erosion, waterlogging, salinization, alkalization, acidification, pollution and compaction, vegetation degradation manifests itself as reduction of vegetation cover or changes in species composition and diversity. It is estimated that 2 billion hectares of soil have become degraded, specifically due to human activities, since 1945, out of these 1.5 billion hectares being in developing countries (see Kangalawe, 2001 and references cited therein). Soil erosion and low fertility in agricultural lands are perceived as the greatest threat to soil productivity in dryland Africa (Kangalawe, 2001).

A survey was carried out along two transects located on the southern slopes of Mount Kilimanjaro, with an overall objective of finding out how different land use practices affect plant biodiversity and consequently land degradation. The two transects run 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.

### A.1. Specific objectives of the study

The study had three main objectives:

1. To compare biodiversity of areas which have been subjected to different land use practices.

2. To establish the relationship between soil conditions and the extant vegetation in the areas understudy.

3. To establish plant bio-indicator species that are associated with different land use practices and soil conditions, in attempt to link them with soil/land degradation.

### A.2. Hypotheses

1. Specific land use practices and soil management such as weeding or monoculture cropping greatly influences species composition of any given area.

2. Species diversity is likely to increase with increase in soil fertility.

3. The rate of deterioration of land/soil quality can be established based on the diversity and number of indicator species.

## B. METHODOLOGY

Reconnaissance survey was conducted in the two transects of Machame and Mbokomu prior to the sampling exercise in order to explore the existing variations in land use patterns and to assist the team in judging whether sampling the two transects could address the objectives outlined above.

Along each transect, 12 sub-transects which run 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 coffee/banana zone (both high and mid-altitude zones); the cultivated land and the lowlands where the main activity was pastoralism and irrigation agriculture. The length of a sub-transect was 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.

In accordance with the sampling protocol outlined in the LUCID cookbook (Maitima and Olson 2001), 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.

In the sampling procedure, individual plants were identified to species level, counted and recorded, and the 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 over time or were increasing. Information was also sought about species which have become extinct in the study area, their possible cause of the extinction and habitats where such species were found.

Composite soil samples were collected from the vegetation plots and were later analysed in the laboratory using the standard procedures for cation exchange capacity, pH, organic carbon, exchangeable bases and total nitrogen. The soil analysis results were combined with the vegetation data 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 $\mathbf{H' = -\sum \mathit{p}_i ln \mathit{p}_I}$, 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 $\mathbf{E = H'/lnS}$, 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** is total number of species found in sample **A** and **B** represents the total number of species found in sample **B**.

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 which 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 Excel & Wild (1960-) in Flora Zambesiaca.

**B.1. Limitation of the Results**

- Although sampling technique which 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 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.

## C. RESULTS AND DISCUSSION

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 on 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. The results are presented as Figures 1-6.

### C.1. Multivariate Analysis Results

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 account 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 account 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 7 and 8).

### C.2. Diversity and Species Richness Patterns along Transects

Generally 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 which were used as pastureland to include the scrubland and the shrubland were much more diverse having a number of grass species and shrubs which were not encountered anywhere else in the transects. The notable shrubs included *Commiphora africana*, *Boscia angustifolia*, *Croton pseudopluchellus*, *Grewia burtii*, *Solanum incanum*, *Hyptis suavelons* and *Ocimum suave*. A number of palatable annual grasses in this vegetation type include *Eragrostis superba*, *Pennisetum polystachion*, *Heteropogon contortus* and *Eragrostis aethiopica*.

