The effects of non-commercial utilisation of forest resources on the species composition and nutrients at Uplands, Kenya.

By

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ABSTRACT

Research to investigate the effects of the continued use of the forest resources by the forest neighbouring communities was carried out at Uplands forest, in Kenya , between October 1999 and March 2000. The investigations were carried out with two objectives i.e. to find out whether the continued use of forest resources, have any effect on either the species composition or the nutritional status of the forest

The natural or indigenous forests in Kenya are protected and managed towards conservation of biodiversity but more for the conservation of soil and water resources. Extraction of resources from these forests have been under a presidential ban since mid.1980's. The legalized activities in forests which includes fuelwood(as dead wood collection), grazing of livestock and farming under the famous shamba system are restricted to areas under plantations.

In Uplands forest, the research findings on the non-commercial use of the forest resources revelled two activities as the most destructive to both the species and nutrients i.e. charcoal and timber. The other activities e.g. fuelwood collection, tool handles, bee-keeping etc. had only peripheral effects as compared to these two.

A total of 57 species of trees, shrubs and lianas were found in area of the forest covered by the research and a few others might occur beyond the area sampled. 40 species of trees and shrubs were found in the test site and 36 species in the reference site plots. The frequency of three pioneer species i.e. *Neoboutonia macrocalyx, Macaranga kilimandscharica* and *Tabernamontana stapfiana* was found to be higher in the test than reference site which could be as a result of the canopy gaps.

Allophylus abyssinicus, Neoboutonia macrocalyx and *Psychotria fractinervata,* the most dominant species in both sites, were chosen for the study of nutrients in the forest ecosystem. For the organic or non-metallic nutrients i.e. carbon, nitrogen, sulphur and phosphorous, *Allophylus abyssinicus* had the lowest content in both sites. *Neoboutonia macrocalyx* had the highest content of nitrogen and phosphorous, while *Psychotria fractinervata* had the highest content of carbon and sulphur.

Allophylus abyssinicus had the highest C:N ratio while *Neoboutonia macrocalyx* had the highest S:N.ratio The content of sulphur and nitrogen showed a type of correlation due to their correlated functioning in proteinsysnthesis. Nitrogen is the limiting resource in primary productivity and so the sulphur in excess of the available nitrogen, is stored in form of sulphate sulphur.

Potassium (K^{+}), Calcium (Ca^{2+}), Magnesium (Mg^{2+}) and Sodium (Na^{+}) are the metallic macronutrients or alkali and alkaline earth metals. *Neoboutonia macrocalyx* had the highest content of K^{+} in both sites. All the three species had higher content of Ca^{2+} in the reference site. *Allophylus abyssinicus* and *Neoboutonia macrocalyx* had higher content of Mg^{2+} in the reference while *Pschotria fractinervata* had the highest in the test site. *Neoboutonia macrocalyx* and *Psychotria fractinervata* had the highest content of Na^{+} in the reference while *Allophylus abyssinicus* had the highest in the test site.

Manganese (Mn^{2+}), Aluminum (Al^{3+}) and Iron (Fe^{+}), which are trace elements and required by plants in very low quantities, had higher concentration in the soil and especially in the test site and thus the acidic nature of the soil (pH range 3.5-4.0).while that of the reference was less acidic (pH range 5.0-6.0).

All the three species had higher content of Mn^{2+} in the test site while they had higher content of Fe^{+} in the reference site. *Allophylus abyssinicus* had the highest content of Fe^{+} in the reference compared to the other two species. *Psychotria fractinervata* and *Neoboutonia macrocalyx* had slightly higher content of Al^{3+} in the test site.

List of abbreviations

F.A.O.-	-Food and Agricltural Organisation
I.U.C.N.-	-The world conservation union
IDL	-Ideal location
K.E.F.R.I.-	-Kenya Forestry Research Institute
K.F.M.P.	-Kenya Forestry Master Plan
O.D.A.	-Overseas Development Agency
RF	-Reference site
TT	-Test site
Q 1,5,....	-Quadrat number

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(CHAPTER 1)

1.0 INTRODUCTION

The increasing destruction of the world's tropical forests, which has been going on for decades, is a well known phenomenon. It results into loss of soil fertility, shortage of wood, creation of degraded and eroded landscapes etc. in most tropical countries (Lamprecht 1989).

The bulk of forests in Kenya are in the afromontane bio-geographical region which stretches from the highland areas in Guinea and Liberia in the west, highlands in Ethiopia to the north-east, and to the Drakensburg Mountains in the south. The Mt.Kenya forests, the Aberdares/Kikuyu Escarpment and the Mau forest complex, greater part of which are under natural forests, are good examples (IUCN & ODA 1995).

In Kenya, the Forest policy has emphasized the management of the natural forests for protective functions i.e. for soil and water resources formerly but has now been expanded to include conservation of bio-diversity. Forest bio-diversity refers to the wealth of life in a forest and any loss of a species represents a loss of bio-diversity resulting into consequent effects on the intricate and closely interwoven web of a forest life (IUCN & ODA 1995).

