ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

A COMPARATIVE ECOLOGICAL STUDY OF THE MIOMBO WOODLAND IN TABORA, TANZANIA.

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN PARTIAL FULLFILLMENT
FOR THE DEGREE OF MASTERS OF SCIENCE IN DRYLAND BIODIVERSITY, ADDIS ABABA UNIVERSITY.

JULY, 2004

DEDICATION

I dedicate this work to my parents, the late Mr. Alfred C. Mbegu and Mrs. Shami Y. Mbegu.

ACKNOWLEGDEMENT

I am grateful to the SIDA-SAREC and RPSUD project for providing me the scholarship and funds to conduct this research. I would like to thank my supervisors Prof. Zerihun Woldu (AAU) and Dr. Shadrack Eliapenda (UDSM) for their assistance and helpful comments.

I am grateful all the lecturers at Addis Ababa University who contributed in one-way or another to the accomplishment of this work.

I am grateful to the following people: Mr. Mnang'wone director of department of research and training at the Ministry of Natural Resources and Tourism Tanzania for providing me with literatures and permission to work in the Igombe dam reserved woodlands. Mr. Haule of Forest Resources Management Project (FRMP) Tabora, for providing me literatures and transport. Head of department of Botany at the University of Dar es Salaam, lecturers and other staff members for their assistance in soil analysis and plant identification. Prof. Malibwi (SUA) for providing me with literatures.

I am very grateful to my family and friend Ibrahim Kargbo in Sierra Leone and some of my friends in Tanzania who encouraged me whenever I had problems

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LIST OF ACRONYMS AND ABBREVIATIONS

1. MNRT: Ministry of Natural Resources and Tourism
2. FRMP: Forest Resources Management Project
3. CEC: Cation Exchange Capacity
4. TMA: Tanzania Meteorological Agency
5. AAS: Atomic Absorption Spectrophotometer
6. USDA; United States Department of Agriculture

ABSTRACT

The plant communities of the Igombe dam protected and non-protected Miombo woodlands of Tabora were described based on the floristic analysis of the data collected between October 2003 and November 2003.Floristic analysis is based on the cover abundance values of both trees, shrubs and field layer which included grasses and herbs. Plant community –environment relationship was assessed based on the soil physical and chemical characteristics. A total 60 plots (relevés) were analysed, and a total 145 species vascular plants were identified.

The vegetation data were subjected to cluster analysis. The cluster analysis resulted into seven community types for field layer, nine community types for shrub layer and eight community types for tree layer. The rations of protected and un-protected plots were subjected to two-sample t-test. The results showed that the shrub layer responded quickly to disturbance than tree and field layer. Environmental data were subjected to Duncan multiple range test. These tests resulted into conclusion that the important nutrients were more in the protected sites than in the unprotected sites.

The results showed that there is significant difference in community composition and structure between the protected and non-protected area due to the activities going on. Also the soils of both two areas showed significant difference in nutrient contents and account for the differences in the composition and structure.

1. INTRODUCTION

1.1. Miombo woodland distribution

Miombo woodlands are found in Zambezian center of endemism, which lies between latitude 3^0 and 26^0 south of the Equator. According to the study done by White (1983) the Zambezian center of endemism has about 8500 species of which about 4600 species are endemic. It is also a center of diversity of genera *Brachystegia* and *Monotes*, which, together with the endemic *Diplorhynchus* and *Pseudolachnostylis* are found in Miombo woodlands. Chidumayo (1997) found out that apart from Miombo woodlands other vegetation types found in this center of endemism are swampy and riparian forests, woodland, thicket and grassland.

Studies conducted by Rogers (1996); Frost (1996) and Millington *et al* (1986) have shown that Miombo woodland is the largest vegetation unit in the Zambezian center of endemism. It is found in seven central and southern African countries which are; Zimbabwe, Zambia, Mozambique, Angola, Malawi, Tanzania and Katanga province in the Democratic Republic of Congo. Miombo woodlands cover an estimated area of about 270 million ha, which is equivalent to 3.0 million square kilometers. This area is about 70% of the Zambezian center of endemism. According to Frost (1996), Miombo woodlands are distinguished from other African savanna woodlands and forest formations by the dominance of tree species in the family Fabaceae, subfamily Casalpinioideae, particularly in the genera *Brachystegia, Julbernardia* and *Isobelinia.*

The study of Rogers (1996) showed that, Miombo woodlands are found in most parts of Tanzania, in the southeast and west parts of the country, except in the coastal and the northeastern part bordering Kenya. Miombo woodlands covers most of the country, about two thirds (2/3) of the total forested area. He further noted that, the Miombo does not extend into Uganda and Kenya. When species *Brachystegia spiciformis* does enter the southeast of Kenya, it is a member of coastal Savanna-dry forest complex, rather than normal Miombo woodland community.

1.1.1. Tabora Region

Tabora region has about 5,500,000, ha of forests. Out of the total area, 3,450,000 ha are forest reserves. (MNRT, 2002). It has about 33 forest reserves, 16 of which are described as intact which mean no settlements in the forest reserves. FRMP (1996) showed that rapid expansion of agricultural activities over the past decades they have resulted in extensive opening up of areas including those areas legally recognized as forest reserves. The 33 forest reserves form about two thirds of the region area, and one quarter of the national forest resource. In addition to these reserved resources there are several thousand ha of woodland in public lands. According to Wily and Monela, (1999) Tabora's forest is a Miombo woodland type, a dry, medium canopy forest extending throughout much of southern and parts of eastern Africa. Tabora' Miombo are famed for its multiple use functions and valuable hardwood timber species. Sub-categories of Miombo found in Tabora typically require 80-120 years to reproduce mature stands.

1.2.1 Miombo woodland ecology

1.2.1.1 Climate

Pratt and Gwayne (1977) have given a detailed description of the Miombo woodlands in Tanzania. According to Pratt and Gwayne (1977), Miombo woodlands thrive at altitude ranging from near sea level to 1,600m with a single-season rainfall of between 500m and 1200m per year. The topography is generally undulating with low hills and valleys. Temperature can rise as high as 40^0c with relative humidity between 50% and 90%, but this depends on the altitude. In Tanzania Miombo are found at an elevation ranges from sea level to 800m and annual rainfall of 500mm to 1200mm and occur within single rainy season of five months (December to April) to seven months (November to May) followed by severe dry season.

Jeffers and Boaler (1964) have also described the phenomenology of the vegetation. Trees are generally deciduous, with few evergreen ones. The leafless season is usually the dry season and this varies in the length from year to year, and also depends on altitude. In general, the higher the altitude, the shorter the leafless period. Rodgers and Luganda (1973) in their study in Tanzania, they found out that dry season lasts from April to November/October, and the Miombo trees flush just before the rains, *i.e.* in September and October.

1.2.1.2 Soils

Herlocker, (1999) found out that Miombo woodlands occupy the well-drained soils of the upper and middle slopes of the undulating topography, coarse, dense, tall grasses they occur on the frequently burnt sandy ridge top. The poorly drained heavy clay soils of the valley bottoms that are known as *Mbuga* in Tanzania generally support tall perennial grasslands. The transional zone between Miombo woodlands and valley grasslands is formed by a mixture of broad-leaved shrubs and small trees mostly *Combretaceae* and grasses. They are also characterized by termites mounds, soils of which are better drained than those of the surrounding *mbugas* support a mix of woodland thicket and tufted grasses (Lind and Morrison, 1974). The ground cover varies from dense coarse grass growth to a sparse cover of herbs and small grasses. Rogers (1976a) in his study in Tanzania found out that periodic dry season fires largely maintain the structure and species composition.

Young (1976; cited in Celander 1983) has given a detailed description of the Miombo soils. According to Young (1976; cited in Celander 1983), the soils are most often old and heavily leached and thus poor and infertile. They are characterized by low cation exchange capacity (C.E.C), low organic matter content and often low content of macro-nutrients; nitrogen, phosphorous and potassium. According to Celander (1983), acidity (pH) is normally between 4 and 6 with pH 5.5 being most common, and the soils are thus best characterized as slightly acidic.

1.2.2 Biodiversity of Miombo woodlands

About 334 tree species in these woodlands are endemic. Generic endemism is low overall (<15% of genera) with species linkages to the Sudanian and coastal formations (Chidumayo, 1997). The diversity of canopy tree species is low, although the overall species richness of the flora is high. Species diversity and localized endemism is high in many herbaceous plant genera, such as *Crotalaria* (over 200 Miombo species) and *Indigofora*. Areas of serpentine soils in Zimbabwe provided localized sites of speciation and endemism (Rogers, 1996).

Studies done by Chidumayo (1997) and Celander (1983) in Zimbabwe and Zambia showed that sub species diversity exists within the Miombo trees. For example the important timber tree *Pterocarpus angolensis* and *Dalbergia melanoxylon* have variety of ecological provenances of differing such as drought, fire and frost tolerance.

Animal diversity has been concentrated on the large herbivore and avifauna (Rogers, 1996). Large herbivores specific to Miombo are Sable antelope (*Hippotragus niger*) and Lichtenstein's hartebeest (*Sigmoceros lichtensteinii*). The overall diversity of Miombo wildlife is enhanced by the inclusion of habitat islands of non-miombo. These are habitat along river terraces with more nutrient-rich soils than miombo soils and more palatable grasses for instance along river Rufiji, Luangwa and Zambezi valley. The swamp floodplains such as Rukwa, Mweru and Moyowosi play a similar role.

A study done by Britten (1980) showed that, Miombo woodlands have distinctive avifauna, with many endemic species, including the miombo Grey Tit (*Parus griseiventris*), Miombo Rock Thrush (*Monticola angolensis*), Shelley's Sunbird (*Cinnyris shelleyi*) and Stierling's Woodpecker (*Dendropicos stierlingi*). For instance, out of Tanzania's 1300 bird species some 40-50 are Miombo specialists. In general, fauna richness is low, probably a consequence of the extreme harshness of the dry season, with a virtual seven-month drought often accompanied by intense fires. Insects and herpetofauna are impoverished (Lind and Morrison, 1974; Chidumayo, 1997). Chidumayo (1997) found that in the unbroken landscapes of Miombo there is much lower diversity.

2. JUSTIFICATION

Miombo woodlands are very important to local people in their day-to-day life and help the ecosystems function stably. Miombo provides a large variety of resources including fuel wood, fruits, fodder, building materials, fibers, timber and medicinal products for the livelihood of local people (Rogers, 1996; Munyanziza, 1999). Miombo woodlands are also important at global scale in that, they help in preventing floods, carbon sequestration and provide watershed protection.

The Miombo areas of Tanzania are generally poorly developed because the soils are poor in nutrients and structure. There is limited surface and underground water especially in areas underlying crystalline rocks. They are also infested with tsetse flies that few cattle and small stock are kept and support only low densities of wildlife (Herlocker, 1999). Hence human population has, typically been low and widely scattered. However the rapid human population growth in the past few decades has increased demand for various products of forests. For example in 1961 the population of Tanzania was 10 million, and the consumption rate of forests was 20 million m^3. In 1988 the population was 23 million people and the rate of consumption was 40 million m^3 (Kilahama, 1988). According to last year's census the population is about 34 million. Thus basing on the past experience the rate of forest products consumption is approximate to 60 million m^3. Miombo woodlands have increasingly been cleared for settlement and establishment of new farms. Tobacco is the major cash crop in the Tabora region producing 60% of the income (Temu, 1979; Stenson, 1996; Stenson *et al.*, 1996). Every two years a farmer has to start a new farm, therefore has to clear a forest, to avoid nematodes (Temu, 1979). Sometimes people clear these woodlands as a means to control tsetse flies (Goodier, 1968). Large-scale deforestation in the Miombo woodlands has brought about considerable changes in the vegetative landscape and ecosystem degradation (Rogers, 1996; Eliapenda, 2000). All these conversion of forestland to other land uses cause habitat destruction, and this may affect the ecology in many ways, such as altering the diversity and composition of fragment biotas (Laurance *et al.*, 2000) and may change the ecological processes such as nutrient cycling and pollination.

Persistent disturbance caused by human interference triggers changes in the vegetation that finally results in the decline of the quality of vegetation and reduction in the diversity and abundance of indigenous flora and fauna (Kaya and Raynal, 2001). For example in Tanzania estimated rate of deforestation for closed broadleaved forest is 100 km^2 per annum (Stephen *et al.*, 1986), FAO (1993) reported a deforestation rate of 432,000 ha between 1980 and 1990 in Tanzania.

Although Miombo plays important ecological roles such as conservation of water and soil and provides people with various services only little information is available (Eliapenda, 2000). Therefore there is a need to study the ecology Miombo so that management plans and the baseline data can be proposed and used for monitoring. The aim of the study therefore, was to explore, describe and compare the floristic composition and structure of protected and non-protected areas. The study will contribute information that is necessary for understanding vital processes within Miombo vegetation and to predict future trends.

3. OBJECTIVES

3.1 General Objective

To assess the status of the protected and non-protected Miombo woodlands and predict future ecological trends for conservation and monitoring purposes.

3.2 Specific Objectives

1. To describe floristic composition of the protected and non-protected Miombo Woodlands.
2. To describe and compare the community structure of the vegetation in the two areas.
3. To investigate ecological relationship between vegetation and environmental factors.

3.3 Hypothesis

1) There is significant difference in species composition, structure and diversity between Miombo woodlands in protected areas and those in non-protected areas.

4. LITERATURE REVIEW

4.1 Forests and woodlands of Tanzania

Tanzania has about 33.5 million ha of forests and woodlands. Out of this total area, almost two thirds consists of woodlands on public lands, which lack proper management. Gazzeted forest reserves cover about 13 million ha (MNRT, 1998).

Table 1. Tanzania forest recourses

Forest type	**000 ha**
Forest (Other than mangrove forest)	1141
Mangrove forests	115
Woodlands	32299
Total	33555
Use of forest land	
Production forest area	23810
Protection forest area (Mostly catchment areas)	9745
Total	33555
Legal status	
Forest reserves	12517
Forest/woodlands within national parks etc	2000
Non-reserved forest land	19038
Total	33555

Source: MNRT (1998)

Forests are very important because they provide habitat for wildlife, beekeeping, prevent soil erosion, natural ecosystems, genetic resources recycling and fixing of carbon dioxide and other nutrients. Also, they provide building materials and wood fuels to most people in rural areas as well as urban areas. Due to inadequate management of the forest and related resources, the actual contribution of the forest sector to national economy is underdeveloped. For instance in 1989, it was estimated that the sector provided 2-3% of the Gross Domestic Product (GDP) and 10% of the country's registered export (MNRT, 1998).

However, the contribution is underestimated because of the unrecorded consumption of wood fuels, bee products, catchments and environmental values and other forest products such as poles.

4.2 Threats to forests and woodlands in Tanzania

Deforestation is a major threat to forests and woodlands in most countries in sub-Saharan Africa. For example, In Tanzania deforestation rate ranges from 0.1-0.5 million ha per annum (MNRT, 1998). Similarly, in Zambia, deforestation caused by cultivation was estimated at 0.8 million ha per annum in 1990 (Chidumayo, 1997).

In Tanzania the main causes of deforestation are clearing for agriculture because of the shifting cultivation, overgrazing, wildfires of which are mostly deliberate, charcoal burning and over exploitation of wood resources for other domestic uses. This is taking place mainly in unreserved forestlands. The major causes of all those activities is population expansion and poor methods of farming which leave the land infertile and so force farmers to look for other areas.

Tobacco growing is the leading problem of deforestation in Tabora region (Manoko, 1999). Tabora region plays important role in Tanzania's economy, by being a producer of about 60% of flue cured tobacco (Temu, 1980). Tobacco is grown for export market as well as for internal market. In 1980's to 90's much emphasis was put on expansion of the tobacco production, but attention had not been paid to the consequences on agriculture, forestry and environment as a result of shifting cultivation and large scale deforestation.

The introduction of flue-cured tobacco as a cash crop for farmers and as important source of foreign exchange for Tanzania attracted farmers from other regions. The results were the number of farmers growing tobacco increased. For instance the population increased from about 6,070 in 1969/70 to 26,880 families in 1977/78 (Temu, 1980). According to the 2002 census, Tabora had 1,717,908 people. Although government regulations prohibit the use of good stems of valuable species like Mninga (*Pterocarpus angolensis*), for fuelwood, in practice farmers do not spare tree species and enforcement of the law is impracticable (Temu, 1980).

Another reason for clearing forests is Nematode problem. A newly cleared and burnt area is usually planted with tobacco for at most two consecutive years, after which the farmer has to shift to another area to avoid the risk of a build up of root-not nematodes (*Meloidogyne spp.*) which cause poor yields of tobacco. *Meloidogyne spp* are widely distributed and feed on various grass species, trees and food crops such as groundnuts. Thus, it causes effective control measures to be difficult. Chemical control measures over large area are very expensive and uneconomic.

Most soils in the region are sandy-loam or loamy-sands. When used in the production of food crops under shifting cultivation usually little or no fertilizer is needed. As long as there is a tree

Forest fires have a significant contribution to deforestation (Manoko, 1999). Miombo woodlands are burnt almost every year during dry season. The fires are most times deliberate but may occasionally be started by lighting or other uncontrollable causes (Celander, 1983). The reasons for burning by traditional pastoralists are to prevent the vegetation cover from being too dense for grazing and to drive game or provide better grazing. The late and fierce burns maintain an open tree storey in the woodland that gives the tsetse fly (*Glossina morsitans*) a less suitable habitat for breeding. Unlike other species of the same genera, this species of tsetse flies prefers a medium cover of trees and shrubs (Celander, 1983). The clear cut of trees so as to get rid of tsetse flies causes compaction of the soil thus makes it hard to till and cause erosion (Manoko, 1999).

Other reasons are burning of brushwood on cultivation sites, to smoke out wild bees from tree for honey and removal of tall grasses form the sides of foot-path (Trapnell, 1959). Fires burn large areas and kills herbs, seedling and sapling and sometimes kills mature trees. It also has effect on soil by causing volatilization of some nutrients such as nitrogen, leaching of some other nutrients and accelerates soil erosion by the removal of vegetation cover.

Illegal logging is a contributing factor to deforestation of Miombo woodlands of Tabora. The pit sawyers mostly do this. Illegal logging seems to increase day after day this is mainly done with individuals especially in the protected areas (Forest reserves). Most people involve themselves in this illegal activity so as to earn money (FRMP, 1997; Temu, 1980); this is because the forest products have become a commercial and therefore a marketable commodity. Selective logging is another factor, which contributes to the deforestation. Selective tree harvesting is commonly practiced to popular timber species like *Pterocarpus angolensis* (Mninga) and *Brachystegia spiciformis* (Mtundu). These are extracted by saw milling industries and illegal pit sawyers. Debarking also contributes to the deforestation. The barks of *Brachystegia spiciformis* are used for making containers, ropes and local beehives. Whenever it occurs, *Dalbergia melanoxylon* (Mpingo) is harvested for carving.

Charcoal production, which is a legal activity in Tanzania, has attracted immigrants to the region since the seventies. Steady entry of cattle keepers into the region was not for the search of new pastures but to earn cash incomes from the production of charcoal, hence the production almost continues to increase annually (Wily and Monela, 1999). Charcoal production contributes to deforestation because it involves many people. It is carried out almost all the year round and is not selective like logging (Manoko, 1999).

Local beehive contributes to deforestation because the best barks for hive making are obtained from the tree species *Brachystegia* and *Julbernardia*. Celander, (1983) has shown that the destruction often affects the highest and most well grown trees.

However, due to inadequate resources to implement active and sustainable forest management, deforestation through encroachment and over-utilization is also taking place in the forest reserves, which are under the jurisdiction of either the central or local governments.

4.3 Vegetation sampling

Vegetation studies base on the description and investigation of plant communities that first are recognized in the field. Community sample are important working materials for community studies. A comprehensive account of the importance of sampling plant communities has been given by Mueller-Dombois and Ellenberg (1974), so that it helps to obtain the maximum information from one set of a sample.

There are wide ranges of kinds of samples that can be applied to plant community studies. According to Greg-Smith (1983 cited in Lisanework Negatu, 1987), sampling procedures fall into one of the following categories.

- An estimate of the overall composition of the vegetation with certain boundaries, with the aim to compare with other areas or with the same area at time.
- Investigate variation within the area.
- Correlation of vegetation differences with differences in one or more habitat factors.

The choice of sampling procedure involves number of things in consideration; First important thing is the homogeneity of the sample (Kershaw, 1973). The sample should be homogeneous in structure and composition so that it can represent community type or relate vegetation to environment. Secondly the sample should be large enough in area so as to represent effectively the composition of the plant community (Goldsmith and Harrison, 1976). As the sample size is increased, a better measure of the mean of the population is obtained. If the sample size is too large it causes difficult in meeting the homogeneity of the sample and efficiency of sampling.