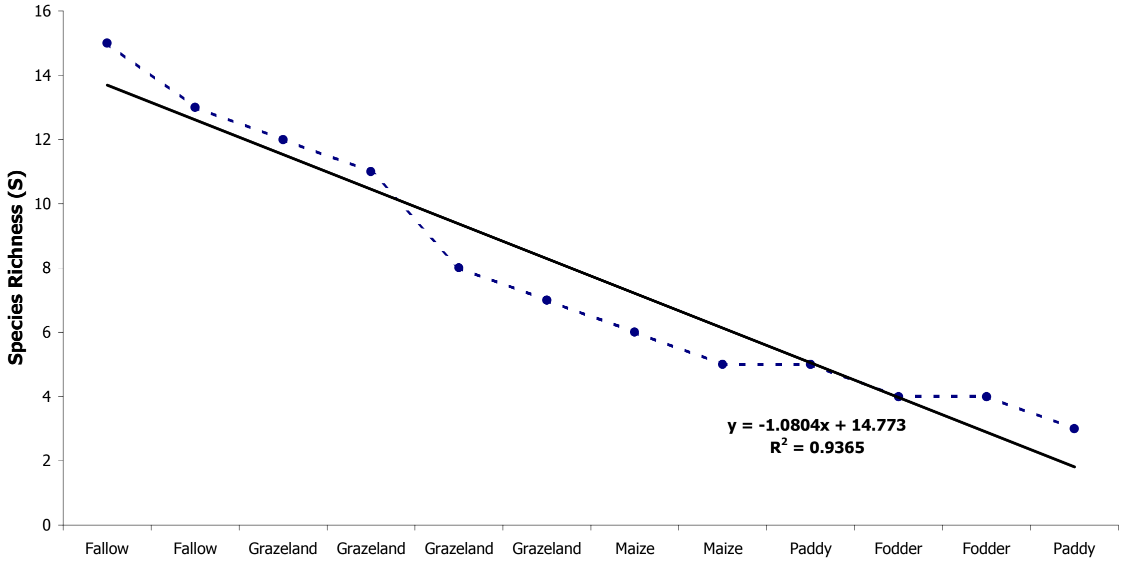


**Figure 1: Effect of Land Use Change on Biodiversity (Mbokomu Transect)**

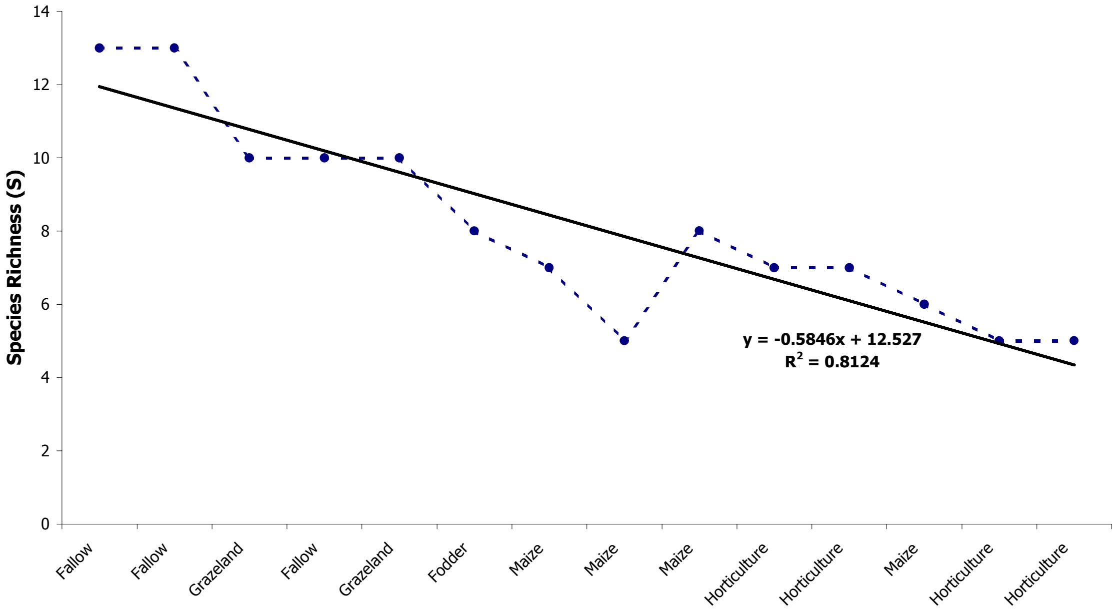


**Figure 2: Effect of Land Use Change on Biodiversity (Machame Transect)**

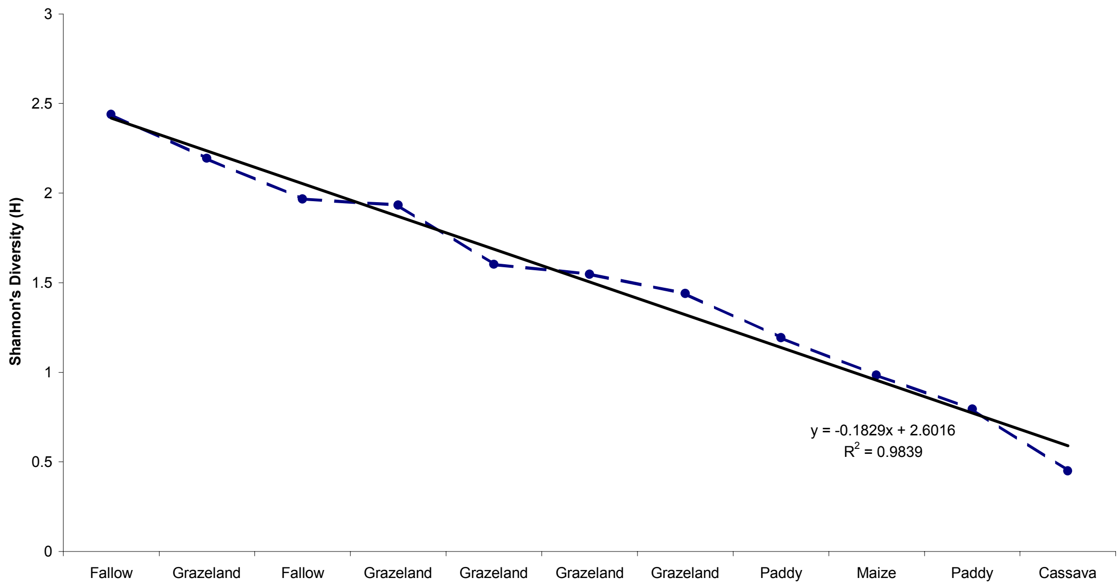