The closed canopy forests, which accounts for only 2% of Kenya's land area , but harbour a large percentage of the country's bio-diversity i.e. 40% of large mammals (over 500g body weight), 30% of birds, 35% of butterflies and about 50% of woody plants (IUCN & ODA 1995). These forests are also important for production of timber and non-timber forest products to meet the demand of the local people (KFMP 1994).

These forests had traditionally been used for production of timber for a long period of time i.e. from the early 1900's to mid 1980's but despite this, there is no scientific management plan which has been developed to govern the extraction of resources from them, which has resulted into these forests being over-exploited, hence depletion of resources and eventually to a ban on exploitation of the natural forests in Kenya in 1986 (Kariuki & Macharia 1997).

The ban also included the grazing of livestock and the shamba system (which is a form of re-establishing plantations), both of which were re-introduced later in early 1990's in areas under plantations. However the non-commercial harvesting of resources from these forests to supply the local needs have continued and the current trends have shown that these forests are not managed on a sustainable basis (KEFRI 1998).

Sustainable tropical forestry must integrate forest conservation and economic development, embracing factors such as reproduction, natural regeneration, growth, ecosystem functions and bio-diversity conservation. Sustainable forestry based on natural forests has the potential to conserve far more bio-diversity than does plantation forestry (Hartshorn 1995). Ecological sustainable forestry will ensure the successful reproduction of focal species. However this has not been possible due to lack of adequate information on the reproductive biology of most commercial species e.g. in the Amazonia, the mahogany, *Swietenia macrophylla* is traditionally harvested from natural forests in the dry season, just before fruit mature and disperse seeds. If in this case, a few seed trees are left or maybe the harvesting is delayed to the middle of the dry season or better still to the wet season, far more seeds will be available for the maintenance of the population (Hartshorn 1995).

Rain forests in the tropics are rapidly undergoing clear-felling , and either being replanted with commercial mono-cultures or converted to different land-uses. There is widespread concern that these ecosystems with unique and valuable bio-diversity resources are being lost. One management conservation strategy would involve leaving „ conservation areas" within the region being felled to act as repositories of bio-diversity and possibly provide a source of natural regeneration. This will then require a prior knowledge of the areas which will contribute most to conservation of bio-diversity, before the felling operations are carried out (Rennolls & Laumonier 2000).

The loss of bio-diversity resulting from the various human activities globally has alarmed many people, and has created a world-wide movement to save the tropical forests and to conserve as much bio-diversity as possible (Solbrig 1994) However, conservation of the tropical forests will depend on an understanding of the forest dynamics, which will include detailed quantitative and qualitative descriptions as well as the information on the regeneration status of species in the remaining forests, to act as a basis for the management and restoration of these vanishing resources (Sundarapandia & Swamy 1998).

Due to the above mentioned, the following research was carried out at Uplands forest in Kenya.

The hypothesis was that „the non-commercial utilisation of the forest resources does not have any effect on either the species composition or nutrients status in the forest ecosystem"

The following two objectives were used to test the hypothesis.

(i) To determine the species composition, their frequencies and their regeneration status in the forest. This is important for one to know the species occurring in a given forest type , to get an insight on what to expect from the forest either from the economic or bio-diversity point of view i.e. the more the number of species, the richer the forest when viewed from the bio-diversity front whereas it is so when it have many commercial timber species when looked from the economic point of view.

Regeneration status, which is seen in terms of the number of seedlings and saplings of the species, can be taken as indicators of species which are more endangered (due to lack of regeneration) or otherwise from the succession point of view.

(ii) To determine the nutrient status of three most dominant tree species in the forest i.e. *Allophylus abyssinicus, Neoboutonia macrocalyx* and *Psychotria fractinervata*. The nutrient status in a forest can be determined from the analysis of some plant components e.g. leaves or branches as well as the bark. The forest floor litter which is composed of fallen leaves, and the soil can also be analysed for the nutrients.

The nutrients or elements in an area mostly originates from the weathering of the bedrock and therefore readily available in the soil from where they are taken by the vegetation and contained in the bio-mass. The organic matter normally occurring on the topsoil, contains nutrients and it's removal will deprive the soil of nutrients and results into loss of soil fertility.

Extraction of resources from the forest will result into loss of nutrients due to the export of organic matter out of the forest ecosystem. Also any disruption of the top soil will interfere with the nutrients cycling in the ecosystem.

(CHAPTER 2)

2.0 LITERATURE REVIEW

2.1 Human activities as a form of disturbance to forest ecosystems

Deforestation which is a common phenomenon in the Tropical region, result's into loss of bio-diversity. Both FAO and WRI have defined deforestation as a complete transformation of forests into other forms of land-use e.g. agriculture, pastures etc. while Botanists, Ecologists and Conservationists, see it as the degradation of the entire forest ecosystem involving wildlife species, gene-pools, bio-mass stocks and climate. Myers (1991) saw deforestation as both the clearing of forests for other land-use as well as the serious degradation of the tropical forest ecosystems (Jempa 1995).