Minimum area of a community can be selected following three objective methods. The first based on species compositions. This results into species –area relation curve. It is simple to use and effective (Goldsmith and Harrison 1976). The minimum size requirement is related to the number of species, which occur as sample size increases Kershaw (1973), Sahle (1984) and Herlocker (1999) have employed a sample size of 20 x 20 m^2 to study would vegetation. Herlocker (1999) has suggested the sample size for herbs and grasses should be 0.5 x 2 m^2. The second objective is species frequency and the third is homogeneity of composition. Sampling should be designed and record instantly the important information because a considerable number of samples may be needed. Thus sampling procedures should relate to the importance of the information sought to problem under investigation.

Sampling stands / plots may be located with the area selected on the either randomly, systematically, based on the investigators subjective choice of typical sites or combination of the former two (Whittaker, 1978).

Systematic sampling is a widely used method of sampling plant community. According to Gauch (1982) this method has disadvantage because of errors introduced by investigators biased preconception and it is invalidity to statistical tests. However the method is preferred because it is more representative of variations over the area, thus likely to give a better estimate than random sampling. It is also easier to carry out efficiently in the field (Greg-Smith, 1978; cited in Lisanework Negatu, 1987)

4.4 Classification Techniques for Data Analysis

Classification involves the arrangement of plant communities in classes; the members of each class structure in common, a group of attributes, which distinguish them apart from the members of other classes (Digby and Kempton, 1987). Classification techniques finally produce groups, which are homogenous in composition. The classification techniques used in produce groups, which are homogenous in composition. The classification techniques used in plant community studies can be put into two groups; hierarchical and Non-hierarchical techniques (Digby and Kempton, 1987).

In the non-hierarchical the clusters are defined separately and links between them form a network and not a tree (Zerihun Woldu, 1980; Digby and Kempton, 1987). It aims to produce the most efficient grouping regardless of the route by which they are divided (Greig-smith, 1983; cited in Lisanework Negatu, 1987). They are good for those applications in which homogeneity of groups is of prime importance (Williams, 1971). Non-hierarchical classification is good in moderating noise, identifying outliers and summarizing redundancy (Gauch, 1982). In hierarchical classification, classes or clusters at any level are subclasses of classes at a higher level (Zerihun Woldu, 1980; Digby and Kempton, 1987). According to Greig-Smith (1983; cited in Lisanework Negatu, 1987), hierarchical produces are better known, less cumbersome and ecologically more readily interpretable.

Hierarchical techniques have been divided into divisive and agglomerative methods. Divisive method starts with a whole collection of stands and divides it into individuals or subgroups on the basis of an appropriate criterion to produce to arrive at ultimate hierarchy (Digby and Kempton, 1987). Agglomerative method starts at the bottom and work upwards beginning with the individuals stands combining them to form successively more inclusive groups of stands (Digby and Kempton, 1987).

These two techniques have been divided into three groups. First is the monothetic divisive classification technique. This begins with all samples in a single group and the divide them hierarchically into progressively smaller groups on the basis of presence absence of a single species. These procedures have disadvantages that they are liable to misclassify stands (Hill *et al.*, 1975). Second is a polythetic divisive classification technique. This technique use information on all species. They begin with all samples together in single cluster and cluster until each cluster contains only one sample or specified small number of samples. Example of this is Two Way Indicator Species (TWINSPAN). According to Orlóci (1967), the disadvantage of this technique is that it is common in rigid dichotomous divisions; the groups may break too early in the process no matter how homogeneous they are. The result is classification hierarchies, which may contain little information about the natural structure within the population. However it has theoretical advantages. It uses all the available information to make the critical divisions. (Lambert *et al.*, 1973).

Third is polythetic agglomerative classification technique. This technique use information of all species: begin with each sample allotted to a cluster with a single member and agglomerate these in hierarchy of larger and larger cluster until a single cluster contain all samples. Polythetic agglomerative methods, cluster analysis proceeds by scanning the whole data set and by examining the relation ships between all possible pairs individuals (1/2n(n-1)) where n = number of samples. At any particular stage the methods fuse individuals or group of individuals, which are most similar (Lisanework Negatu, 1987). These procedures are less likely to lead to misclassification because they cluster on the basis of overall similarity (Greig-Smith, 1983; cited in Lisanework Negatu, 1987).

5. MATERIALS AND METHODS

5.1 Description of the study Area

5.1.1 Location

The study was conducted in Igombe dam reserved woodlands in Tabora region, which is in the central western part of Tanzania. This region lies between longitude 30^0 to 34^0 East and latitude 4^0 to 7.5^0 south. It borders Kigoma and Rukwa region on the west and the southwest, Mbeya region on the south, Singida region on the northeast and Shinyanga on the north. The native people are Nyamwezi and Sukuma. The main activities include agriculture where they grow food and cash crops, beekeeping and livestock rearing. The study area (Igombe dam reserved woodland) is located between longitude $32^0$43' to $32^0$45' East and latitude $4^0$48' to $4^0$54' South. It covers about 7,501 ha. This reserved woodland was made a protected area in 1958, and it is owned by the central government.

5.1.2 Climate and soils

The region is characterized by warm climate with the highest temperature recorded in September and October about 30^0C, and the lowest temperatures are experienced between May and July about 23^0C. It experiences long rains between January and April and short rains between November and December. Mean annual rainfall ranges from 700mm in the East to 1000mm in the west. The soil type is manly sandy loam with low nutrient content and low water holding capacity (ODA, 1982).

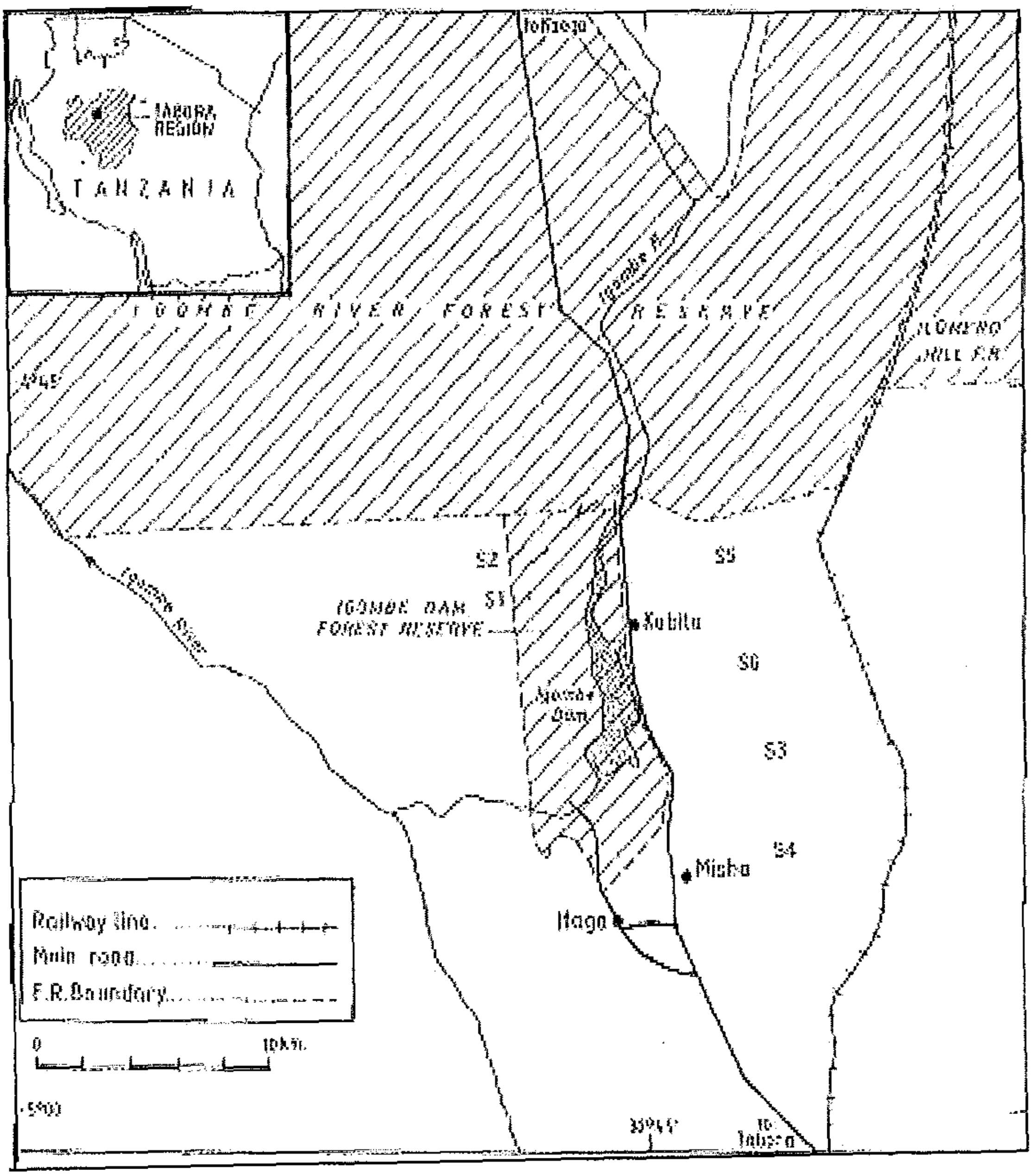

Figure 1: Study area and sites

Tabora (4^0 - 7.5^0 S and 30^0 - 34^0 E, 1100m - 1500m asl) [10 years]

56.5 mm, 26 ^{0}C

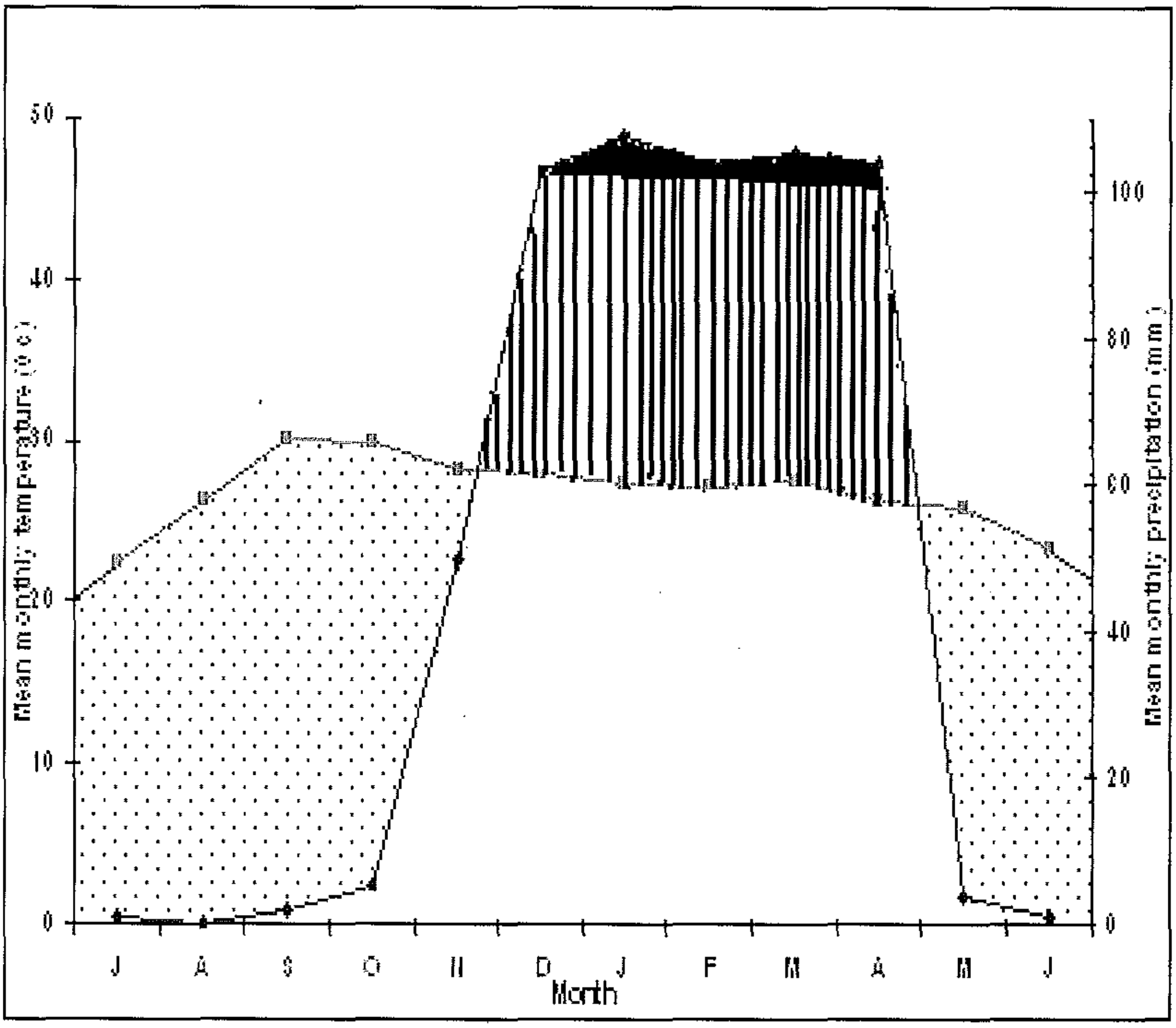

Figure 2: Climate diagram of ten years precipitation and temperature

5.1.3 Vegetation

The study area is within the Zambezian center of endemism, which is characterized by Miombo woodlands (*Brachystegia-Julbernardia* savanna woodlands ecological zone). In Tabora region, the vegetation falls into two main categories. This vegetation includes Miombo woodlands, which cover 60% of the region, and is about 38160 Km^2 (ODA, 1982). It also includes *Acacia - Combretum* woodland, bushland and grassland in the northeast. Second category include vegetation occurs in the valley floor, flood plains and waterlogged areas. It includes Mbugas or wooded grassland, which consists of tall coarse grasses with scattered trees especially around termite mounds. It is extensive within Miombo especially on valley floors and flood plains and occurs mainly in areas that are flooded for long periods during wet seasons (ODA, 1982).

5.1.4 Topography and drainage

Altitude of study area ranges between 1100m and 1500m above sea level with only two small areas in the northwest and southeast rising to some 1800m above sea level. The region is drained by two river systems of the Malagarasi and Manonga-Wembere. Malagarasi river flows westwards into the Malagarasi basin and pour its water into lake Tanganyika. Manonga-Wembere river flows northwards into Manonga-Wembere basin pouring its waters into lake Eyasi.

5.2 Vegetation survey

A reconnaissance survey was done from September – October 2003. This was followed by three inventories of the study areas, which was between October and November 2003. Preliminary identification was done in the field and voucher specimens were collected for proper identification and conformation of the taxons at the herbarium at University of Dar es Salaam. After inventory of the study area, an initial checklist of plants and communities occurring in the study area has been prepared. Reference was also made to records held in other institutions.

5.3 Site selection

The Igombe dam forest reserve was chosen because it is a protected area and it is adjacent to a forest that has been left for public use and therefore designated as non-protected. Sites were selected within the study areas on the basis of terrain (sloppy or lowland) and degree of disturbance *i.e.* high, medium and low for those in the non-protected areas. Disturbance was considered to be very high if it covered about 80% or more of the area. High if covered 40-80% of the area. Moderate if covered about 20-40% and low if covered less than 20%. Before setting sampling points of the vegetation and soil, a reconnaissance survey was carried out with the aim of recognizing the disturbed and undisturbed sites. Within the non-protected areas sites were selected on the basis of type of disturbance most of which were cultivation and fire. Logging was considered low because the area was open; meaning that there were few scattered trees, except on the sloppy site, which was far from where people were living.

5.4 Physiographical variables and climatic data

The physiographic variables of interest were slope and altitude. Slope was measured using Suunto Clinometer. Altitude and geographic coordinates were recorded using Garmin GPS. Altitudinal range was between 3760 ft – 4070ft asl. Slope was 2^0-10^0

Rainfall, temperature and relative humidity data of ten years (1992 to 2002) were obtained from the Tanzania meteorological agency (TMA) station in Tabora.

5.5 Vegetation sampling

In order to be able to compare the two areas, a total of six sites were chosen as follows:

In protected area, one site on the lowland vegetation labeled S1. Another site on the sloppy side of the rocky hill, and this was named S2.

In non-protected area, site one (S3) was highly disturbed lowland. The disturbance was due to cultivation and charcoal burning. The second site (S4) was the area with medium disturbance; the disturbance was due to fire. The third site was on the sloppy side of the disturbed rocky hill (S5). And last site (S6) was on the lowland previously disturbed but now in recovering state. Ten sample points were established along each site following systematic sampling. The interval between plots was between 100m, making a total of twenty plots in protected area and forty plots in non-protected area.

A modified Whittaker Nested-Quadrant sampling method (Strahlgren *et al.*, 1994) was applied for sampling vegetation at different levels. Trees were sampled in 20m x 20m plots, shrubs and juveniles in 5m x 2m plots and grasses and herbs in 2m x 0.5m plot.

The plot dimensions for shrubs and juveniles and field layer were modified to rectangle to suit the sampling of these vegetation types. This is because the rectangular plots reduce variance in data and more efficiently sample sparse and clumpy vegetation (Herlocker, 1999). Square plot (large plots) was used for trees. According to Herlocker (1999) large plots reduce the number of decisions about whether a plant is in or out of the plots and provide less variable data than small plots.

All plants occurring within the plot were identified, recorded and measured. Measurements for trees included height, circumference at breast height (cbh) and crown diameter.

5.6 Cover abundance

Estimation of percentage cover abundance for all vascular plants was done. Each tree's crown cover was measured in meters. For shrubs and field layer cover was estimated in percentages covered by each species in a plot.

Basal area (Ba) is defined as the area of the cross-section of a tree trunk near its base, was calculated for each tree using diameters measured at 1.5m above ground (dbh). Basal area is a way to measure how much of a site is occupied by trees and gives an indication of wood volume available.

For each site species density was calculated by dividing the number of individuals in a site per unit area (Deshmukh, 1986). Later on it was converted to number of individuals in each site per ha.

5.7 Soil

5.7.1 Soil Sampling

Soil was sampled in every plot. Three soils were collected diagonally at depths of 0 – 10 cm and 10 - 20 cm from each point using a soil auger. The three collected sub-samples at each level, were mixed and homogenized to form composite for ten samples per site. The samples were kept in labeled polythene bags, properly sealed to prevent contamination and moisture loss and subsequently transported to the University of Dar es Salaam for laboratory analysis.

5.7.2 Soil Analyses

5.7.2.1 Bulk density

The samples collected using "core method" (Blake and Hartge, 1986), were dried in an oven maintained at 105°C for 24 hours to attain constant weight. The bulk densities were then obtained by dividing the oven dry weight of the sample by the sample volume. Bulk density was expressed in SI units as g/cm^3.

5.7.2.2 Soil texture

Soil texture was determined by using the pipette method as described by Gee and Bauder (1986). The method involves a pre-treatment in which 80 g of air-dried, ground soil sample was weighed into a 250 ml flask, 100 ml of water added followed by 10 ml of 1M sodium acetate and the mixture centrifuged for 10 minutes. The supernatant, which was a clear solution, was poured off and the remaining soil suspension washed with 50 ml of distilled water centrifuged and decanted again so as to remove carbonates and soluble salts. In order to remove organic matter, 4 ml of Hydrogen Peroxide was added and the samples heated until frothing ceased.

In order to separate sand-sized particles, the treated soil was poured through a 270-mesh (53 µm) sieve and then the sand was washed. The sand on the 270-mesh (53 µ m) sieve was collected in a weighing dish, dried at105°C for 24 hrs and weighed. The remaining soil suspension in a cylinder was stored for analysis of silt and clay.

Silt (2 – 20 µm particle size) and clay (less than 2 µm particle size) were determined using the pipette method described by Gee and Bauder, (1986). The suspension (filtrate) obtained above, was put in a one litre cylinder, followed by addition of 10 ml of hexametaphosphate solution and then distilled water to make one litre. The cylinder was then stoppered and shaken for one minute and left to settle. After settling for 4 - 6 minutes at 22^{0}C a 25ml were taken at a depth of 10cm using a pipette, and the solution placed in a pre-weighed evaporating dish and dried at 105°C for 24 hours. The resulted residues represent the silt fraction. Another 25ml were taken at a depth of 10 cm after 6-7 hours, and dried at 105^{0}C for 24 hours. The resulted residues represent the clay fraction. All fractions dried in the oven were cooled in a dessicator before weighing.