**Figure 3: The Effect of Land Use Change on Biodiversity (Mbokomu Transect).**

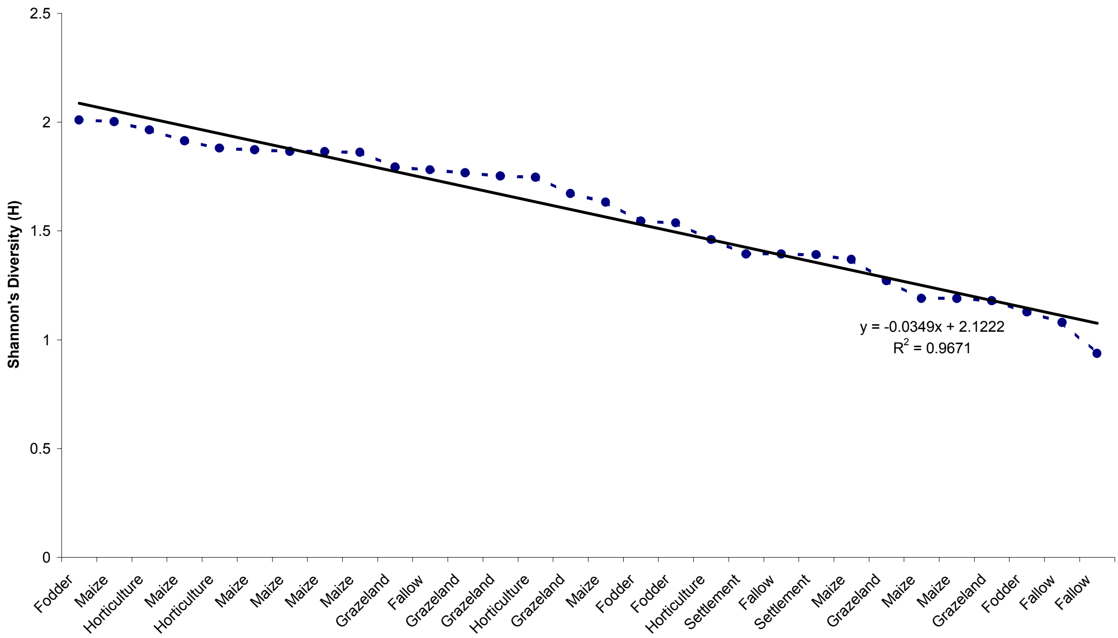


**Figure 4: The Effect of Land Use Change on Biodiversity (Machame Transect).**

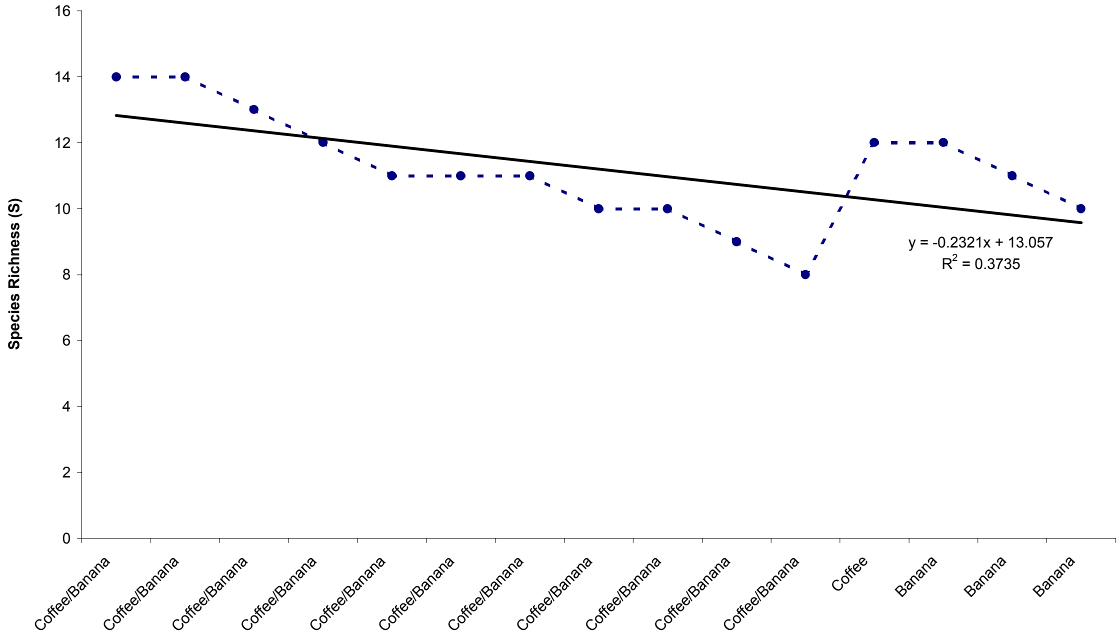