The weight of the remaining treated soil was determined by adding 10 ml of 1M Calcium chloride and 1 ml of 1M Hydrochloric acid to the remaining suspension in the cylinder to prevent the formation of calcium carbonate and form flocculent. After flocculent has occurred, the clear solution was removed using a siphon and discarded. The soil flocculent was poured into an evaporating dish, dried at 105^0C for 24 hours and weighed. The purpose of weighing the treated sample was to compensate for the difference between the original soil weight and the remaining weight after the loss of soil during pre-treatment, solution loss, sieving loss, and the samples removed for pipette analysis. The total oven dry weight of the treated sample was used as a base to determine the size of the soil fractions. The total weight was obtained from the formula below:

$$Ws + Wp + Wr = Wt$$

Where

Ws = weight of the sand fraction

Wp = weight of the fractions taken by pipette (silt & clay)

Ws = weight of the remaining fraction

Wt = total oven dry weight

Data are presented as percent (of total dry weight) sand, silt and clay according to the texture classification system of the International Soil Science Society System (ISSS Gee and Bauder, 1986).

5.7.2.3 Moisture content

Soil moisture content was determined in the laboratory using the gravimetric method (Gardner, 1986). The method involves oven-drying 50 g of the fresh soil in an oven at 105^oC

for 24 hours. Moisture content was calculated by dividing the difference between the initial sample weight and oven dry weight of the soil by the initial sample weight, and then multiplied by 100 to obtain the percentage moisture content. The following formula was used:

$$\text{Moisture (\%)} = \frac{\text{Loss in weight on drying (g)}}{\text{Initial sample weight (g)}} \times 100$$

5.7.2.4 Soil reaction (pH)

Soil pH was measured electrometrically using a Metrohm E510 pH meter. This was done using a ratio of 1:1 soil and water mixture, which was stirred in a beaker for 30 minutes (McLean, 1982). The pH of a stirred suspension was read from the pH meter and recorded as pH in water (pHw).

5.7.2.5 Organic matter

Soil organic matter was determined by using the Walkley-Black potassium dichromate method as described by Olsen and Sommers (1982). For each sample 200mg air-dry soil was accurately weighed into a 500ml wide mouth erlemmeyer flask to which 10ml of 1M potassium dichromate was added and swirled to disperse the soil in the solution. Then 20 ml of concentrated sulphuric acid was rapidly added. After shaking the soil dichromate mixture was left to stand for 30 minutes after which 200ml of distilled water was added. The resulting solution was then titrated against 0.5 M ferrous sulphate using ortho-phenanthroline as an indicator. The % organic carbon was calculated using the formula below.

$$\text{Organic C \%} = \frac{(\text{meqK}_2\text{Cr}_2\text{O}_1 - \text{meq/FeSO}_4)\ (0.3) \times f}{\text{g dry soil}}$$

Where

f = 1.3, is a correction factor to account for carbon that does not oxidize in the procedure.

The organic matter content was obtained by multiplying the organic carbon concentration by 1.72 (Olsen and Sommers, 1982).

5.7.2.6 Available Soil Phosphorus

Available soil phosphorus was determined by using the Olsen extraction method as described by Olsen and Sommers (1982) and Emteryd (1989). One gram of air-dried soil was transferred into a 250ml flask, followed by 50ml of 0.5 sodium bicarbonate solution and the mixture shaken for 30 minutes. The mixture was filtered and the filtrate retained for determination of phosphorus. Ortho-phosphate was determined colorimetrically using a spectrophotometer according to the ascorbic acid method of Allen (1989) and Olsen and Sommers (1982). The wavelength was 720nm. The amount of phosphorus in the sample was obtained from the calibration curve of standard phosphate.

5.7.2.7 Total Organic Nitrogen

Total soil nitrogen was determined by using a semi-microKjeldahl digestion (Allen 1989) and calorimetric determination of the resultant ammonium by colour reaction (Endo-phenol blue). Into a Kjeldahl flask 0.2 g of air-dried soil was added followed by. 0.2 g of copper metal, 0.1 g selenium (Kjeldahl tablets), and 15 ml of sulphuric acid-salicylate mixture. The sulphuric acid-salicylate mixture was used in scales included to determine nitrate and nitrite forms of nitrogen present in the soil. In order to oxidise the organic matter, 2 ml of hydrogen peroxide was added and then heated to boil for 5 minutes. Later, 4 g of potassium sulphate was added and the mixture digested at 430°C using a thermal Kjeldahl apparatus. The nitrogen present in the sample was thus converted to the ammonium form and the ammonium was determined colorimetrically using a spectrophotometer wavelength 660nm. The amount of total nitrogen in the sample was obtained from the calibrated standard curve of ammonium ions (NH_4^+).

5.7.2.8 Soil Exchangeable Bases

Five grams of oven-dried soil sample was weighed into 250ml conical flasks. Exchangeable bases were then extracted from the soil samples as described in the cation exchange capacity method in section 2.8.2.9 below. Then, the exchangeable Ca^{2+}, Mg^{2+}, Na^+ and K^+ were analyzed using an Atomic Absorption Spectrophotometer (AAS), Perkin Elmer 3100.

5.7.2.9. Cation Exchange Capacity

The cation exchange capacity is the sum of the exchangeable cations that a soil can absorb. Five grams of oven-dried soil were weighed into conical flasks and 100 ml of 1M-ammonium acetate saturating solution was added. Samples were shaken for 2 hours in shaker and filtered using suction pump. The filtrates were analyzed for exchangeable bases. The soil suspensions were rinsed onto the filter paper with 200ml absolute alcohol till the electro-conductivity of alcohol reached 5 µs per centimeter. This was done to remove excess Ammonium. The ammonium was exchanged with 100 ml of 1M potassium chloride solutions. This was shaken and filtered and the filtrates collected were then analyzed for CEC (Ammonium acetate pH_7) using an Atomic Absorption Spectrophotometer (AAS), Perkin Elmer 3100.

5.8 Vegetation data analyses

In order to be able to compare vegetation between protected and non-protected areas the data were subjected to various numerical analyses.

5.8.1 Cluster analysis

Unweighted pair group averaging method (UPGM) was used to analyse crown cover of the trees and percentage cover of the shrubs and field layer. The data were first standardized using log of 10, which minimizes the differences, later on the data was computed to identify the communities. Dendograms were used to depict the community groups. The Multivariate Numerical Package – Syn-tax was used (Podani, 2000). Similarity ratio was used as a resemblance index.

5.9 Other ecological measures

Comparing the species diversity and evenness assessed the relationship between protected and non-protected Miombo woodland.

5.9.1 Diversity

Species diversity is a number of species (richness or variety) and the relative number of individuals of each species in a community. Diversity measures are used to evaluate different aspects of variability within and between communities. Species diversity can also be used to compare the similar communities or habitats within a given area or region.

The species diversity was calculated to find out whether human related disturbances (cultivation, charcoal production and fire) and terrain (sloppy or lowland) have any effect on the species diversity. Diversity index indicates the extent to which different species are represented within community. Thus, the Shanon-Weaner (1949) diversity index was calculated by using the following formula:

$$H' = -\Sigma (pi \log pi)$$

Where

pi = the proportion of the total sample (number of individuals of species i)

i = Species

Evenness or equitability measures distribution of individuals among the different species in the community (Chidumayo, 1997). It gives the picture of whether those individuals are evenly distributed or concentrated in one or few species. The index of evenness is based on the Shannon-Wiener diversity function (Chidumayo, 1997; Odum, 1971) and is given by the following formula:

$$E = (H' / \log S)$$

Where;

E = the evenness.

S = the total number of species in the sample.

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$$E = (H' / \log S)$$

Where;

E = the evenness.

S = the total number of species in the sample.

5.10 Statistical analyses

The density and basal area were compared using the two-sample t-test. The ratios of plots in the protected and non-protected areas were compared by using a two sample t-test so as to get which vegetation layers *i.e* tree layer, shrub layer or field layer has been mostly affected by disturbance. The soil data were organized in groups based on the community types of the tree layer obtained on the dendograms. The values of the soil parameters were initially subjected to Analysis of Variance (ANOVA). To find out which soil parameters significantly influence the composition and structure. Later, each soil parameter was subjected to multiple comparisons using Duncan multiple range test. The values of soil parameters from different sites were presented in appendix 2.

6. RESULTS

6.1 Density

6.1.1 Trees

Tree density and basal area differed from one site to another and between protected and non-protected areas. Generally the tree density and basal area were higher in the protected area than in non-protected area except for the site on the slope. ANOVA results showed that site S6 had significantly lower density than sites S1, S2, S4 and S5. Also site S2 had significantly higher tree density than site S3 (Table 2a). The tree basal area was significantly higher in Sites S1, S2 and S5 than in site S6. Within the protected area, the sloppy site S2 had significantly higher basal area than site S1 in the lowland. The sites on the slopes both in the protected and non-protected areas i.e. S2 and S5 had significantly higher basal areas than sites S3 and S4 in the lowland of the non-protected area (Table 2b).

The highest basal area and density were recorded in the sloppy site of the protected area (S2) while the lowest values for the two parameters were recorded in lowland non-protected site (S6). Tree density ($P = 0.0072$) and basal area ($P = 0.0001$) in the lowland protected area were significantly higher than in the lowland unprotected area (Table.3). There was however, no significant difference in tree density ($P = 0.6278$) and basal area ($P = 0.5702$) in sites on the slope between the two areas (Table 4).

Within the protected area, the tree density ($P =. 0.0249$) and basal area ($P = 0.0011$) on the slope site were significantly higher than in the lowland (Table 5). The difference in tree density and basal area in lowland and slope sites in the non-protected area were highly significant (P = 0.0007 for density and P = 0.0001 for basal area). The density on the slope site was 335ind.ha^{-1} and basal area was 2.239m2.ha^{-1} and both were higher than the density of 192.5 ind.ha^{-1} and basal area of 0.5674 in lowland (Table 6).

Table 2a: ANOVA of the tree density. M.D = mean difference; ns = not significant, * = significant at P < 0.05; ** = significant at P< 0.01, * = significant at P = 0.001.**

Sites		1	2	3	4	5	6
1							
2	M.D	72.5					
	F	2.59ns					
3	M.D	60.0	132.50				
	F	2.14ns	4.74*				
4	M.D	42.5	115.0	17.50			
	F	1.52ns	4.11ns	0.63ns			
5	M.D	55.0	17.50	115.0	97.50		
	F	1.97ns	0.63ns	4.11ns	3.48ns		
6	M.D	160.0	232.50	100.00	117.50	215.00	
	F	5.72**	8.31***	3.57ns	4.20*	7.68***	

Table 2b: ANOVA of the tree basal area. M.D = mean difference; ns = not significant, * = significant at P < 0.05; ** = significant at P< 0.01, * = significant at P = 0.001.**

Sites		1	2	3	4	5	6
1							
2	M.D	0.86					
	F	4.74ns					
3	M.D	0.79	1.65				
	F	4.40ns	9.12***				
4	M.D	1.02	1.88	0.23			
	F	5.67ns	10.41***	1.28ns			
5	M.D	0.67	0.18	146.00	1.70		
	F	3.72ns	1.02ns	8.11***	9.39***		
6	M.D	1.18	2.04	0.40	0.16	1.85	
	F	6.55***	11.28***	2.16ns	0.88ns	10.26***	

Table 3 Comparison of trees between lowland in the protected and non-protected area (= very significant, *** = extremely significant)**

Parameter	Protected area	Unprotected area	t	P
Density	280.00 ± 24.664	192.50 ± 14.982	3.032	0.0072 **
Basal area	1.567 ± 0.1449	0.5674 ± 0.0578	6.41	0.0001 ***

Table 4 Comparison of trees between slopes in the protected and non-protected area (ns =not significant)

Parameter	Protected area	Unprotected area	t	P	
Density	352.50 ± 16.436	335 ± 31.447	0.4932	0.6278	ns
Basal area	2.423 ± 0.1653	2.239 ± 0.2720	0.5784	0.5702	ns

Table 5 Comparison of trees between slope and lowland in the protected area (*= Significant, ** = very significant)

Parameter	Lowland	Sloppy	t	P	
Density	280.00 ± 24.664	352.50 ± 16.436	2.45	0.0249	*
Basal area	1.567 ± 0.1449	2.443 ± 0.1653	3.89	0.0011	**

Table 6 Comparison of tree between slope and lowland in the non-protected area (* = Extremely significant)**

Parameter	Lowland	Sloppy	t-value	P-value	
Density	192.50 ± 14.982	335 ± 31.447	4.09	0.0007	***
Basal area	0.5674 ± 0.0578	2.239 ± 0.2720	6.01	0.0001	***

6.1.2 Shrub density

Shrub density differed from one site to another in the non-protected area and between protected and non-protected areas in sloppy sites. ANOVA showed that site (S1) in the lowland of the protected area had significantly higher density than sloppy site (S5) of the non-protected area. Other sites showed no significant difference (Table7).

The highest density was recorded in the site in the protected area (S1), while the lowest value for the parameter was recorded on the slope non-protected site (S5). Shrub density on the lowlands (P = 0.2019) showed no significant difference between the two areas (Table 8). On the sloppy sites, shrub density (P = 0.0261) in the protected area was significantly higher than in the non-protected area (Table 9). Within protected area Shrub density (P = 0.2989) in sites in the protected area shows similar trend (Table 10). Within the non-protected area, shrub density (P = 0.007) in the lowland was significantly higher than on the slope. The density in the lowland was 7966 ind.ha^{-1} being higher than the value of 5500 ind.ha^{-1} on the slope (Table 11).

Table 7: ANOVA of the shrub density. M.D = mean difference; ns = not significant, * = significant at P < 0.05.

Sites		1	2	3	4	5	6
1							
2	M.D	2700.0					
	F	2.29ns					
3	M.D	1600.0	1100.0				
	F	1.35ns	0.93ns				
4	M.D	4900.0	2200.0	3300.0			
	F	4.15ns	1.86ns	2.79ns			
5	M.D	5600.0	2900.0	4000.0	700.0		
	F	4.74*	2.46ns	3.39ns	0.59ns		
6	M.D	2900.0	200.0	1300.0	2000.0	2700.0	
	F	2.46ns	0.17ns	1.10ns	1.69ns	2.29ns	

Table 8 Comparison of shrubs between lowland in the protected and non-protected area (ns = not significant)

Parameter	Protected area	Unprotected area	t-value	P-value
Density	11100 ± 2335.5	7966.7 ± 376.63	1.325	0.202 ns

Table 9 Comparison of shrubs between slopes in the protected and non-protected area (* = significant)

Parameter	Protected area	Unprotected area	t-value	P-value
Density	8400.0 ± 956.85	5500.0 ± 718.80	2.423	0.026 *

Table 10 Comparison of shrubs between slope and lowland of the protected area (ns = not significant)

Parameter	Lowland	Sloppy	t-value	P-value
Density	11100 ± 2335.5	8400.0 ± 956.85	1.07	0.299 ns

Table 11 Comparison of shrubs between slope and lowland in the non-protected area (= very significant)**

Parameter	Lowland	Sloppy	t-value	P-value
Density	7966.7 ± 376.63	5500.0 ± 718.80	3.04	0.007 **

Table 12: ANOVA of the Field layer density. M.D = mean difference; ns = not significant, * = significant at $P < 0.05$; ** = significant at $P < 0.01$.

Sites		1	2	3	4	5	6
1							
2	M.D	56000.0					
	F	3.39ns					
3	M.D	36000.0	20000.0				
	F	2.18ns	1.21ns				
4	M.D	84000.0	28000.0	48000.0			
	F	5.09**	1.70ns	2.91ns			
5	M.D	79000.0	23000.0	43000.0	5000.0		
	F	4.78*	1.39ns	2.60ns	0.30ns		
6	M.D	48000.0	8000.0	12000.0	36000.0	31000	
	F	2.91ns	0.48	0.73ns	2.18ns	1.88ns	

6.1.3 Field layer

Field layer density differed from one site to another and between the protected and non-protected areas. Generally the field layer density was higher in the lowland sites than on the sloppy sites, except for the site S4 in the lowland non-protected area. ANOVA revealed that site S1had significantly higher density than sites S4 and S5. Other sites showed no significant difference (Table 12).

The highest density was recorded in the site in the lowland of the protected area (S1), while the lowest value was recorded in lowland non-protected site (S4). Field layer density (P = 0.0325) in the lowland protected area was significantly higher than lowland non-protected area (Table 13). However, the field layer density showed no significant difference (P = 0.2932) in sites on the slopes between the two areas (Table 14).

Within the protected area, the field layer density (P = 0.8055) in the lowland and on the sloppy showed no significant difference (Table 15). The trend shown in the non-protected area, where field layer density (P = 0.0239) in the lowland and sloppy site was not significant (Table 16).

Table 13 Comparison of field layer between lowland in protected and non-protected areas

(* = significant)

Parameter	Protected area	Unprotected area	t-value	P-value
Density	136000 ± 22121	80000 ± 9737.3	2.317	0.0325*

Table 14 Comparison of field layer between slopes in protected and non-protected areas

(ns = not significant)

Parameter	Protected area	Unprotected area	t-value	P-value
Density	80000 ± 20000	57000 ± 7157.0	1.083	0.293ns

Table 15 Comparison of field layer between slope and Lowland in the protected area

(ns = not significant)

Parameter	Lowland	Sloppy	t-value	P-value
Density	136000 ± 22121	80000 ± 20000	1.878	0.077ns

Table 16 Comparison of field layer between slope and lowland in the non-protected area

(ns = not significant)

Parameter	Lowland	Sloppy	t-value	P-value
Density	80000 ± 9737.3	57000 ± 7157.0	1.903	0.073ns

6.2. Height distribution

The tree Height was classified into five (5) height classes (Figure 3).

as follows:

Class 1 with individuals less than 5m in height

Class 2 with individuals 5m - 9.9m in height.

Class 3 with individuals between 10.0 – 14.9m in height

Class 4 with individuals between 15.0m-19.9m in height

Class 5 with individuals over 20m height.

The height class 1 was poorly presented in all sites and was completely missing in sites S2 and site S5. Class 2 was abundant in many sites as was represented by more than 25 individuals in all sites except in site S2 and sites S5. Class 3 was well represented in all sites except in site S3 and sites S6 where less than 25 individuals represented them. Class 4 dominated in sites S2 and S5 and was poorly represented in all other sites. The last class 5 just like the first class was poorly represented in all sites though it was fairly represented in site S1.This class was completely missing in site S4 and site S6.

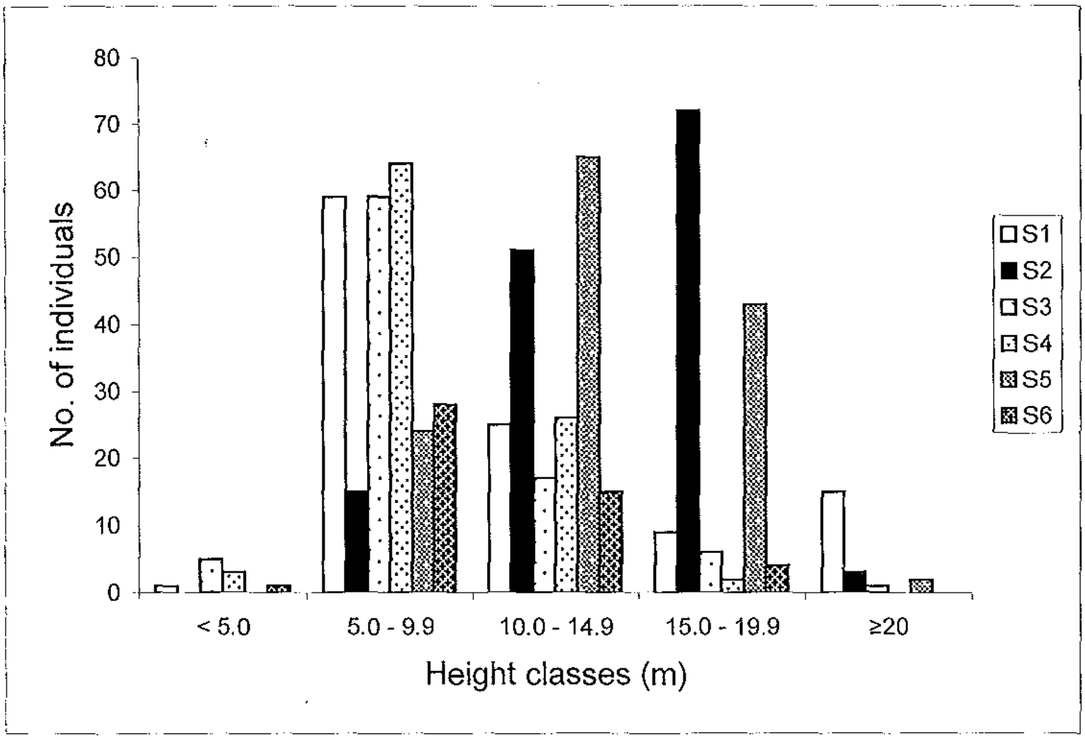

Figure 3: Tree heights in classes of the six sites at Igombe, Tabora.

6.3. Cluster Analysis

6.3.1 Tree

A total of eight community groups were obtained (Figure 4). The plots were derived from the similarity in the crown cover of the tree.

Table 17: Tree community types

Community	Community type	Plots
1	*Brachystegia spiciformis – Combretum molle – Julbernardia globiflora*	1, 42, 26, 41, 5, 47, 46, 21
2	*Brachystegia spiciformis - Julbernardia globiflora – Terminalia sericea*	23, 58, 59, 25, 52, 57, 56, 29, 30, 51, 53, 55, 54
3	*Brachystegia boehmii - Combretum molle – Ficus natalensis*	24, 27
4	*Brachystegia – Dalbergia melanoxylon*	34, 38, 39, 40, 43, 35, 37, 49
5	*Brachystegia boehmii – Pilliostigma thoningii - Terminalia sericea*	22, 28, 31, 36
6	*Brachystegia - Julbernardia globiflora*	2, 6, 7, 33, 4, 9, 3, 20, 32
7	*Brachystegia microphylla - Julbernardia globiflora – Pterocarpus angolensis*	8, 13, 50, 45, 48, 10, 11, 12
8	*Brachystegia – Pterocarpus angolensis*	14, 44, 15, 16, 18, 17, 60

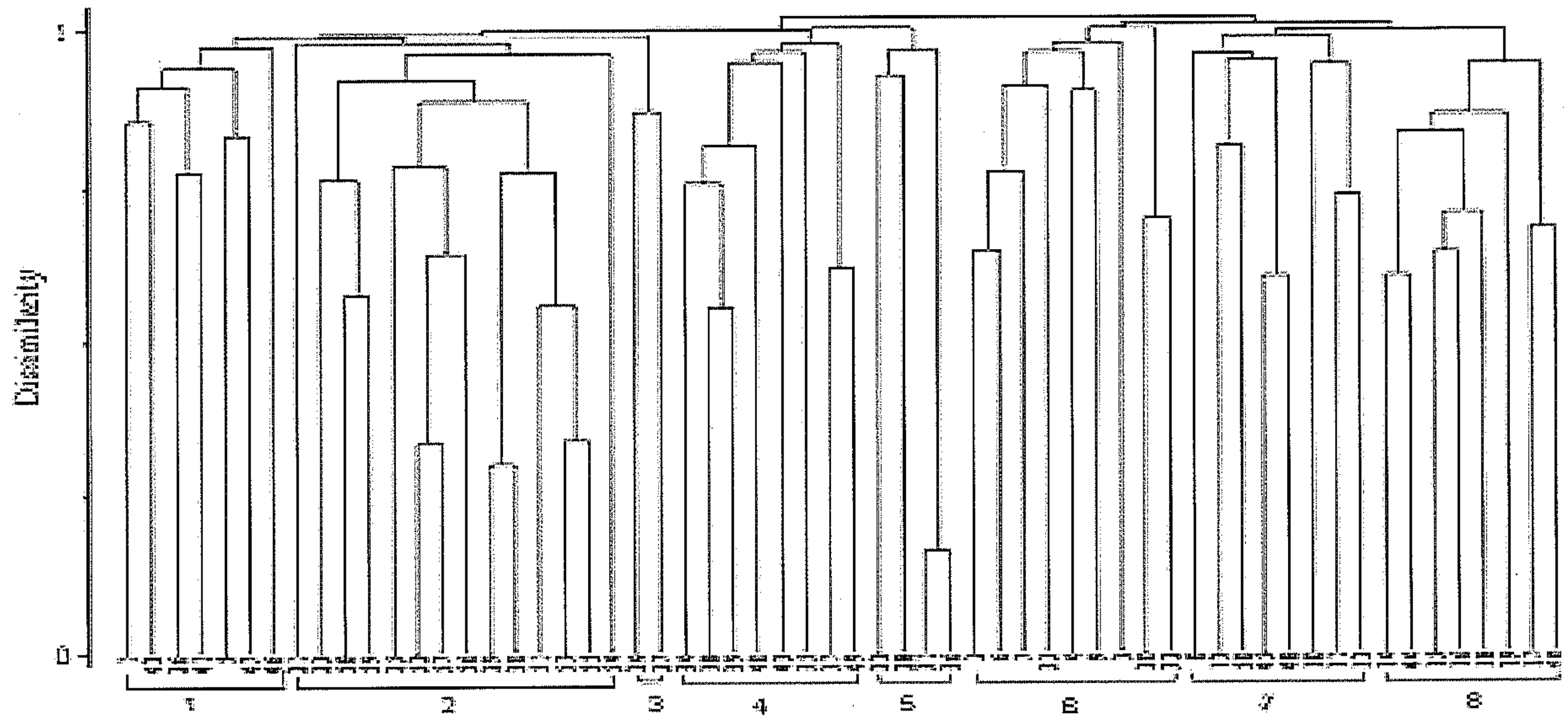

Figure 4: Dendogram showing the tree cover clusters from the Miombo woodland, Tanzania

Table 18: Synoptic table for trees

Species name/ Community types	1	2	3	4	5	6	7	8
Acacia nilotica (L) Del.	0.000	0.321	0.000	0.000	0.000	0.000	0.000	0.000
Acacia senegal (L) Willd	0.000	0.000	0.000	0.000	2.595	0.000	0.000	0.000
Acacia sieberiana DC.	0.000	0.000	0.000	0.000	1.750	0.000	0.000	0.000
Acacia torttilis (Forssk) Heine	0.000	0.000	0.000	1.563	0.000	0.000	0.000	0.000
Afzelia quanzensis Welw.	0.000	1.821	0.000	0.000	0.000	0.000	0.000	0.000
Albizia petersiana (Bolle) Oliv.	1.371	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Albizia verscolor Welw.	0.000	0.000	0.000	0.000	2.750	0.000	0.000	0.000
Annona senegalensis Pers.	0.000	0.000	0.000	0.000	0.000	0.000	0.813	0.000
Boscia salicifolia Oliv	0.000	0.000	0.000	0.000	0.000	0.000	1.063	0.000
Brachystegia boehmii Taub	0.000	0.000	6.125	4.000	3.625	3.972	1.375	1.625
Brachystegia longifolia Benth	0.000	0.000	0.000	0.000	1.250	0.000	0.000	0.000
Brachystegia microphylla Harm	1.429	0.000	0.000	0.000	0.000	1.067	4.424	6.973
Brachystegia spiciformis Benth	6.129	3.489	4.100	5.331	0.875	13.539	2.781	11.068
Catunaregam spinosa Thunb.	0.000	0.196	0.000	1.113	1.250	0.667	0.000	0.000
Combretum molle R.Br ex G. Don	4.800	0.607	5.000	0.000	0.000	0.000	0.000	0.513
Combretum zeyheri Sonder	1.774	0.489	2.500	0.000	0.875	3.630	1.813	0.000
Commiphora africana (A.Rich) Engl	0.000	0.000	0.000	0.000	0.000	0.722	0.000	0.000
Crossopteryx febrifuga (Afzel ex G.Don) Benth.	2.729	0.000	0.000	1.188	0.625	0.661	0.000	0.000
Dalbergia melanoxylon Guillenni & Perrotter	1.071	0.000	0.000	4.875	0.000	0.667	0.563	0.875
Dalbergia nitidula Welw ex Baker	0.000	0.000	0.000	0.000	0.000	0.000	0.688	0.000
Dichrostachys cinerea (L) Wight & Arn	0.000	0.000	0.000	0.750	0.000	0.444	0.000	0.000
Diplorhynchus condylocarpon (Muell.Erg) Pichon	3.393	0.000	0.000	1.469	0.000	3.906	1.100	3.350
Entada abyssinica Steud ex A.Rich	0.571	0.000	0.000	2.675	0.000	0.000	0.000	0.000
Erythrina abyssinica Law ex DC	0.000	0.214	0.000	0.813	0.438	0.000	0.000	2.281
Euphorbia candelabram DC	0.893	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ficus glumosa (miq) Delile	0.000	0.000	0.000	0.000	0.000	1.611	0.000	0.000
Ficus sur Warb	0.000	0.460	0.000	0.000	1.613	0.000	0.000	0.000
Ficus natalensis Horst	0.000	0.000	6.250	0.000	0.000	0.000	0.000	0.000
Flueggea virosa (Roeb.ex Willd) Baillon	0.000	0.000	0.000	0.000	0.000	0.944	0.000	0.000
Hymenocardia acida Tul	0.000	0.000	0.000	0.000	0.000	1.694	1.419	0.000
Julbernardia globiflora (Benth) Troupin	4.957	2.125	0.000	3.031	1.125	4.444	7.656	6.369

Kigelia africana (Lam) Benth	0.000	0.000	0.000	0.000	0.000	1.111	0.000	0.000
Lannea humilis (Oliv) Engl.	0.000	0.250	1.750	0.000	2.375	0.000	0.000	0.000
Lannea schimperi (Hochst ex A.Rich) Engl.	0.000	0.286	0.000	0.000	0.000	0.667	2.906	1.094
Lannea stuhlmannii (Engl) Engl.	0.000	0.000	0.000	0.000	0.000	0.000	3.063	0.000
Lonchocarpus eriocacalyx (Harnus)	0.000	1.816	0.000	2.594	0.000	0.000	0.000	0.000
Margaritaria discoidea (Baillon) Webster	0.000	0.000	0.000	0.000	2.000	0.833	2.125	0.000
Markhamia obtusifolia (Baker) Sprague.Syn	0.250	0.000	0.000	0.563	0.000	0.000	0.000	0.000
Monotis africanus A.DC.	0.571	0.000	0.000	0.000	0.000	2.583	0.000	1.363
Ozoroa insignis Delile	0.000	0.000	0.000	0.000	0.875	0.000	0.438	1.563
Pericopsis angolensis (Bakar) Van meeuwen	2.664	1.280	0.000	1.219	1.375	0.000	0.750	0.000
Phyllanthus engleri Pax	0.000	0.268	5.125	0.000	0.000	0.000	0.000	0.000
Pilliostigma thonningii (Schummacher)	0.357	0.000	0.000	0.625	5.063	0.000	0.000	0.000
Pterocarpus angolensis DC	2.893	0.250	0.000	1.813	1.200	2.056	3.563	8.451
Pterocarpus tictorius Welw.	0.000	0.214	0.000	1.063	0.000	0.778	1.089	4.738
Rothmannia fischeri (K.Schum) Bullock.	0.000	0.000	0.000	0.000	0.000	0.000	0.563	0.000
Sclerocarya birrea (A.Rich) Hochst	0.000	0.000	0.000	1.963	0.000	0.000	0.000	0.594
Senna singueana (Del) Lock	0.000	0.000	1.750	0.000	0.000	0.000	0.000	0.000
Stereospermum kunthanum Cham.	0.000	0.224	0.000	0.000	0.000	0.000	0.000	0.000
Sterculia quinqueba (Garcke) K.Schum.	5.000	0.000	0.000	0.000	0.000	0.000	0.000	3.894
Strychnos madascariensis Poir.	0.000	0.000	0.000	0.000	0.000	0.000	2.313	0.000
Strychnos potatorum L.f.	0.000	0.375	0.000	0.469	0.000	0.000	2.075	0.838
Strychnos pungensis Solered	0.000	0.000	0.000	0.000	0.000	3.442	0.000	0.000
Strychnos spinosa Lam.	0.000	0.000	0.000	0.000	0.000	0.000	1.531	0.000
Swertizia madagascariensis Desv.	3.054	0.000	0.000	0.000	0.000	0.611	1.000	0.813
Terminalia mollis M.A. Lawson	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.056
Terminalia sericea Burch.ex DC	1.571	2.418	4.375	1.250	2.938	2.023	0.469	4.281
Vitex doniana Sweet	0.000	0.000	2.000	0.000	0.000	0.000	0.000	0.000
Ximenia americana L.	0.000	0.000	0.000	0.000	0.000	0.556	0.000	0.000
Xylopia aethoipica (Dunal) A. Rich.	0.000	0.000	0.000	0.000	0.000	3.889	0.000	0.000
Zanthoxylum chalybeum Engl.	2.007	0.250	0.000	0.000	0.000	0.000	0.000	0.000

6.3.1.1 Tree diversity

Results showed that tree diversity differed from one community type to another, which reflects the difference between the protected and non-protected areas (Table 19). The highest diversity index was recorded in the community type seven which had more plots from sites S1, S2 and S5. These sites had very low level of disturbance as compared to other sites.

The second diversity index was recorded in the community type five, which had plots from sites S4 and S3. This shows that although these two sites were located in the non-protected area but disturbance has influenced the species diversity of the sites.

The third diversity index was recorded in the community type six, which had plots from site S1, S2 and S4. This tells that there was no difference in species diversity between site S4 and sites in the protected area the S1 and S2. The fourth diversity index was recorded in the community type four, which had plots from sites S4 and S5, but many plots were from sites S4.

The fifth diversity index was recorded in the community type one, which had plots from sites S1, S3 and S5. The sixth diversity index was recorded in the group eight, which had plots from sites S2, S5 and S6. These two community types do not show clear demarcation on diversity between the sites in the protected and those in the non-protected area. This is probably because their plots had low diversity.

The seventh diversity index was recorded in the community type two, which had plots from sites S3 and S6. This is because the community type two had many plots from site S6 that had few trees because it was a fallow land. Thus many trees were cut when the farmers were clearing the forest for cultivation. The last diversity index was recorded in the community type three, which had plots from site S3 alone. The reason that account for the lower diversity index is that the plots in this community type were those, which were, had few species.

These results depict the picture that diversity was higher in protected sites and sloppy site of the non-protected area followed by sites S3 and S4. Site S6 had lowest species diversity.

Tree evenness differed from one community type to another and between the protected and non-protected areas (Table 19). The highest evenness was recorded in the community types three, followed by community types five, and four. The community type three had plots from site S3, community type five had plots from sites S3 and S4.Community type four had plots from sites S4. These sites were located in the lowland of the non-protected area. The lowest evenness was recorded in the community types six and eight. The community types six had many plots from site S1 in the lowland of the protected area. Community type eight had many plots from sloppy site of the protected area.

Generally the tree evenness was higher in the lowland than in the sloppy sites except for the sites S4 and S6 in the non-protected are. Also, evenness was low in the protected area than in the non-protected area. The sites in the protected area showed no significant difference.

Table 19: Tree diversity and evenness

Community type	No. of attributes	Diversity index	Evenness index
7	25	2.947	0.916
5	20	2.821	0.942
6	25	2.771	0.861
4	20	2.764	0.923
1	20	2.716	0.907
8	19	2.590	0.879
2	20	2.521	0.841
3	10	2.204	0.975

6.3.2. Shrub

A total of nine community groups were obtained (Figure 5). The plots were derived from the similarity in the percentage cover of the shrubs.

Table 20: shrub community types

Community	Community type	Plots
1	*Crossopteryx febrifuga – Plectranthus barbatus – Termialia sericea*	1, 7, 16, 18, 33, 36, 41, 35, 37, 14, 49, 47, 50, 15
2	*Acacia senegal - Crossopteryx febrifuga – Terminalia sericea*	19, 38, 28
3	*Brachystegia microphylla - Diplorhynchus condylocarpon – Pterocarpus angolensis*	8, 11, 12, 13, 20, 44
4	*Brachystegia spiciformis - Catunaregum spinosa – Phyllanthus englerii*	5, 30, 34, 27, 32, 60, 24
5	*Dichrostachys cinerea – Lannea humilis – Pilliostigma thiningii*	21, 29, 31, 40, 23, 26, 25,
6	*Combretum – Strophantus eminii*	22, 39, 46
7	*Annona senegalensis – Markhamia obtusifolia – Pterocarpus tictorius*	2, 4, 58, 17, 42, 43, 48
8	*Flueggea virosa – Holarrhena febrifuga – Strophantus eminii*	3, 10, 51, 6, 52, 53
9	*Brachystegia spicifromis – Cassipourea molasana – Ximenia americana.*	9, 45, 55, 57, 56, 59, 54

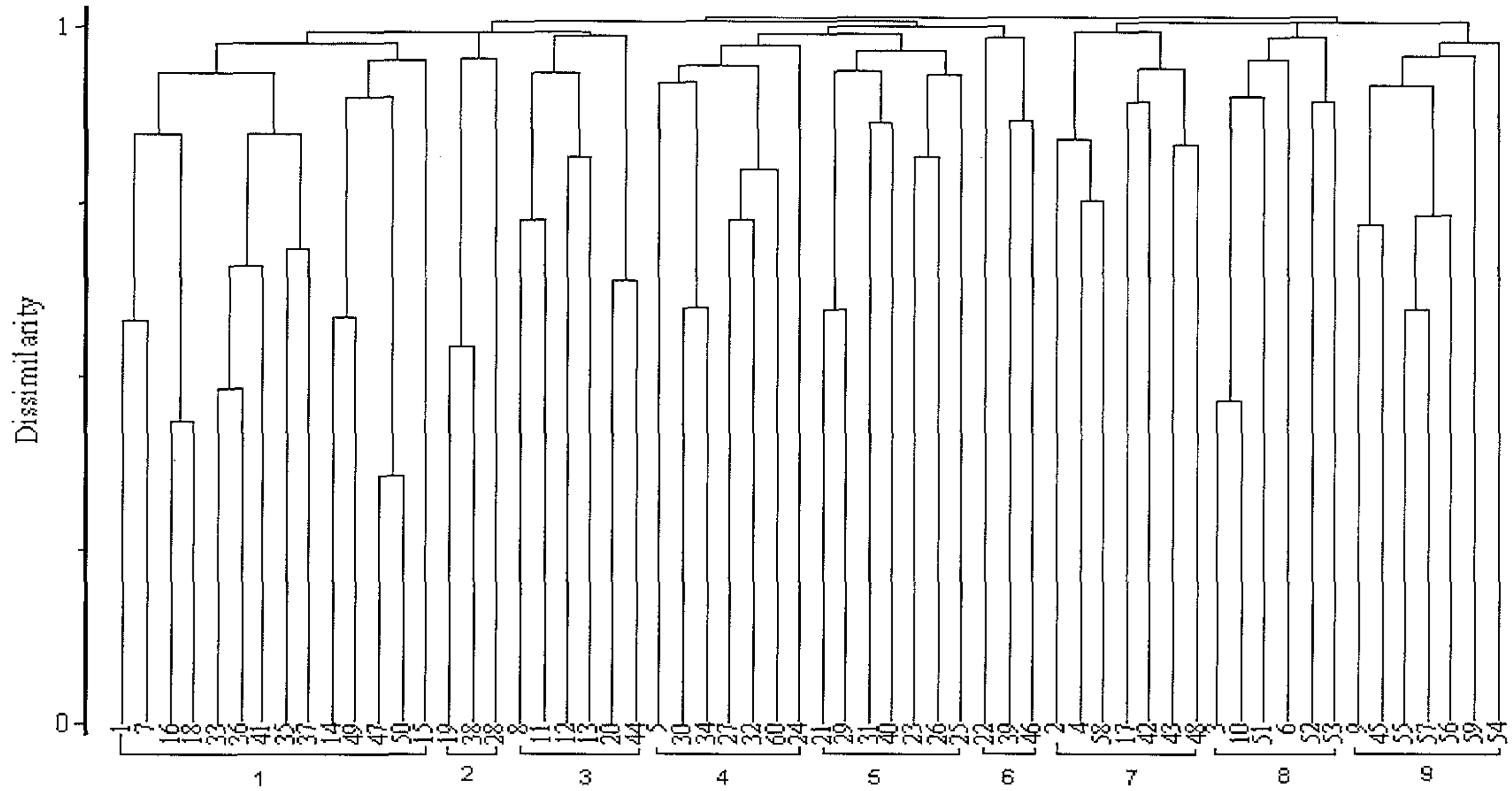

Figure 5: Dendogram showing the shrub cover clusters from the Miombo woodland, Tanznzania