**Figure 5: The Effect of Land Use Change on Biodiversity (Poly- vs Monoculture Mbokomu Transect).**

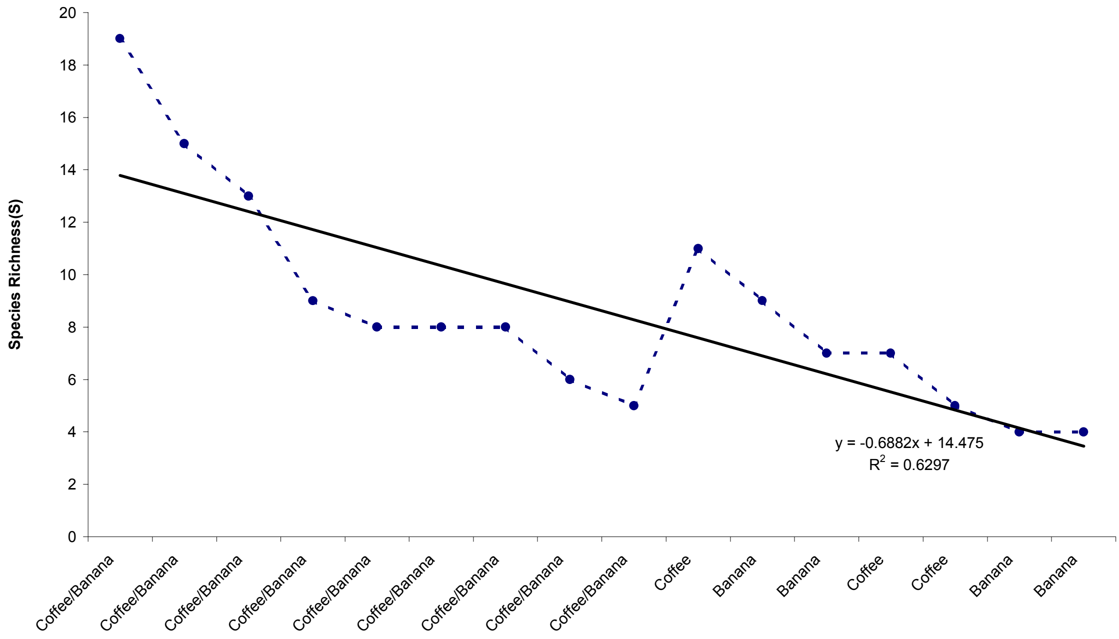


**Figure 6: The Effect of Land Use Change on Biodiversity (Poly-vs Monoculture Machame Transect).**

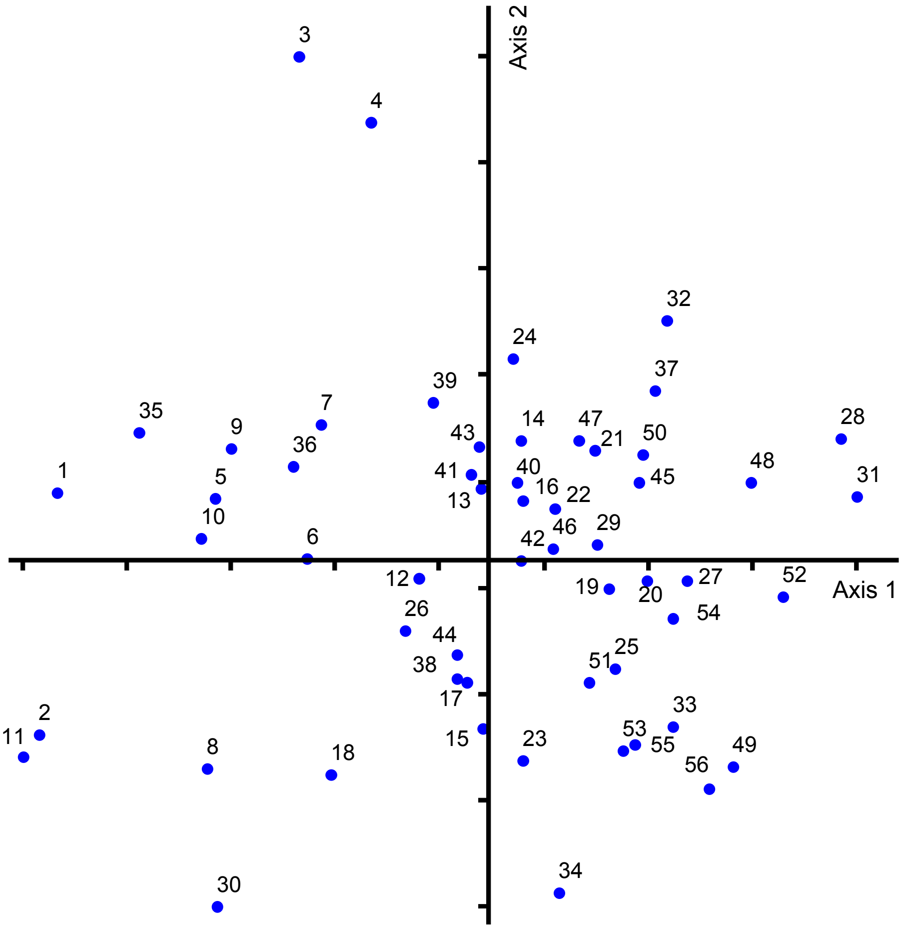


**Figure 7.** Scatter Diagram Depicted from Detrended Correspondence Analysis of Plots Under Different Land Use Systems in Machame and Mbokomu transects.

There was not 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.