Table 22: Synoptic table for shrubs

Species name /Community types	1	2	3	4	5	6	7	8	9
Acacia drepanolobium Harms ex Sjöstedt	0.000	0.000	0.000	5.000	0.000	0.000	0.000	0.000	0.000
Acacia senegal (L) Wild	0.000	11.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Acacia sieberiana DC.	0.000	1.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Annona senegalensis Pers.	0.000	0.000	0.000	0.000	0.000	0.000	6.714	0.000	0.000
Boscia salicifolia Oliv	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.833	0.000
Brachystegia boehmii Taub.	0.214	0.000	0.000	0.714	2.143	1.667	0.000	0.000	0.000
Brachystegia longifolia Benth	0.000	0.000	0.000	0.000	2.143	0.000	0.000	0.000	0.000
Brachystegia microphylla Harm	1.071	0.000	12.500	0.000	0.000	0.000	0.429	0.000	0.000
Brachystegia spiciformis Benth	0.714	0.000	0.000	2.857	0.000	0.000	4.571	2.833	7.857
Cassia abbreviata Oliv.	0.000	0.000	0.000	0.000	2.857	0.000	0.000	0.000	0.000
Cassipourea malosana (Bak.) Alston	0.357	0.000	0.000	0.000	0.000	0.000	0.000	1.667	8.571
Catunaregam spinosa Thunb.	0.357	0.667	0.667	3.429	3.286	5.333	0.000	0.000	5.000
Chrisophylum bangweolense	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.714
Combretum aculeatum Vent.	0.714	0.000	0.833	0.143	1.286	13.333	0.000	0.000	0.000
Combretum collinum Fresen.	0.000	0.000	0.000	1.429	0.000	0.000	0.000	0.000	0.000
Combretum molle R.Br ex G. Don	0.357	0.000	0.000	0.857	3.143	0.333	0.000	0.833	2.857
Combretum zeyheri Sonder	2.500	0.000	0.000	0.000	0.714	6.667	2.143	3.333	0.714
Commiphora africana (A.Rich) Engl	0.000	0.000	0.000	0.000	0.000	0.000	1.429	0.000	0.000
Crossopteryx febrifuga (Afzel ex G.Don) Benth.	7.857	5.000	0.000	0.143	0.000	0.000	0.000	1.666	0.000
Dalbergia melanoxylon (Guillenni & Perrotter)	2.571	0.000	0.000	1.429	0.000	0.000	0.000	0.000	0.714
Dichrostachys cinerea (L) Wight & Arn	0.000	0.000	0.000	0.000	7.286	0.000	0.000	1.667	0.000
Diospyros usambarensis F.White	0.000	0.000	2.167	0.000	0.000	0.000	0.000	0.000	0.000
Diplorhynchus condylocarpon (Muell.Erg) Pichon	2.500	0.000	5.000	0.000	0.000	0.000	0.000	0.000	0.000
Euphobia grantii Oliv.	0.000	0.000	0.000	0.000	0.000	0.000	3.429	0.000	0.000
Ficus sur Warb	0.000	0.000	0.000	0.000	0.000	1.667	0.000	0.000	0.000
Flueggea virosa (Roeb.ex Willd) Baillon	0.000	3.333	2.167	0.000	0.571	0.000	4.286	4.500	1.429
Grewia bicolor Juss	0.714	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Harissonia abyssinica Oliv. Mssaborini	1.429	0.667	0.000	0.286	0.143	0.000	0.000	0.000	0.000
Holarrhena febrifuga Klotzsch.	0.000	0.000	0.833	0.000	0.000	0.000	0.714	6.833	0.000
Hoslundia opposita Vahl; Benth. in DC. Prod.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000
Hymenocardia acida Tul	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.833	0.000
Julbernardia globiflora (Benth) Troupin	0.714	3.333	4.167	0.000	0.000	0.000	1.429	3.333	6.429

Lannea humilis (Oliv) Engl.	0.000	0.333	0.000	1.571	6.000	0.333	0.000	0.000	0.000
Leonotis nepetifolia R.Br.	0.000	0.000	0.000	0.000	0.000	0.000	0.714	0.000	0.000
Leptactina banguelansis Benth	0.000	0.000	0.000	0.000	0.000	0.000	0.714	0.000	0.000
Markhamia obtusifolia (Baker) Sprague.Syn	0.429	0.000	0.833	0.000	0.000	1.667	9.286	1.000	0.714
Monotis africanus A.DC.	0.000	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ozoroa insignis Delile	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.000	0.000
Pavetta bagshawei S.Moore	0.000	0.000	0.000	0.857	0.714	0.000	0.000	0.000	0.000
Pericopsis angolensis (Bakar) Van Meeuwen	0.000	0.000	0.000	0.000	1.429	0.000	0.000	0.000	0.000
Phyllanthus engleri Pax	0.000	0.000	0.167	7.857	1.286	3.667	0.143	0.167	0.000
Pilliostigma thonningii (Schummacher)	0.000	1.667	0.000	0.000	5.000	0.000	0.000	0.000	0.000
Plectranthus barbatus DC	2.857	0.000	0.000	0.000	0.000	0.000	0.714	0.000	0.000
Psorospermum febrifugum Spach	0.143	0.000	0.000	0.143	0.000	0.000	0.000	2.500	0.000
Pterocarpus angolensis DC	0.000	0.000	5.000	0.000	0.000	0.000	0.000	0.000	0.000
Pterocarpus tictorius Welw.	0.000	0.000	0.833	0.000	0.000	0.667	7.857	0.000	0.000
Schrebera trichoclada Welw.Syn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.333	0.000
Sclerocarya birrea (A.Rich) Hochst	0.000	0.000	0.000	0.000	0.000	6.667	0.000	0.000	0.000
Senna singueana (Del) Lock	0.000	0.000	0.000	0.000	0.714	0.000	0.000	0.000	0.000
Stereospermum kunthanum Cham.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.714
Strophanthus emini Asch.& Pax	2.643	0.000	1.667	0.714	1.429	10.000	2.143	5.000	2.857
Strychnos madascariensis Poir.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.333	0.000
Strychnos spinosa Lam.	0.286	0.000	0.000	2.286	0.000	0.000	0.714	0.333	0.000
Synodenium mole Pax	0.000	0.000	2.500	0.000	0.000	0.000	0.000	0.000	0.000
Terminalia sericea Burch.ex DC	2.929	6.667	0.000	2.143	0.714	1.000	1.429	5.000	6.429
Vangueria infausta Burch.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.714
Vitex mombasae Vatke	0.000	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.000
Xeroderris stuhlmannii (Taub.) Mendonça & Sousa	0.000	1.000	0.833	0.000	4.286	0.000	0.000	0.000	0.000
Ximenia americana L.	0.714	0.000	0.000	0.000	0.000	0.000	0.714	0.000	11.000
Xylopia aethoipica (Dunal) A. Rich.	0.000	0.000	0.000	0.000	0.000	0.000	5.000	0.833	0.000
Zanha africana (Radlk.) Exell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.429

6.3.2.1 Shrub diversity

The results showed that shrub diversity differed from one community type to another (Table 22). The highest diversity index was recorded in the community type eight. This community type had plots from sites S1 and from site S6 that were on the lowlands of the protected and non-protected area. This implies that sites S1 and S6 had more shrub diversity than other sites.

The second highest diversity index was recorded in community type five. Community type five had plots from sites S3 and S4 both on the lowland of the non-protected area. This indicates that S3 and S4 had higher species diversity. The third diversity index was recorded in the community type seven. Community type seven had many plots from sites S5 on the hill slope of the non-protected area and few plots from site S6 and S1. It possible that these two sites (S1 and S6) had plots which had higher shrub diversity.

The fourth diversity index was recorded in the community type one. Community type one had plots from the sites S1, S2, S4 and S5. Many plots were from sites S4 and S5, which were in the non-protected area. The fifth diversity index is from the community type four. Community type four had plots from the sites S1, S3, S4 and S6. The sixth diversity index is from the community type nine. Community type nine had plots from the sites S1, S5 and S6. The seventh diversity index is from the community type three. Community type three had plots from the sites S1, S2 and S5. The eighth diversity index is from the community type six. Community type six had plots from the sites S3, S4 and S5. The ninth diversity index is from the community type two. Community type two had plots from the sites S2, S3 and S4.

Shrub community types eight showed that sites S1 and S6 had highest shrub diversity. The next are sites S3 and S4. It is also indicates that sites on the slopes had lowest shrub diversity. Other community types did not show the differences in diversity indices between the protected and non-protected area.

Shrub evenness differed from one community type to another (Table 22). The highest evenness was recorded in the community type eight. This community type had plots from sites S1 and S6. The second evenness was recorded in the community type five, which had plots from sites S3. The lowest evenness was recorded in community types two and six. Generally the shrub evenness was almost equal in the protected and non-protected areas. All community types with highest evenness values had also highest diversity values. The same applies to those community types with lowest evenness values.

Table 22: Shrub diversity and evenness

Community type	No. of attributes	Diversity index	Evenness index
8	21	2.749	0.903
5	19	2.576	0.875
7	20	2.573	0.859
1	21	2.486	0.817
4	18	2.387	0.826
9	16	2.368	0.854
3	15	2.230	0.823
6	14	2.144	0.812
2	12	2.002	0.805

6.3.3. Field layer

A total of seven community types were obtained (Figure 6). The plots were derived from the similarity in the percentage cover of the herbs and grasses.

Table23: Field layer community types

Community	Community type	Plots
1	*Erragrostis aspera – Heteropogon contortus – Panicum coloratum*	1, 3, 7, 13, 51, 9, 30, 5, 2, 6, 60, 16, 57
2	*Aristida - Rottboellia exaltata – Hyparrhenia filipendula*	4, 47, 54, 35, 20, 44, 45, 48, 52, 50
3	*Heteropogon contortus – Loudetia simplex – Pellea videris*	11, 14, 19, 42, 12, 17
4	*Sporobolus pyramidalis - Hyparrhenia filipendula – Hygrophila auriculata*	33, 34, 36, 38, 58
5	*Hyparrhenia rufa – Seteria sphacelata – Trimfetta rhomboidea*	10, 15, 41, 18, 49, 28, 21, 56
6	*Sporobolus pyramidalis – Pennisetum mezianum – Erragrostis patens*	22, 25, 59, 32, 31, 39, 53, 23, 43, 27
7	*Harpachne schimperi - Sporobolus pyramidalis – Tragus berteronianus.*	24, 55, 26, 29

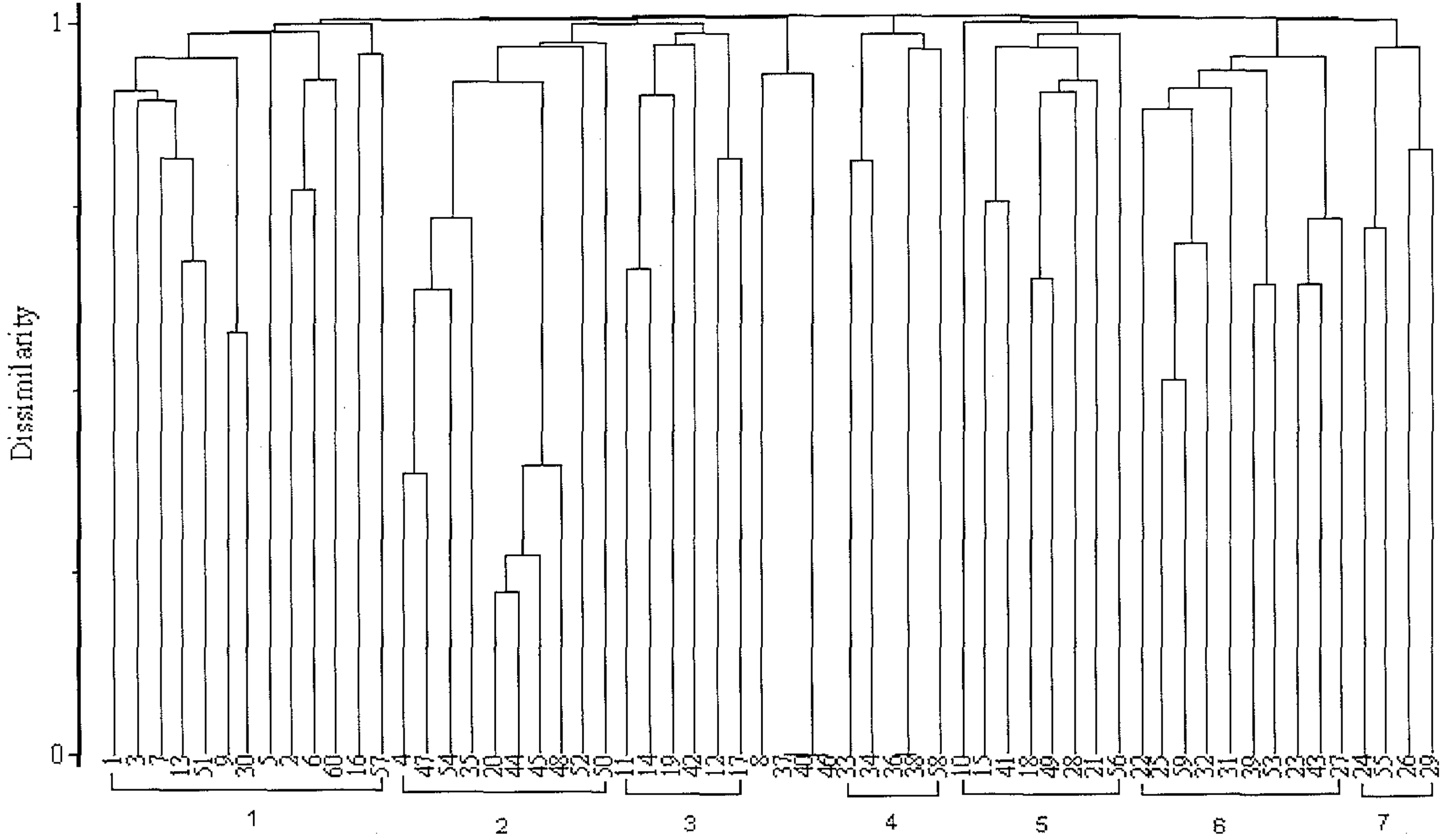

Figure 6: Dendogram showing the field layer cover clusters from the Miombo wooland, Tanzania.

Table 24: Field layer synoptic table

Species name / Community types	1	2	3	4	5	6	7
Aerva lanata (L.) Juss. ex Schules	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ageratum conyzoides L.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Aristida adoensis Hochst.	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Aristida barbicollis Trin. & Rupr.	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Asparagus aethopicus L.	0.00000	0.00000	0.00000	0.00000	0.12500	0.00000	0.00000
Aspilia mossambicensis (Oliv.) Wild	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000
Bidens pilosa L.	0.07690	0.10000	0.00000	1.60000	0.00000	0.00000	0.00000
Blepharis affinis Lindau	0.53846	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Blepharis maderaspatensis (L.) Roth	0.15385	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Capparis tomentosa Lam.	0.23077	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Chloris pycnothrix Trin.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Chloris virgata Sw.	0.00000	0.10000	0.00000	0.00000	0.37500	0.00000	0.00000
Clerodendron myricoides R.BR. & Vatke	0.07690	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Commelina africana L.	0.00000	0.00000	0.50000	0.00000	0.00000	0.00000	0.00000
Cyanotis foecunda Hochst. ex Hassk	0.00000	0.00000	0.83333	0.00000	0.00000	0.00000	0.00000
Cyperas obtusiflorus Vahl	0.15385	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Dactyloctenium aegyptium (L.) Willd.	0.38462	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Desmodium barbatum (L.) Benth	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.25000
Dichanthium annulatum (Forssk.) Stapf	0.23077	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Ethulia conyzoides L.	0.07690	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Eragrostis aspera (Jacq.) Nees	1.53850	0.10000	0.83333	0.00000	0.62500	0.70000	0.00000
Eragrostis patens Oliv.	0.07690	0.00000	0.00000	1.20000	0.00000	2.80000	1.25000
Eragrostis racemosa (Thunb.) steud	0.00000	0.00000	0.16667	0.00000	0.00000	0.50000	1.00000
Euphorbia hirta L.	0.00000	0.00000	0.00000	0.00000	0.12500	0.00000	0.00000
Harpachne schimperi Hochst. Ex A. Rich.	0.46154	0.00000	0.00000	0.00000	0.00000	0.00000	8.75000
Heteropogon contortus (L.) Roem. & Schult.	8.07690	0.80000	1.66670	1.40000	0.00000	0.10000	0.75000
Hygrophila auriculata (Schumach.) Heine	0.00000	0.00000	0.00000	4.00000	0.00000	0.00000	0.00000
Hyparrhenia filipendula (Hochst.) Stapf	1.23080	5.20000	0.83333	4.00000	0.00000	0.10000	0.75000
Hyparrhenia rufa (Nees) Stapf	0.00000	0.00000	0.00000	0.00000	1.50000	0.00000	0.00000
Indigofora arrecta A. Rich.	0.00000	0.00000	0.00000	0.00000	0.12500	0.00000	0.00000
Loudetia simplex (Nees) C.E. Hubb	0.61538	1.50000	15.00000	0.00000	0.00000	0.00000	0.00000
Melinis repens (Wild.) Zizka	0.00000	0.00000	0.16667	0.00000	0.00000	0.00000	0.00000

Monechma debile (Forsska.) Nees	0.00000	0.30000	0.00000	0.00000	1.00000	0.10000	0.00000
Orthosiphon suffrutescens	0.07690	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Panicum coloratum L.	3.46150	0.00000	2.50000	0.00000	0.00000	0.10000	0.25000
Panicum maximum Jacq	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000
Panicum trichoculadum K. Schum.	0.76923	0.50000	0.00000	0.00000	0.12500	0.00000	0.00000
Pellae viridis (Forssk)	0.00000	0.00000	1.66670	0.00000	0.00000	0.00000	0.00000
Pennisetum mezianum Leeke	0.00000	0.00000	0.00000	0.00000	0.00000	2.50000	0.00000
Pennisetam polystachion (L.) Schult.	0.00000	0.00000	0.00000	0.00000	0.12500	0.00000	0.00000
Perotis hildebrandtii Mez	0.00000	0.10000	0.00000	0.00000	0.00000	0.10000	0.00000
Pogonarthria squarrosa (Roem. & Schult.) Pilg.	0.00000	0.00000	0.00000	0.20000	0.00000	0.00000	0.00000
Portulaca oleracea L.	0.00000	0.00000	0.16667	0.00000	0.00000	0.00000	0.00000
Rottboellia exaltata L.f.	0.00000	2.60000	0.00000	0.00000	0.00000	0.00000	0.00000
Setaria sphacelata (Schumach.) Moss	0.00000	0.00000	0.00000	0.00000	2.62500	0.00000	0.25000
Setaria verticillata (L.) P. Beauv	0.00000	0.00000	0.00000	0.00000	0.12500	0.10000	0.00000
Spaeranthus gomphrenoides O.Hoffm.	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000
Spermacoce senensis (Koltzch) Hiern.	0.69231	0.00000	0.00000	0.00000	0.25000	0.00000	1.25000
Sporobolus fimbriatus (Trin.) Nees	0.07690	0.00000	0.16667	0.00000	0.00000	1.50000	0.00000
Sporobolus panicoides A. Rich.	0.00000	0.00000	0.00000	0.00000	0.62500	0.00000	1.25000
Sporobolus pyramidalis P. Beauv.	0.38462	0.10000	0.00000	3.00000	0.00000	3.40000	3.50000
Sporobolus stafianus Gand.	0.76923	0.00000	0.00000	0.00000	0.62500	0.00000	1.25000
Themeda triandra Forssk.	0.00000	0.10000	0.00000	0.00000	0.00000	0.50000	0.00000
Tragus berteronianus Schult.	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	2.50000
Triumfetta rhomboidea Jacq.	0.00000	0.00000	0.00000	0.00000	1.87500	0.00000	0.00000
Vernonia glabra (Steetz) Vatke	0.07690	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Vernonia perrottetii Sch. Bip ex Walp.	0.00000	0.00000	0.00000	1.40000	0.00000	0.00000	0.00000
Vernonia poskeana Vatke & Hildeb.	0.00000	0.00000	0.00000	0.40000	0.00000	0.00000	0.00000

6.3.3 1 Field layer diversity

The results showed that field layer diversity differed from one community type to another, which reflects the difference between the protected and non-protected areas (Table 25). Highest diversity index was recorded in the community type six. Community type six had many plots from sites S3, S4 and S6, which were on the lowlands of the non-protected area. This indicates that the field layer diversity was higher in the lowland sites of the non-protected area

The second highest diversity index was recorded in community type one. Community type one had many plots from sites S1 in the lowland of the protected area and sites S6 of the non-protected area. This indicates that the lowland of both sites had higher species diversity than the sloppy sites. The third diversity index is from the community type five. Community type five had many plots from the sites S3, S4 and S6, which were from the non-protected are. This also indicates that that area had higher species diversity.

The fourth diversity index is from the community type seven. Community type seven had more plots from sites S3. The fifth diversity index was recorded in the community type two. Community type two had many plots from the sites S5. The sixth diversity index is from the community type three. Community type three had plots from the Sites S2 and S5.This group shows that sites on the slopes both in the non-protected area and protected area had lower field layer diversity than other sites in the lowland.

The seventh diversity index was recorded in the community type four. Community type four had more plots from site S4. This indicates that among the sites in the lowland of non-protected area site s4 had lower diversity

These results indicate that the field layer diversity was higher in the lowland sites than in the sites on the slopes. Field layer diversity in the lowlands of the two areas was different, with that of the non-protected area being higher than that of the protected site. The field layer diversity in the sloppy sites of the two areas too, showed similar trend, *i.e.* it was different. The highest diversity was in the site (S6), while sites S4, S2 and S5 had lower diversities.

Field layer evenness differed from one community type to another and between the protected area and the non-protected area (Table 25). The highest evenness was recorded in the community type five, six and seven. These community types had many plots from sites in the lowland of the non-protected area. Lowest evenness indices were recorded in the community types one, three and four. The community type one had many plots from site S1, community type three had many plots from sites S2 and community type four had many plots from sites S4. Generally the field layer evenness was higher in the non-protected area than in the protected area.

Table 25: Field layer diversity and evenness

Community type	No. of attributes	Diversity index	Evenness index
6	16	2.317	0.836
1	24	2.180	0.686
5	10	2.044	0.888
7	13	1.916	0.747
2	14	1.907	0.722
3	13	1.511	0.589
4	4	0.608	0.438

6.3.4 Comparison of Soil Parameters Based on Community Types

ANOVA shows that all parameters are significant except sand, silt, sodium and magnesium (Table 26). When the soil parameters were arranged according to groups that were derived from plots and compared statistically several groups showed differences.

The result of multiple comparisons of trees given in table 20 showed that community type eight was significantly different in pH values from other community types. Also community types one and two were significantly different from other community types. Plots in the community type one, two and eight were from sites S2 and S5. The two sites had higher pH values than other sites. Community type eight was significantly different from other community types in electrical conductivity. Also Community type one showed significant difference with other community types in electrical conductivity. The community type eight had many plots from sites S2 and S5, which had higher values of electrical conductivity.

Community types four showed significant difference with other community types in silt percentages. This is because the community type four had many plots from sites S4, which had higher percentages of silt content. The site S4 was located in the non-protected area. Community type three was significantly different from other community types in clay percentages. Also community type two showed significant difference with other community types. The community types two and three had plots from sites S6 and S3, which had slightly higher clay percentages. Both two sites were located in the non-protected area.

Community type six showed significant difference with other community types in moisture content. Also community types seven and eight were significantly different from other community types. This is because most of the plots in the community type six, seven and eight were from sites S1 and S2, which had higher moisture content than the sites and were located in the protected area. Community type eight showed significant difference with other community in aggregate stability. This is because it had many plots from the sloppy sites S2 and S5, which had higher percentages of water aggregate stability than other sites.

Community types three, four, five, six and seven showed significant difference with the other community types in bulk density. This is because the five community types had more plots from sites S3 and S4, which had higher values of bulk density. Community types six and eight were significantly different from other community types in total nitrogen. Also community type seven showed significant difference. Community types six, seven and eight had many plots from sites S1 and S2. These two sites had higher values of total nitrogen than the other sites in the non-protected area. The two sites were located in the protected area.

Community type six, seven and eight were significantly different from other community types in nitrate. Community types six, seven and eight had many plots from sites S1 and S2. The two sites had higher values of nitrate than the other sites in the non-protected area. These two sites were located in the protected area.

Community type eight showed significant difference from other community types in available phosphorous. Also community types one, six and seven and showed significant difference and were denoted. Community types one, six seven and eight had plots from sites S1, S2 and S5. Both sites had higher values of available phosphorous, although site S5 was in the non-protected area.

Community type eight was significantly different from other community types in organic matter. Also community types one, six and seven and showed significant difference. Community types one, six, seven and eight had plots from sites S1, S2 and S5; both of which had higher values of organic matter, although site S5 was in the non-protected area. Community type six was significantly different from other community types in cation exchange capacity. Community type six had more plots from sites S1 and S2. The two sites had slightly higher values of cation exchange capacity than the other sites. The two sites were located in the protected area.

Community type six, seven and eight were significantly different from other community types in potassium. Community type six, seven and eight had many plots from sites S1 and S2 that had higher values of potassium than the other sites. Community types six and eight were significantly different from other community types in calcium. Also community types seven showed significant difference. Community type six, seven and eight had plots from site S1 and S2. The two sites had higher values of calcium than the other sites, and were located in the protected area.

Community types one, two, three, four and five had all the plots from the non-protected are with an exception of two plots in the community type one which were from sites S1. Site S1 was located in the lowland of the protected area and had higher values calcium, potassium, phosphorous, nitrate, total nitrogen, moisture content, and organic matter. That is why it behaves as community types six seven and eight, which had many plots from the protected sites i.e. S1 and S2.

Table 26: ANOVA of the soil parameters based on the tree community types

	Sum of squares	df	Mean square	F	P
PH Btn gps W/in gps Total	2.992 3.417 6.409	7 52 59	0.427 0.066	6.503	0.00*
EC Btn gps W/in gps Total	31289.530 47173.823 78463.353	7 52 59	4469.933 907.186	4.927	0.00*
Sand Btn gps W/in gps Total	17.042 62.80 79.842	7 52 59	2.435 1.208	2.016	0.07
Silt Btn gps W/in gps Total	153.733 608.413 762.146	7 52 59	21.962 11.700	1.877	0.92
Clay Btn gps W/in gps Total	86.815 168.919 255.734	7 52 59	12.402 3.248	3.818	0.002*
Mf Btn gps W/in gps Total	1733.666 1541.268 3274.934	7 52 59	247.667 29.640	8.356	0.00*
Stag Btn gps W/in gps Total	2227.282 4375.656 6602.938	7 52 59	318.183 84.147	3.781	0.02*
Bd Btn gps W/in gps Total	2.711 4.800 7.511	7 52 59	0.387 0.092	4.195	0.01*
TN Btn gps W/in gps Total	25.025 21242 46.267	7 52 59	3.575 0.409	8.751	0.00*
NO3- Btn gps W/in gps Total	174.769 149.327 314.096	7 52 59	24.967 2.872	8.694	0.00*

Continued Table 26: ANOVA of the soil parameters based on the tree community types

	Sum of squares	df	Mean square	F	P
PO4- Btn gps W/in gps Total	25.955 12.689 38.644	7 52 59	3.708 0.244	15.195	0.00*
Om Btn gps W/in gps Total	68.627 26.112 94.739	7 52 59	9.804 0.502	19.523	0.00*
CEC Btn gps W/in gps Total	366.909 900.647 1267.556	7 52 59	52.416 17.320	3.026	0.01*
K Btn gps W/in gps Total	207.739 178.198 375.937	7 52 59	29.677 3.427	8.660	0.00*
Na Btn gps W/in gps Total	0.589 2.348 2.937	7 52 59	0.08 0.05	1.864	0.1
Mg Btn gps W/in gps Total	7.642 53.555 60.975	7 52 59	1.092 1.030	1.060	0.40
Ca Btn gps W/in gps Total	724.373 929.113 1653.486	7 52 59	103.482 17.868	5.792	0.00*

Table 27: Multiple comparisons of soil parameters based on the tree community types

Soil par./com type	1	2	3	4	5	6	7	8
pH	6.93cd	6.88cd	6.70abc	6.62abc	6.53ab	6.43a	6.83bcd	7.16d
Sand	48.14b	48.07b	46.50a	47.50ab	47.25ab	48.33b	48.75b	48.63b
Silt	35.29ab	32.82ab	34.50ab	36.50b	35.25ab	34.78ab	31.25a	33.88ab
Clay	17.43ab	19.71bc	20.50c	17.50ab	18.75abc	16.56a	17.00a	18.13ab
Mf	8.18ab	2.91a	2.31a	5.48a	2.71a	17.46c	12.59bc	12.92bc
Bd	0.59a	0.93ab	1.24b	1.26b	1.26b	1.19b	1.06ab	0.84ab
TN	0.68ab	0.28a	0.19a	0.16a	0.12a	1.58c	1.31bc	1.78c
NO3-	1.36a	0.67a	0.29a	0.38a	0.19a	3.01b	3.64b	4.86b
PO4-	1.46bc	0.43a	0.77a	0.94ab	0.77a	1.75bc	1.93bc	2.27c
Om	2.45bc	0.76a	0.79a	1.62ab	1.03a	2.85bc	3.23bc	3.58c
C.E.C	65.11ab	63.32a	66.15ab	63.92a	67.92ab	70.51b	67.50ab	67.22ab
K	1.33a	0.23a	0.18a	0.29a	0.24a	3.78b	3.75b	4.87b
Na	0.62ab	0.66ab	0.59ab	0.75b	0.53ab	0.52ab	0.54ab	0.42a
Mg	5.69a	4.99a	4.96a	5.23a	5.33a	5.89a	5.77a	5.08a
Ca	15.58ab	14.01a	11.71a	14.34a	13.68a	21.06c	20.68bc	21.63c

Key:

Values with same letter are in the same range *i.e.* showed no significant difference

A value with two or more letters falls in the range of the first letter.

6.3.5 Comparison of Protected and Non-protected Plots

6.3.5.1 Tree layer

The results showed that there is no significant difference between that plots in the protected and non-protected areas (Table 28). This means that, tree layer has not affected much by the disturbance.

6.3.5.2 Shrub layer

The results showed that there is significant difference between that plots in the protected and non-protected areas (Table 28). This means that, shrub layer has been mostly affected much by the disturbance.

6.3.5.3 Field layer

The results showed that there is no significant difference between that plots in the protected and non-protected areas (Table 28). This means that, field layer has not affected much by the disturbance.

Table 28: Comparison of plots in the protected and non-protected areas.

(M.D mean difference, ns = not significant, * = significant.)

Vegetation layer	M.D	t-value	df	p
Tree	0.416	1.74	7	0.126ns
Shrub	0.413	2.64	8	0.03*
Field	0.43	1.61	6	0.158ns

6.4 Soil Physical Characteristics

According to USDA classification the soil type of is Ultisols The physical characteristics involved measurement of soil texture (sand, silt and clay) soil moisture factor, soil bulk density and determination of soil color by using Munsell colour chart.

6.4.1 Soil colour

Soil colour in the protected area and in the non-protected area differ slightly, croma was moderate i.e. 5YR. The top soil and sub soils from the protected area where organic matter was relatively higher than in the non-protected area tends to be brown. In the non-protected area top soil and sub soil where organic matter was low the colour tends to be grey and pinkish - grey (Table 33). Results of other soil parameters were presented in Appendix 1.

6.4.2 Soil Texture

The soil texture is expressed in percentages Soils in the protected area and non-protected area were dominated by sand fractions. Generally, soils in the protected area and the non-protected area can be described as sandy loam. Soils collected from plots established in the lowland of the protected area, had 48.4 ± 0.84 % sand for soils collected at a depth of 0-10 cm. Soils collected at a depth of 10-20 cm had 46.10 ± 0.1.66 % sand. Soils collected on sloppy site had 48.51 ± 0.74 % sand for soils collected at a depth of 0-10 cm.

Table 29 Soil colour

Site	Soil depth	Croma	Status	Colour
S1	0-10cm	5YR 3/1	Moist	Very dark grey
	10-20cm	5YR 6/3	Dry	Light reddish brown
S2	0-10cm	5YR 3/2	Moist	Dark reddish brown
S3	0-10cm	5YR 6/2	Dry	Pinkish grey
	10-20cm	5YR 6/1	Dry	Grey
S4	0-10cm	5YR 6/2	Dry	Pinkish grey
	10-20cm	5YR 6/1	Dry	Grey
S5	0-10cm	5YR 4/3	Dry	Reddish brown
S6	0-10cm	5YR 6/3	Dry	Light reddish brown
	10-20cm	5YR 6/4	Dry	Light reddish brown

The same trend was observed in the non-protected area where, sand fractions dominated over other fractions. The highest value for soils collected from plots established on lowland at a depth of 0-10 cm 48.80 ± 0.79 % and the lowest value was 46.7 ± 0.95 % .At a depth of 10-20 cm the highest value was 49.10 ± 0.57 % and the lowest was 47.40 ± 0.70 %. Soils collected on sloppy site had 48.50 ± 0.97 % at a depth of 0-10 cm.

6.4.3 Bulk Density

The soil bulk density is expressed as grams per cubic centimeter. Soil bulk densities in the protected area and non-protected area both in the lowland and sloppy sites varied slightly. The highest value was 1.35 ± 0.19 g/cm^3 which was recorded in the lowland of the non-protected area, the lowest value was 0.74 ± 0. 51 g/cm^3, which was recorded in the sloppy site of the non-protected area.

6.4.4 Moisture content

All sites in the protected area and non-protected area were sampled during the dry period. Moisture factor was very high in the protected area where the values on lowland were 21.33 ± 0.29 % for 0 -10 cm and 21.17 ± 1.52 % for 10 -20 cm deep soils. On sloppy site the value was 16.17 ± 0.08 %. The Moisture factor was found to be generally very low in the non-protected area soils. In the lowland the highest values were 5.61 ± 1.30 % for soil collected at 0-10 cm depth and 3.67 ± 0.63% for 10-20 cm depth. On sloppy site the value was 3.22 ± 0.10 %.

6.5 Chemical characteristics

Results obtained after chemical analysis of the soil samples collected from sites located on the lowland and slope both in the protected area and non-protected areas are presented in appendix 2.

6.5.1 Soil reaction (pH)

Generally soil reaction (pH) in the two areas had slight variations. It tends to increase as slope increase and decreases from top to sub soil. These results suggest that soils in the two study areas are slightly acidic to neutral.

6.5.2 Organic Matter

The organic matter was expressed in percentage. The percentage organic matter for soils collected from lowland and sloppy sites in the protected area and sloppy site in the non-protected area were high. The highest value was 4.20 ± 0.12 % for soil collected at the 0-10 cm depth in the sloppy sites of the protected area and the lowest value was 0.19 ± 0.08 % was for soil collected in the non-protected area at a depth of 10-20 cm. The result shows that there was clear trend or pattern of variation along the soil profile in that, organic matter tends to decrease down the profile and also increase as slope increase.

6.5.3 Total Nitrogen

Total nitrogen was expressed in percentages. Total nitrogen was high in the protected area. Highest percentage of total nitrogen was observed in the soils collected at 0-10cm on the slope 2.21 ± 0.13 %. The lowest percentage nitrogen was 0.04 ± 0.06 obtained in the soil collected in the non-protected area at the 0-10 cm depth. The result shows that there was clear trend or pattern of variation along the soil profile in that, percentage of total nitrogen tends to decrease down the profile except for site S6 where it increases as depth increases. Also it tends to increase as slope increase.

6.5.4. Nitrate (NO_3-)

Nitrate was high in the protected area compared to the non-protected area. The values in the protected area were 6.22 ± 0.07 mg/100g for soils collected from the sloppy at 0-10 cm depth. In the lowland the values were 4.18 ± 0.02 mg/100g for a 0-10 cm depth, and 5.09 ± 0.57

mg/100g for a 10-20cm depth. The values in the non-protected area were 0.61± 0.36 mg/100g for samples collected from the sloppy site at a depth of 0-10 cm. In the lowland the highest values were 0.85 ± 0.38 mg/100g at 0-10cm and 0.86 ± 0.21 mg/100g at 10-20cm depth both of which were recorder from site S6.

6.5.5 Available Phosphorus

Available Phosphorus was expressed as mg/100g. Higher values of available phosphorus were observed in the protected area and in from the sloppy site of the non-protected area. In the lowland of the protected area the values were 1.81 ± 0.18 mg/100g for soil samples collected in the lowland at the 0-10 cm depth and 1.29 ± 0.09 mg/100g at 10-20cm depths. On sloppy site in the protected area, the value was 2.64 ± 0.25 mg/100g while, in the non-protected area sloppy site, the value was 1.37 ± 0.15 mg/100g. There was a clear pattern whereby phosphorus tends to increase from the non-protected area to the protected area. Further more, the results shows that phosphorus was decreasing from top soil to sub soils.

6.5.6 Cation Exchange Capacity (C.E.C)

C.E.C is expressed in meq/100g. Soils collected from the protected area had slightly higher C.E.C values compared to the soils in the non-protected area. The highest value recorded was 76.17 ± 3.19 meq/100g for the soil sample collected in the lowland of the protected area at a depth of 10-20 cm. The lowest value was 52.50 ± 5.34 meq/100g for the soil sample collected in the lowland of the non-protected area at a depth of 10-20 cm.

6.5.7 Exchangeable Bases [K, Na, Mg and Ca]

6.5.7.1 Potassium

Results on exchangeable potassium show that sites in the protected area had generally high levels of potassium compared to sites in the non-protected area. The highest value was 6.44 ± 0.20 meq/100g for soils collected from the sloppy site in the protected area at 0-10 cm depth. The lowest value was 0.12 ± 0.01 which was recorded in the non-protected area at 10-20cm depth Potassium tends to decrease as depth increases.

6.5.7.2 Sodium

Exchangeable sodium does not show definitive pattern of variation between protected and non-protected areas. The lowest value was recorded in the sloppy site of the protected area, 0.29 ± 0.19 at 0-10cm depths. The highest value was 0.72 ± 0.14 which was recorded from site S6 in the lowland of the protected area at 10-20cm depths.

6.5.7.3 Magnesium

The levels of magnesium were almost equal to sites at all depths, except in the protected area at 10-20cm depths where the value was slightly high i.e. 7.73 ± 0.92 meq/100g.

6.5.7.4 Calcium

Exchangeable calcium was high in the protected area compared to non-protected area. It tends to increase as depth increases except in one site (S4) in the lowland of the non-protected area, where it has decreases.

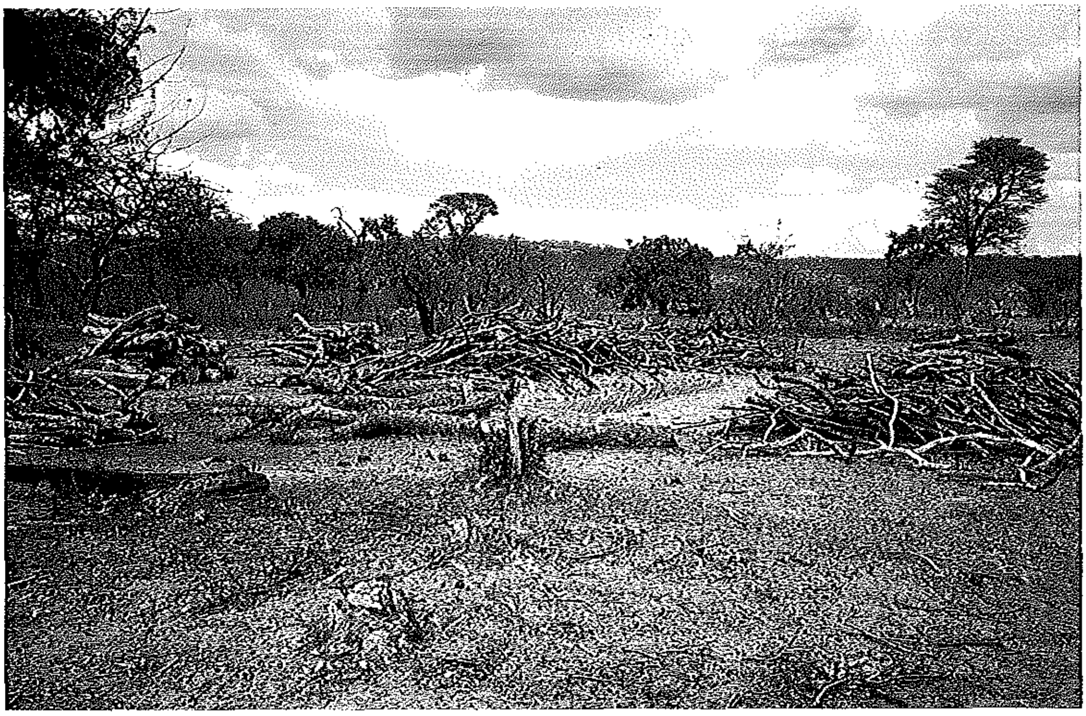

Figure 7: Logs prepared for charcoal burning in the public land.