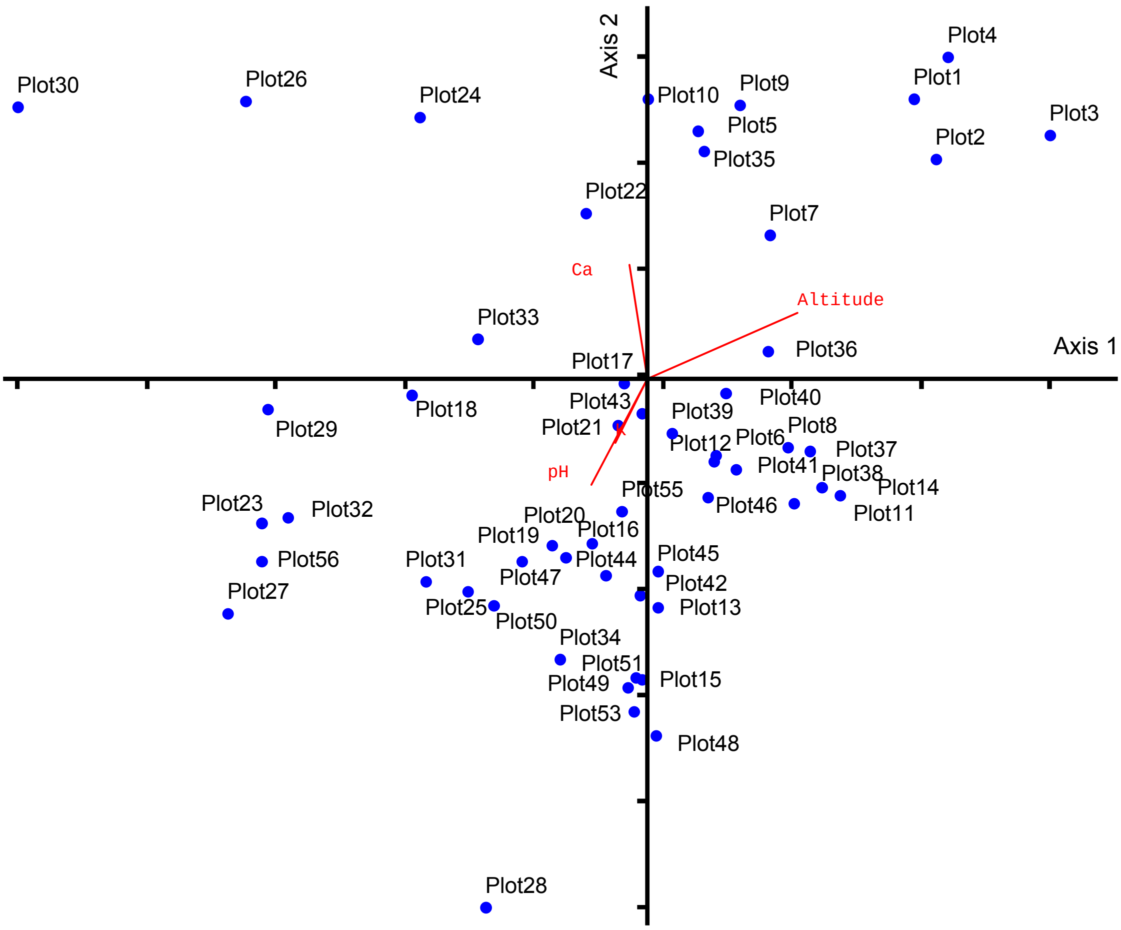


**Figure 8.** Scatter Diagram of the Plots Under Different Land Use Systems in Machame and Mbokomu transects as Depicted from Canonical Correspondence Analysis (CCA) Results.

### C.3. 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, ethnoveternary 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 1 and 2 below.

### C.4. Patterns of Change of Biodiversity

There was a tendency of decreasing species richness and diversity from uncultivated land to cultivated land along the transect (see Figures 1 – 6). 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 favouring selectively specific species.

At agro-ecological zone level, an increase in diversity was observed with decrease in altitude. The lowlands of which the common land use practice was irrigation agriculture and pastoralism had high diversity of grass species and shrubs which were absent in the highlands.

## C.5. Impact on Floral 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 *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*, *Helianthus annuus* and *Carica papaya*.

## C.6. Species of High Conservation Value

In the context of this work, I consider species of conservation concern as any of the species which fall in any one of the categories below:

- endemic species,
- species overexploited 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 figs which have fruits all year round and so are the cultivated fruit crops.

Among the timber trees, *Olea welwitschii*, *Cordia africana* 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. Generally, the diversity of medicinal plants was highest in the uncultivated land than in 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.

# D. DISCUSSION AND RECOMMENDATIONS

The interview 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. The most important explanation to 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 favour of building houses.

Another possible explanation to the observed loss of biodiversity can partly be attributed 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 tomato, onions etc. Generally, vegetable farming requires a lot of agricultural inputs such as fertilizers and pesticides which have detrimental effects on 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 favouring certain groups of plants.

The practice of using organic manure resulting from zero grazing and mulches which was very common along Machame transect should be encouraged as a means to improve soil fertility as well as increasing soil pH and consequently productivity and species diversity.