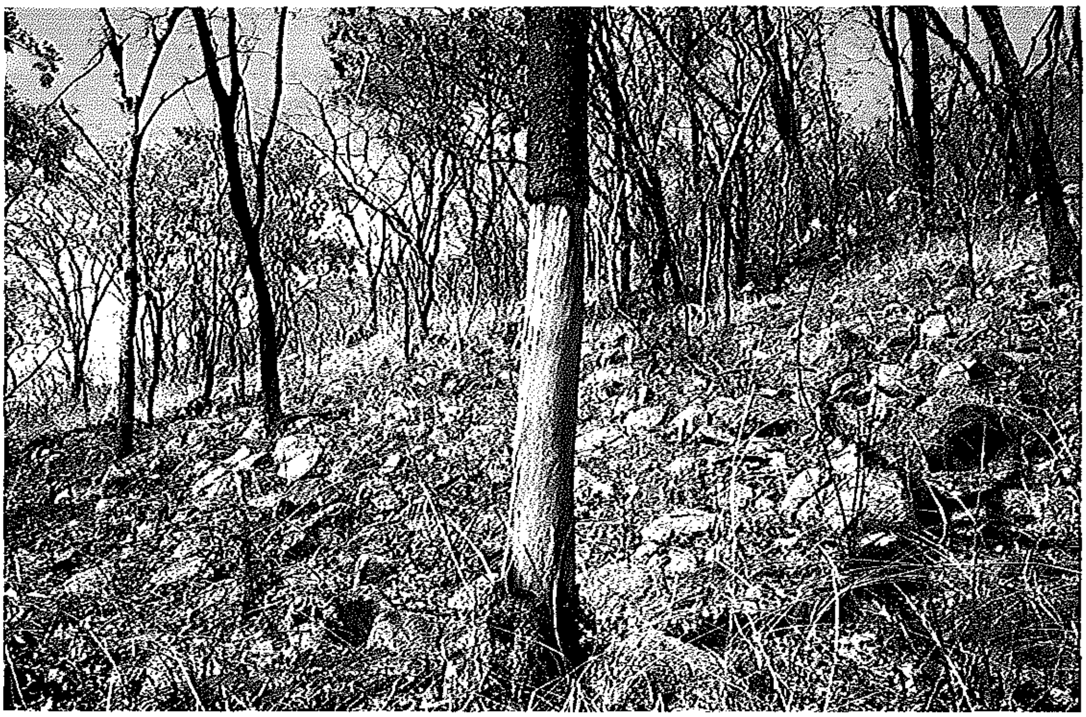

Figure 8: Debarking on a *Julbernardia globiliflora* for making beehives and containers.

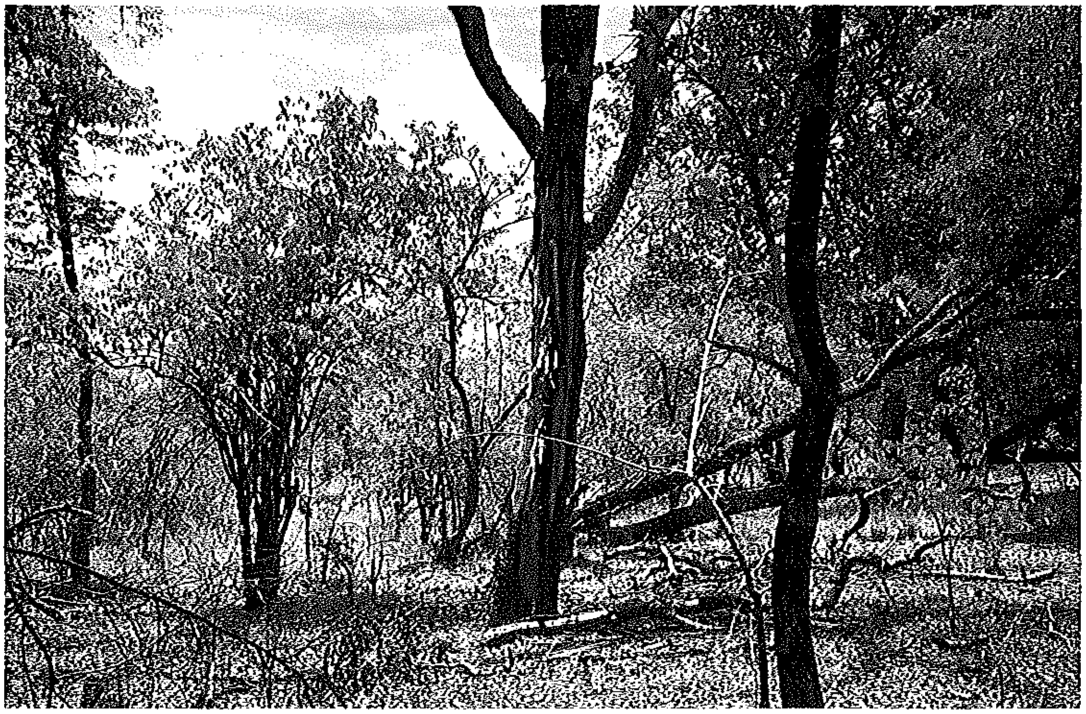

Figure 9: Debarking by elephant, in the forest reserve.

Figure 10: *Pterocarpus. angolensis* cut and left because it was not mature enough to produce good timber (In the forest reserve).

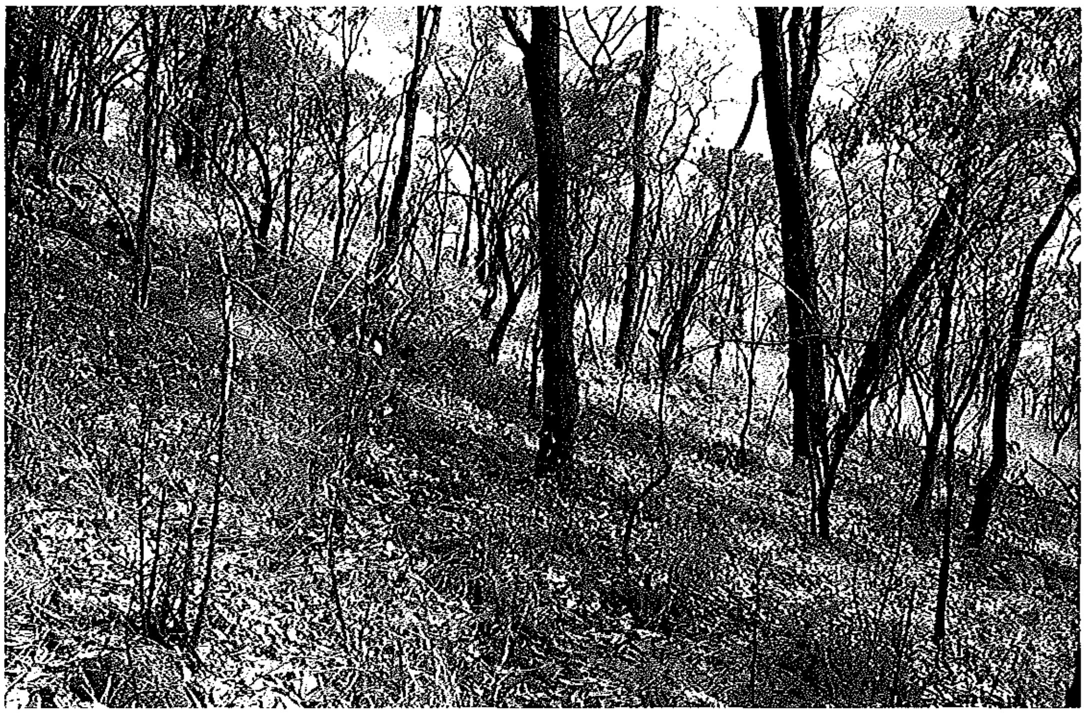

Figure 11: Sloppy site covered with rocks and stones

Figure 12: A beehive hanged on *Flueggea virosa* (In the forest reserve)

7. DISCUSSION

7.1 Composition

A total of 145 species were encountered in the two areas; these represent 105.genera and 30 families of which one is a fern. Family Fabaceae and Combretaceae dominated the tree and shrubs while family Poaceae dominates field layer (Appendix 1). Out of these woody plant species were 87, this shows that the area has lower diversity when compared to 650 species in Zambia (Fanshawe, 1971; cited in Chidumayo, 1997).

7.1.1 Trees

The results show that, highest diversity was in the community type seven, which had plots from forest reserve and the sloppy sites of the public land. The presupposing was that the diversity would be higher in the public land. This study found out the vice versa. This is probably because of the protection from selective logging, burning and land clearance.

In the case of sloppy site in the public land, which also had higher tree, diversity compared to its sister sites in the lowland. This is probably due to the intensity or level of disturbance. In the lowland plants were near settlements thus were more or heavily utilized than those at distant or on slopes. This suggests that once recourses are near settlements or when more accessible people will go for them until they deplete, that is when people will be obliged to progress into distant ones that is, slope or other wise they will encroach a nearby forest reserve as Moshi (2000) observed in Udzungwa mountains. Another reason is that it is easier to work on the lowland than on slopes. Therefore activities such as clearing of forest for preparation of farms do not affect sloppy sites.

It is also possible that, most trees on the sloppy site were big enough to tolerate the effects of fire, or else fire was not fierce enough to kill the big tree though it was late burning. According to Trapnell (1959) and Freson *et al.*, (1974) in Miombo woodlands, fire tolerance depends on time of onset, frequency, intensity of fire, age of a tree and plant species.

The community type five followed. This community type had all plots from sites S3 and S4 of the public land. This shows the two sites had higher diversity compared to site S6 in the same area. Newmark, (2001) shown that disturbance makes environment heterogeneous as a result of change of abiotic and biotic conditions thus creating new habitat. Human activities such as cultivation, which involve clear cutting of trees, leave the soil surface exposed for much of the year except during the cropping season. This creates different local habitats as compared to undisturbed area. These microclimates independently or in combination with biotic factors, influence the diversity of plants together with the fauna in an area. Fire also, creates new habitats by either releasing nutrient from vegetation when burnt or cause leaching of nutrients from the topsoil and subsoil to lower horizons. In case of nutrients released from burnt vegetation, nutrients will encourage growth of deep-rooted plant species. In most cases the type of species regenerating from burnt areas may be quite different from those in uncultivated or undisturbed areas.

However, type and intensity of activities has a significant contribution to either increase or decrease of diversity. This has been revealed in the result, which shows that community type two had lower diversity. This community type had plots from site S6. Thus shows that S6 had lower diversity than other sites. This is probably because of high disturbance on that site base on the constituency argument that, diversity is greatest at intermediate levels of disturbance (Connell, 1978; Grime, 1979; Armesto and Pickett, 1985; Huston, 1994). Site S6 was seen to be recovering from disturbance. The area was cultivated some time ago, and was left fallow. Thus, the trees were small below 1.3 m above ground with very few big trees.

Evenness was high in the public land than in the forest reserve. The species were distributed evenly in the communal land. This is probably because of the activities going on in that area.

7.1.2 Shrub

The results show that, highest diversity was in the community types eight. This community type had plots from sites S1 and S6. This implies that the two sites had higher diversity than other sites. The community type five which had plots from sites S3 and S4 followed this. Thus the lowlands had higher shrub diversity than the sites on the slopes. The reasons are probably that the soils in the lowlands were deep unlike those in the slopes, which were shallow. So it was easier for the shrubs to establish them selves, because there is no competition for space. It is also probably that the disturbance on the lowlands, especially by cultivation, fire and grazing encourage establishment of species. As it was stated earlier that, disturbance creates new environment and thus encourages establishment of new species.

Evenness was high in the lowlands than the slopes. This implies that species in the lowlands were evenly distributed.

7.1.3 Field layer

Community types six and five showed that the diversity of field layer was highest in the lowland of the public land. This is because of the disturbances in the lowland sites. Both early and late fires together with cultivation mostly affected these lowlands. This encourages establishment of fire tolerant species and other species, which can sprout earlier. Also the area was not overgrazed thus; encourage increase in diversity (Zerihun Woldu, 1985). The community type one which had plots from lowlands of the forest reserve was second in having higher diversity. Though the lowland sites of the forest reserve was said to be intact but illegal grazing of the domestic animals within the reserve was going on. Thus, this increases the diversity.

Although the diversity was higher in the lowland of the public land but the results showed that sites S6 had highest diversity than any other site. As described earlier, the site was a cultivated land, which was abandoned so as to recover. The high diversity may be caused by the effect of prolonged use of land for agriculture. As Lang-Brown and Harrop (1962; cited in Telke Kebron and Tesfaye Bekele 2000) argued, the prolonged use of land for agriculture cause depletion of soil nutrients and seed banks, thus fostering establishment of fast growing grasses.

Community types two; three and four had lowest diversity indices. These community types had plots from the sloppy sites and site S4 of the lowland of the public land. The sloppy site of the public land and S4 were affected by late burning. Local people burnt the area so as to chase away wild animals especially velvet monkey and baboons because they eat their crops. Site S4 was used for grazing, and it was burnt so as to encourage growth of field layer for pasture. The sloppy sites of both areas had low diversity probably because of the shallowness of the soil on sloppy sites contributes to the low diversity. The sites were almost covered with rocks and stones, so it becomes difficult for the grasses and herbs to establish themselves unless they are able to compete with shrubs and trees for the space.

Evenness was high in the public land than in the forest reserve. Thus herb and grass species were evenly distributed in the public land than in the forest reserve.

7.2 Structure

7.2.1 Tree

The results show that density and basal areas of tree was higher in the lowland of the forest reserve than in the lowland of the public land. These differences in density and basal area between the forest reserve and communal land is probably due to high disturbance in the public land.

The communal land is under pressure as a result of increasing human population, so there is an increasing need of more land for cultivation. The area has been reduced considerably through small-scale agriculture, which is associated with frequent fires and charcoal burning (Figure 7). Also demand for fuel wood and construction poles have been greatly intensified. The activities have been accompanied by soil deterioration on land previously cleared for farming, putting further pressure on cultivators to clear more forest. Thus these activities caused reduced density and basal of trees and low basal areas ha^{-1}. Other activities such as debarking for making containers and local beehives and cutting down of trees so as to collect honey have significant contribution to the low basal area, density and diversity of trees. Genus *Brachystegia* and *Julbernardia* are mostly preferred for charcoal burning. Local beehives and containers are made up of the barks of *Lannea stuhlmanni* and *Julbernardia globiflora* (Figure 8).

Few scattered trees remained especially in sites in the communal land, because transportation is difficult; from where they are cut to the area where charcoal production is carried out. Other trees remain because they have bad shapes (branched stems), so pit sawyers reject them. Other species like *Afzelia quanzensis* is left because they are used for charcoal only.

In the forest reserve density and basal area were low in the lowland than on the slope. This may probably because of the activities, which were going on, like illegal logging, lumbering and debarking. There were trees found killed by animals. Herbivores especially elephants, contributes in the reduction of density, basal area ha^{-1} and also diversity (Figure 9). These animals eat the barks of the tree. By removing the barks they remove the phloem, which transport manufactured food from branches to the lower parts of the tree, eventually the tree die. Thus many mature trees are being destroyed each year because of this. Some *Pterocarpus angolensis* were found cut and left in the forest because the diameter of the core (Xylem) was not big enough to produce good timber. The circumference at breast height of the dead trees was mostly between 35cm to 60cm (Figure 10). This practice reduces much the density and basal area ha^{-1} and also it gives a clue that some illegal pit sawyers do not have the knowledge to recognize the mature trees.

It is also possible that, there is competition for resources among seedlings, herbs and grasses in the lowland of the forest reserve. As DiTommaso and Aarssen (1991) observed, competition intensity within vegetation should generally increase not only as disturbance level decrease but also as habitat fertility increase. Also it is determined by the resource supply / demand rations and not by resource supply alone. The soil results show that the plants growth promoters (NPK) were more in the forest reserve. When the demand is high competition increase even if the level of the resource are high so, it is possible that the seedlings compete with the mature tree, shrubs, herbs and grasses for those nutrients (NPK), those which compete successfully grows others die. Thus indirectly reduce the density of mature trees.

Site S6 in the lowland of the public land had low density and basal area than other sites. Site S6 was seen to be recovering from disturbance. The area was cultivated some time ago, and was left fallow. This site was mostly affected by clearance of land. Thus directly reduce the density and basal area of mature trees. Therefore the level of disturbance affected the density and basal area ha^{-1}.

The structure was also presented by the height distribution in classes. There were very few individuals in the first class (<5m), which were from the lowlands in the forest reserve and public land respectively. These were of species *Erythrina abyssinica, Phillanthus englerii, Terminalia sericea, Commifora africana, Dalbergia melanoxylon and Pilliostigma thoningii*, which were in the public land. *Hymenocardia asida* was the only species in the forest reserve. The reason for the low species composition in this class may be the land clearance for cultivation, which goes hand in hand with burning especially in the public land. There were evidence of new clearing in the public land (Figure 7) while place of old habitation were revegetating, largely to grass woodland especially site S6. In case of site S1 in the lowland of the forest reserve the reason might be environmental stress and competition between seedling and bigger trees, or seedling and shrubs and field layer. Thus the competition adversely affects seedlings growth (Chidumayo, 1992).

On the other hand sites on the slopes both in the reserve and public land had no members in this class. This is probably because of competition between large trees and the seedlings over the area to establish them selves. This is because the two sites are more covered with rocks and stones.

The second class 5.0m to 9.9m was dominated with the same sites as the former class. The possible reason is that, the pattern of vegetation dynamics in wooded savanna or open woodland is created by disturbances, which will open the canopy gap, which foster seedling and small tree growth. So an ecosystem can remain stable for a long time until when the right circumstances occur (Celander, 1983). Thus, it is possible that, trees in that height class are waiting for the disturbance, which can enable some of them to enter next class. Another possibility is that many bigger trees have been cut down for various purposes such as building poles, charcoal production, wood, making local beehives and making ropes.

The third and fourth classes (10.0-19.9 m) were dominated with trees from sloppy sites. Dominant species in those classes were *Brachystegia spiciformis*, *Brachystegia microphyla*, *Brachystegia boehmii*, *Diplorhynchus condylocarpon*, *Julbernardia globiflora*, *Pterocarpus angolensis*, and *Pterocarpus tectorius*. The reasons may be the trees were big enough to tolerate effects of fire and also the distance from villages and slope prevents those valuable species from being cut. These reasons can only apply in the public land.

In case of site in the forest reserve, there were more trees in the two height classes because of the protection from disturbances of fire; also because of the slope illegal logging becomes difficult. Also slope might discourage herbivores like elephants.

The fifth class (≥20 m) was dominated with trees from lowland site of the protected area. Dominant species in those classes were *Brachystegia spiciformis*, *Brachystegia boehmii*, *Strichnos madagascariensis*, *Julbernardia globiflora*, *Combretum zeyheri*, *Swertizia madagascariensis* and *Pterocarpus tectorius*. The reasons may be the trees are cannot produce good timber, because among these species valuable species like *Pterocarpus angolensis* were not presented. Also the protection of the forest contributes, because it reduces pressure from the local people.

7.2.2 Shrub

The density of shrubs in the sloppy site of the forest reserve was significantly higher than that in the sloppy site of the public land. It is probably because there was no disturbance in the forest reserve. Another reason might be that though the soil was shallow like in the public land but at least moisture content and plant growth promoters (NPK) were high in the forest reserve. Thus encourages the growth of shrubs.

7.2.3 Field layer

Field layer density was higher in the lowland of the forest reserve than in the lowland of the public land. This is because of the disturbance, in the public land, which is due to fire, grazing and cultivation.

7.3 Soils

Tree community types six, seven and eight had high moisture content, organic matter, total nitrogen, nitrate, available phosphorous, potassium and calcium. These community types had plots from the forest reserve.

This indicates that soils in the forest reserve have more moisture than those in the public land. Vegetation cover causes this. In the forest reserve especially in the lowland, the area was almost covered with the field layer; the tree canopy was almost closed unlike in the public land where the area was almost exposed. Vegetation covers reduce moisture evaporation hence; help to hold soil moisture in the forest reserve.

This study revealed that the organic matter content was high in the forest reserve with an addition that sloppy site in the public land had high organic matter too. The difference in organic matter content in the public land and forest reserve especially for top soil is mostly because in the public land, organic matter is under constant disturbances as cultivation and burning is practiced, whereas in the forest reserve the disturbance is mainly due to trampling by wildlife, which are few. However, in the forest reserve the amount of organic matter returned to the soil by litter fall and root death is much higher because there is much more vegetation than in the public land. The sub soil in the forest reserve had high organic matter compared to the sub soil in the public land possibly because of downward movement of organic matter in the sub soil, which is a long-term process that has continued for many years, depending on seasonal precipitation and leaching rates, which were not investigated in this study.

Soil samples, from the forest reserve had high total nitrogen compared to those from public land. This is because there is much more of organic matter due to litter fall of dead leaves and branches. The organic matter decomposes and adds nutrients such as nitrogen in the soil. Some tree species of Miombo woodlands have vesicular-arbuscular mycorrhizal. Some of those species form nitrogen-fixing nodules. Some of those species were found in the forest reverse, like *Pericopsis angolensis*, *Pterocarpus angolensis* and *Albizia spp.* (Frost, 1996), thus they contributed in the high values of nitrogen in the forest reserve. Available phosphorus (PO_4^-) like the other elements, were more in the forest reserve than in the public land. The topsoil in both public land and forest reserve had high PO_4^- levels and this decreased as moving down to subsoil. This indicates that the source of PO_4^- were from plant residue mineralization and not weathering from the parent material. Frequent burning and plant residue on the sloppy site of the public land accounts for increasing levels of available phosphorus in the top soil of that site. As Yanai (1992) in the northern hardwood forest found out that soil nutrients have been directly correlated to wildfires

The presence of high levels of calcium and potassium in the forest reserve is attributed to pH levels, which favour the solubility of those exchangeable bases. Most nutrient elements are readily available within the pH range of 6.0 to 7.5, because it does not have direct effect to plant roots and microorganisms (Smith and Doran, 1996). Calcium and potassium were low in the public land probably because, they have leached from the topsoil and subsoil to lower horizons. This is caused by low clay percentages in the topsoil and subsoil hence the soils are light. Because there were not enough clay particles to hold calcium and potassium ions, the ions leached to lower horizons. Availability of these ions has been associated with clay particles (Allen, 1989).

The soils in both two-study areas had low bulk densities of below 1.5 g/cm^3. Tree community types three, four, five and six had high bulk density. These community types had plots from the sites S3 and S4, which were in the lowland of the public land. Except the tree community type six which had plots from the lowland of the forest reserve. Generally the lowland sites in the public land had higher values compared to lowland in the forest reserve. This is possibly due to cultivation practices and trampling by domestic animals. Also in the forest reserve the bulk density was slightly high in the lowland, this is probably due to trampling by domestic animals and wildlife. Arshad *et al*., (1996) showed that bulk density is an indicator of soil compaction, which is reflected by relative restrictions to root growth. The known minimum bulk density thresholds for root restricting compacted condition for loamy-sand; clayey-loam is 1.7g/cm^3 (Arshad *et al*., 1996). Therefore, though bulk density showed significant difference the values are low to cause harm to the vegetation structure and composition.

The tree community types one, two, seven and eight had high pH values. These community types had plots from sites on the lowland and slopes of both two areas. Thus there is no clear trend if pH was high in the forest reserve or communal land. The pH of most soil samples ranged from being slightly acidic to alkaline.

7.4 Shrub layer

The results showed that the shrub layer has been mostly affected much by the disturbance *i.e.* the later which has responded to disturbances. This is because of the onset of fire. According to Symoens and Bingen-Gathy, 1959; Trapnell, 1959 and Lawton, 1972; cited in Celander (1983) many shrub species in Miombo woodland are fire tolerant concerning early and light burns but fire sensitive when late and fierce burns. In the public land there was no heavy grazing, which could lower the dry season standing crop of grass, which would act fuel for fire. As a result there was increased fire intensities and damage to woody plants in this case shrubs. The perseverance fires too, contributed, as Krannitz and Bennet (1999) in their study in South Okagan shrub steppe, found out that persistence fires turn shrub steppe into annual grasslands with a fire periodicity of 1-3 years.

It is also probably because of the activities, which are going on in the public land. Cultivation, charcoal production, and fire wood collection these activities involve clear-cutting of woody plats. In that public land the trees remained were scattered, so charcoal producers and fire wood collectors are forced to go for shrubs. As Zerihun Woldu and Backéus (1991) observed in Western Shewa, Ethiopia that firewood collection significantly affected the shrub land.

The field layer has not responded quickly as it was presupposed because, grasses and other non-wood herbs tolerate intense dry season fires than most wood plants (Frost and Robertson 1987; Herlocker, 1999). They have growing points, which are better protected from fire and tend to sprout earlier after a burn has occurred (Pratt and Gwynne, 1977).

8. CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

- The study showed that tree diversity is higher in the forest reserve. Thus protection is important for conservation purposes. Without protection, the biological diversity within Miombo woodlands of Tanzania would be poor and it would lead to disappearance of endemic species. This is because increase in the areas of degraded forest; cultivation and settlement indicate a decline in the natural habitat. Thus, the future of the Miombo woodlands depends on the changing attitude of the local people and governments *i.e.* Local and Central governments.

- The slopes provide protection to trees diversity in the communal land.

- Disturbance in the forms of grazing, burning, clearance of land for cultivation increases shrub and field layer diversity in the communal land.

- The difference in nutrient levels and activities going on in the two study areas account for differences of diversities, evenness and density of the trees, shrubs and field layer. Thus impairs the ecosystem function, because in the absence of vegetation cover, changes such as tremendous loss of biodiversity of shade loving fauna are possible

8.2 Recommendation

- As stated earlier that, the future of the Miombo woodlands depends on the changing attitude of the local people and governments (Local and Central governments). Thus, for effective implementation, involvement of local people in the conservation of these woodlands is vital as well as indigenous knowledge and skills should be incorporated in polices and by-laws governing natural resources management.

- Tree planting in the communal land should be given first priority. The existing trees needs to be paralleled by planting fast growing species which would provide wood for fuel and construction, hence reduce pressure to the forest.

- Attention should be given on providing education and encouragement on the use of energy serving stoves.

- Clearing an area around hives should be permitted. This is important to beekeepers because it reduces the risk of runaway fires and also it helps clear a flight-path for the bees. But clearing should not involve large tree.

- There is a need to conduct an intensive floristic study especially on the ecological part.

- Ecological work is needed on the biology of fauna, and the effects of the on going activities to those organisms in the study area.

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10 APPENDICES

10.1 Appendix 1: List of Botanicals Collected

Species name	**Family name**	
Acacia drepanolobium Harms ex Sjöstedt	Mimosaceae	MM 0114-03
Acacia nilotica (L) Del.	"	MM 0088-03
Acacia senegal (L) Wild	"	MM 0082-03
Acacia sieberiana DC.	"	MM 0110-03
Acacia torttilis (Forsskal) Hayne	"	MM 0118-03
Aerva lanata (L.) Juss. ex Schules	Amaranthaceae	MM 0049-03
Afzelia quanzensis Welw.	Caesalpiniaceae	MM 0093-03
Ageratum conyzoides L.	Compositae	MM 0047-03
Albizia petersiana (Bolle) Oliv.	Mimosaceae	MM 0125-03
Albizia verscolor (Welw.)	"	MM 0111-03
Annona senegalensis Pers	Annonaceae	MM 0012-03
Aristida adoensis Hochst.	Gramineae	MM 0129-03
Aristida barbicollis Trin. & Rupr.	"	MM 0144-03
Asparagus aethopicus L.	Liliaceae	MM 0086-03
Aspilia mossambicensis (Oliv.) Wild	Compositae	MM 0060-03
Bidens pilosa L.	"	MM 0120-03
Blepharis affinis Lindau	Acanthaceae	MM 0001-03
Blepharis maderaspatensis (L.) Roth	"	MM 0041-03
Boscia salicifolia Oliver	Capparaceae	MM 0128-03
Brachystegia boehmii Taub	Caesalpiniaceae	MM 0032-03
Brachystegia longifolia Benth.	"	MM 0092-03
Brachystegia microphylla Harm	"	MM 0061-03
Brachystegia spiciformis Benth.	"	MM 0018-03
Capparis tomentosa Lam.	Capparaceae	MM 0022-03
Cassia abbreviata Oliv.	Caesalpiniaceae	MM 0102-03
Cassipourea malosana (Bak.) Alston	Rhirophoraceae	MM 0119-03
Catunaregam spinosa (Thunb.)	Rubiaceae	MM 0055-03
Chloris pycnothrix Trin.	Gramineae/Poaceae	MM 0112-03
Chloris virgata Sw.	"	MM 0105-03
Chrisophylum bangweolense R.E.Fries	Sapotaceae	MM 0059-03
Clerodendron myricoides R.Br.& Vatke	Verbenaceae	MM 0142-03
Combretum aculeatum Vent.	Combretaceae	MM 0090-03
Combretum collinum Fresen.	"	MM 0108-03
Combretum molle R.Br ex G. Don	"	MM 0005-03
Combretum zeyheri Sonder	"	MM 0003-03
Commelina africana L.	Commelinaceae	MM 0075-03
Commiphora africana (A.Rich) Engl	"	MM 0084-03
Crossopteryx febrifuga (Afzel ex G.Don) Benth.	Rubiaceae	MM 0033-03
Cyanotis foecunda Hochst. ex Hassk.	Commelinaceae	MM 0076-03
Cyperas obtusiflorus Vahl	Cyperaceae	MM 0011-03
Dactyloctenium aegyptium (L.) Willd.	Gramineae/Poaceae	MM 0137-03
Dalbergia melanoxylon Guillenni & Perrotter	Papilionaceae	MM 0006-03
Dalbergia nitidula Welw ex Baker.	"	MM 0127-03

Desmodium barbatum (L.) Benth.	Papilionaceae	MM 0095-03
Dichanthium annulatum (Forssk.) Stapf	Gramineae/Poaceae	MM 0138-03
Dichrostachys cinerea (L) Wight & Arn	Mimosaceae	MM 0085-03
Diospyros usambarensis F.White	Ebanaceae	MM 0050-03
Diplorhynchus condylocarpon (Muell.Erg) Pichon	Apocynaceae	MM 0019-03
Entada abyssinica Steud ex A.Rich	Mimosoideae	MM 0107-03
Ethulia conyzoides L.	Compositae	MM 0036-03
Eragrostis aspera (Jacq.) Nees	Gramineae/Poaceae	MM 0066-03
Eragrostis patens Oliv.	"	MM 0009-03
Eragrostis racemosa (Thunb.) steud	"	MM 0073-03
Erythrina abyssinica Law ex DC	Papilionaceae	MM 0069-03
Euphobia grantii Oliv.	Euphorbiaceae	MM 0078-03
Euphorbia candelabram DC	"	MM 0123-03
Euphorbia hirta L.	"	MM 0136-03
Ficus glumosa (miq) Delile	Moraceae	MM 0020-03
Ficus natalensis Hochst	"	MM 0109-03
Ficus sur Warb	"	MM 0091-03
Flueggea virosa (Roeb.ex Willd) Baillon	Euphorbiaceae	MM 0027-03
Grewia bicolor Juss	Tiliaceae	MM 0126-03
Harissonia abyssinica Oliv. Mssaborini	Simorabaceae	MM 0023-03
Harpachne schimperi Hochst. Ex A. Rich.	Gramineae/Poaceae	MM 0098-03
Heteropogon contortus (L.) Roem. & Schult.	"	MM 0002-03
Holarrhena febrifuga Klotzsch.	Apocynaceae	MM 0013-03
Hoslundia opposita Vahl; Benth. in DC. Prod.	Apocynaceae	MM 0131-03
Hygrophila auriculata (Schumach.) Heine	Gramineae/Poaceae	MM 0116-03
Hymenocardia acida Tul	Euphorbiaceae	MM 0043-03
Hyparrhenia filipendula (Hochst.) Stapf	Gramineae/Poaceae	MM 0029-03
Hyparrhenia rufa (Nees) Stapf	"	MM 0070-03
Indigofora arrecta A. Rich.	"	MM 0135-03
Julbernardia globiflora (Benth) Troupin	Caesalpiniaceae	MM 0004-03
Kigelia africana (Lam) Benth	Bignoniaceae	MM 0046-03
Lannea humilis (Oliver) Engl.	Anacardiaceae	MM 0087-03
Lannea schimperi (Hochst ex A.Rich) Engl.	"	MM 0026-03
Lannea stuhlmannii (Engl) Engl.	"	MM 0124-03
Leonotis nepetifolia R.Br.	Labiaceae	MM 0077-03
Leptactina banguelensis (Benth)	Rubiaceae	MM 0014-03
Lonchocarpus eriocacalyx Harms	Papilionaceae	MM 0104-03
Loudetia simplex (Nees) C.E. Hubb	Gramineae/Poaceae	MM 0010-03
Margaritaria discoidea (Baillon) Webster	Euphorbiaceae	MM 0034-03
Markhamia obtusifolia (Bakar) Sprague	Bignoniaceae	MM 0015-03
Melinis repens (Wild.) Zizka	Gramineae/Poaceae	MM 0121-03
Monechma debile (Forsska.) Nees	Acanthaceae	MM 0079-03
Monotis africanus A. DC.	Dipterocarpaceae	MM 0054-03
Orthosiphon suffrutescens (Thonn.) JK Morton	Labiatae	MM 0040-03
Ozoroa insignis Delile	Anacardiaceae	MM 0065-03
Panicum coloratum L.	Gramineae/Poaceae	MM 0035-03
Panicum maximum Jacq	"	MM 0071-03
Panicum trichoculadum K. Schum.	"	MM 0044-03
Pavetta bagshawei S.Moore	Rubiaceae	MM 0099-03
Pellaea viridis (Forssk)	Plantii	MM 0062-03

Pennisetam polystachion (L.) Schult.	Gramineae/Poaceae	MM 0058-03
Pennisetum mezianum Leeke	"	MM 0089-03
Pericopsis angolensis (Bakar) Van Meeuwen	Papilionaceae	MM 0101-03
Perotis hildebrandtii Mez	Gramineae/Poaceae	MM 0048-03
Phyllanthus engleri Pax	Euphorbiaceae	MM 0031-03
Pilliostigma thonningii Schummacher	Caesalpiniaceae	MM 0106-03
Plectranthus barbatus DC	Labiaceae	MM 0067-03
Pogonarthria squarrosa (Roem. & Schult.) Pilg.	Gramineae/Poaceae	MM 0139-03
Portulaca oleracea L.	"	MM 0081-03
Psorospermum febrifugum Spach	Guttiferae	MM 0038-03
Pterocarpus angolensis DC	Papilionaceae	MM 0008-03
Pterocarpus tictorius Welw.	"	MM 0016-03
Rothmannia fischeri (K.Schum) Bullock.	Rubiaceae	MM 0051-03
Rottboellia exaltata L.f.	Gramineae/Poaceae	MM 0083-03
Schrebera trichoclada Welw.Syn	Oleaceae	MM 0130-03
Sclerocarya birrea (A.Rich) Hochst	Anacardiaceae	MM 0080-03
Senna singueana (Del) Lock	"	MM 0103-03
Setaria sphacelata (Schumach.) Moss	Gramineae/Poaceae	MM 0057-03
Setaria verticillata (L.) P. Beauv	"	MM 0132-03
Spaeranthus gomphrenoides O. Hoffm.	Compositae	MM 0115-03
Spermacoce senensis (Klotzch) Hiern	Rubiaceae	MM 0045-03
Sporobolus fimbriatus (Trin.) Nees	Gramineae/Poaceae	MM 0074-03
Sporobolus panicoides A. Rich.	"	MM 0096-03
Sporobolus pyramidalis P. Beauv.	"	MM 0094-03
Sporobolus stafianus Gand.	"	MM 0113-03
Sterculia quinqueba (Garcke) K.Schum.	Sterculiaceae	MM 0068-03
Stereospermum kunthanum Cham.	Bignoniaceae	MM 0134-03
Strophanthus emini Asch.& Pax	Apocynaceae	MM 0042-03
Strychnos madascariensis Poir.	Loganinaceae	MM 0024-03
Strychnos potatorum L.f.	"	MM 0064-03
Strychnos pungensis Solered.	"	MM 0021-03
Strychnos spinosa Lam.	"	MM 0025-03
Swertizia madagascariensis Desv.	Papilionaceae	MM 0039-03
Synodenium mole Pax	Euphorbiaceae	MM 0063-03
Terminalia mollis M.A. Lawson	Combretaceae	MM 0072-03
Terminalia sericea Burch.ex DC	"	MM 0028-03
Themeda triandra Forssk.	Gramineae/Poaceae	MM 0030-03
Tragus berteronianus Schult.	"	MM 0097-03
Triumfetta rhomboidea Jacq.	Tiliaceae	MM 0056-03
Vangueria infausta Burch.	Rubiaceae	MM 0141-03
Vernonia glabra (Steetz) Vatke	Tiliaceae	MM 0037-03
Vernonia perrottetii Sch. Bip ex Walp.	"	MM 0117-03
Vernonia poskeana Vatke & Hildeb.	"	MM 0121-03
Vitex doniana Sweet	Verbenaceae	MM 0100-03
Vitex mombasae Vatke	"	MM 0145-03
Xeroderris stuhlmannii (Taub.) Mendonça & Sousa	Papillionaceae	MM 0052-03
Ximenia americana L.	Olacaceae	MM 0053-03
Xylopia aethoipica (Dunal) A. Rich.	Annonaceae	MM 0017-03
Zanha africana (Radlk.) Exell	Sapimoraceae	MM 0133-03
Zanthoxylum chalybeum Engl.	Rutaceae	MM 0007-03

10.2 Appendix 2: Mean Values of the Soil Parameters

	pH	Sand	Silt	Clay	MF	BD	TN	NO3-
S1 0-10cm	6.51 ± 0.26	48.4 ± 0.84	34.6 ± 2.0	16.9 ± 1.1	21.33 ± 0.29	1.19 ± 0.04	1.81 ± 0.47	4.18 ± 0.02
S2 0-10cm	7.02 ± 0.27	48.51 ± 0.74	34.6 ± 2.84	16.4 ± 2.01	16.17 ± 0.08	0.81 ± 0.31	2.21 ± 0.13	6.22 ± 0.07
S3 0-10cm	6.85 ± 0.28	46.7 ± 0.95	34.6 ± 0.84	19.8 ± 1.48	2.25 ± 0.07	1.17 ± 0.06	0.20 ± 0.04	0.27 ± 0.07
S4 0-10cm	6.44 ± 0.19	47.7 ± 1.34	36.6 ± 1.58	17.0 ± 0.94	5.61 ± 1.30	1.35 ± 0.19	0.05 ± 0.01	0.16 ± 0.04
S5 0-10cm	6.99 ± 0.24	48.5 ± 0.97	32.00 ± 6.15	18.5 ± 1.84	3.22 ± 0.10	0.74 ± 0.51	0.39 ± 0.17	0.61 ± 0.36
S6 0-10cm	6.90 ± 0.23	48.8 ± 0.79	31.85 ± 3.71	19.80 ± 1.93	3.26 ± 0.11	0.81 ± 0.26	0.31 ± 0.20	0.85 ± 0.38
S1 10-20cm	6.30 ± 0.26	46.1 ± 1.66	37.10 ± 0.74	17.10 ± 1.52	21.17 ± 0.05	1.2 ± 0.06	0.61 ± 0.06	5.09 ± 0.57
S3 10-20cm	6.61 ± 0.22	49.1 ± 0.57	31.10 ± 0.74	19.60 ± 1.78	2.32 ± 0.30	1.06 ± 0.17	0.10 ± 0.02	0.20 ± 0.06
S4 10-20cm	6.33 ± 0.31	47.4 ± 0.70	34.20 ± 1.40	18.4 ± 0.84	3.30 ± 0.70	1.01 ± 0.33	0.04 ± 0.01	0.30 ± 0.08
S6 10-20cm	6.68 ± 0.18	47.7 ± 0.82	36.40 ± 1.08	15.40 ± 1.27	3.67 ± 0.63	0.54 ± 0.17	0.55 ± 0.02	0.86 ± 0.21

	PO4-	OM	C.E.C	K	Na	Mg	Ca
S1 0-10cm	1.89 ± 0.18	3.07 ± 0.13	72.27 ± 3.29	4.52 ± 0.22	0.57 ± 0.30	6.82± 0.59	24.12 ± 4.70
S2 0-10cm	2.64 ± 0.25	4.20 ± 0.12	68.90 ± 1.45	6.44 ± 0.20	0.29 ± 0.19	5.04 ± 0.89	22.82 ± 2.25
S3 0-10cm	0.78 ± 0.24	0.72 ± 0.14	66.48 ± 6.54	0.18 ± 0.1	0.55 ± 0.17	4.91 ± 0.54	11.41 ± 1.22
S4 0-10cm	0.79 ± 0.06	1.33 ± 0.07	63.67 ± 1.10	0.28 ± 0.07	0.69 ± 0.11	5.29 ± 0.65	14.41 ± 1.97
S5 0-10cm	1.37 ± 0.15	2.50 ± 0.2	62.85 ± 0.95	0.22 ± 0.11	0.69 ± 0.08	5.02 ± 0.62	14.52 ± 1.83
S6 0-10cm	0.30 ± 0.16	0.88 ± 0.27	62.82 ± 1.28	0.27 ± 0.09	0.72 ± 0.10	5.17 ± 1.32	15.34 ± 1.30
S1 10-20cm	1.29 ± 0.09	2.12 ± 0.03	76.17 ± 3.19	2.47 ± 0.46	0.81 ± 0.16	7.73 ± 0.92	27.18 ± 2.70
S3 10-20cm	0.12 ± 0.12	0.19 ± 0.08	64.59 ± 3.24	0.12 ± 0.01	0.68 ± 0.15	4.56 ± 0.78	13.16 ± 1.09
S4 10-20cm	0.06 ± 0.03	0.38 ± 0.09	52.50 ± 5.34	0.18 ± 0.03	0.75 ± 0.05	4.12 ± 1.14	12.51 ± 1.22
S6 10-20cm	0.04 ± 0.03	0.38 ± 0.08	66.57 ± 2.58	0.30 ± 0.03	0.72 ± 0.14	4.58 ± 0.68	15.31 ± 1.57