In view of this study, it is recommended to carry out intensive studies for all those species which 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.

Machame transect is much more diverse in terms of land use categories, species diversity and species richness compared to Mbokomu transect. Along Machame transect below 1000 metre altitude, there is very arid vegetation confined to shallow skeletal soils which I have termed scrub land. 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'Connor & Pickett, 1991), increasing seed influx passively into the area (Lyaruu, 1999) as well as reducing the perennial grasses which are obligate seed producers.

Agricultural practices of tilling the land selectively favours certain groups of plants which feature as weeds. Secondly the practice of turning the soil exposes seeds to optimum germination conditions, thereby increasing the short-lived ephemerals.

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 I am convinced that the coffee/banana zone is non-existent but 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 no banana crops in the lowland.

**Acknowledgements**
This study forms part of a multidisciplinary research on Land Use Change, Impacts and Dynamics (LUCID) in East Africa funded by UNEP-GEF. The author would like to express heartfelt appreciation for being part of the project as a contracted researcher for Geography Department of the University of Dar es Salaam. I would like to thank my employer, the University of Dar es Salaam for granting me permission to undertake this assignment in Mount Kilimanjaro.

**Table 1.** 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 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. |

**Table 2.** 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 | 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 dysentry | 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 |

## References

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

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.

Maitima, J.M. and J.M. Olson. 2002. Guide to Field Methods for Comparative Site Analysis for the Land Use Change, Impacts and Dynamics Project. LUCID Working Paper 15. Nairobi, Kenya: International Livestock Research Institute.

O'Connor TG and Pickett, GA 1991. The influence of grazing on seed production and seed banks of some African savanna grasslands. *J. Appl. Ecol*. **29**: 247-260.

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

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.

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