According to the WIR (1990), there are three main causes of deforestation which includes the following :-

(i) Parmarnent conversion of forests into agricultural land e.g. the process of shifting cultivation, which due to the increasing population pressure has resulted into shorter fallow periods resulting into degradation of the land.

(ii) The logging activities in most of the tropics where there are only a few commercial timber species, results into damage of non-target species and the opening of forest areas for other activities e.g. grazing of livestock.

(iii) Demand for fuel-wood, fodder and other forest products.

Deforestation has negative environmental impacts and in addition leaves those people who benefits from the use of forest products worse off. Also it degrades the ecosystems and thus putting some species under stress (Pearce & Brown 1994)

Over-logging due to selective harvesting or other forms of logging, which results into degradation of forests is also included in the term „deforestation". Selective logging creates micro-habitats that permits the establishment and growth of a wide range of species, both shade tolerant and intolerant (Pinnard et al. 1999).

2.2 Effects of disturbances to forests and species composition

Tropical forests are among the richest and complex biological communities on earth and exhibits tremendous intrinsic abiliiy for self maintenance. However most of these forest have lost this ability due to the increasing biotic interference i.e by both people and animals. These forests are disappearing at an estimated rate of 1-2% annually, which is happening when the knowledge on the structural and functional dynamics is inadequate The ever increasing demand for forest products and land for other uses, coupled with the rapid rate of population growth, has put the remaining patches of these forests on the verge of extinction (Sundarapandia & Swamy 1998).

In many tropical forests, tree-fall gaps are a common form of disturbance and are thought to be important in the life cycles of many tree species, and thus contributing to the maintenance of the species diversity in the forest (Webb 1997). When a tree falls in a forest, the canopy hole or „light gap" it creates sets into motion a chain of events, the „gap phase regeneration" which culminates in the replacement of the previous canopy tree by another one. Gap disturbance provides the principle or only means by which most trees species maintain their representation in closed canopy forests. It is therefore important to have knowledge on the gap-disturbance regimes and the rules for tree-by-tree replacement process, which are fundamental to understanding the structure and dynamics of the closed canopy forests (Hubbell & Foster 1985).

Light in gaps is higher in intensity, lasts longer during the day, and is of different spectral quality than in the under-storey of the closed - canopy forest. Soil and the Air layer near the ground are often much hotter in the gaps during the day and cooler at night. Humidity is often lower in the gaps than in the surrounding forest, but soil water may actually be higher because of reduced root uptake and lower transpiration water loss from the gaps (Hubbell & Forster 1985).

Tropical wet forests are characterised by a high abundance and diversity of lianas, which are more conspicuous in naturally and anthropogenically disturbed areas. Lianas contribute significantly to species richness, sometimes accounting to as high as 25% of woody stem diversity, and play an important role in tropical forest dynamics because they respond rapidly to canopy opening and can easily suppress the regeneration of saplings in tree-fall gaps. They are thought to be light demanders due to their rapid growth in high light and their abundance in disturbed areas such as tree-fall gaps and abandoned pastures (Dewalt 2000).

Natural and semi-natural tropical rain forests are structurally stable, maintaining an approximately the same decline in numbers of trees with increasing size. This kind of size class distribution is the consequence of forest dynamics in which the available space constrains the number of trees that can be in any size class. The continuous tree mortality of about 1-2% annually permits further growth of the surviving trees and recruitment of others (Swaine 1989).

The population structure typical of shade tolerant tree species is of moderate stature with small to medium size stems. In contrast, the emergent and canopy species have a population structure lacking large number of juvenile individuals and they are either emergent or canopy dominants. Species with this type of a structure are considered to be pioneers or heliophytes which do not produce well in a primary forest.(Killen et al. 1998).

Majority of stems on the forest floor i.e. the under-storey, are composed of juvenile individuals of tree and lianas, most of which reach the upper strata upon maturity. This is an indication that the under-storey strata is dominated by specialists species rather than juveniles of the canopy species (Killen et al. 1998).

2.3 Effect of human activities to nutrients in forest ecosystems

Trees contain nutrients, and consequently removal of tree parts during the process of harvesting of forest products, results into loss of nutrients from the site, the extent depending on the intensity of resource use (Kimmins 1997).

The utilisation of forest resources including the forest soil, involves removal of products and their nutrient content. The nutrient capital will continuously decrease if the removals exceeds the inputs e.g.removal of boles of a few trees per hectare for timber leave most of the nutrients behind because they are concentrated in the branches, twigs and leaves (Whitmore 1990).

The most serious effect of logging on nutrients results from the damage of the soil surface which causes disruption to the roots and stems that provide sucker roots as well as to the decomposer community. All these type of damages will impair the recovery of the ecosystem after logging, including nutrients uptake into the bio-mass, this being strongest in the areas where the soil have been scrapped-off or excessively compacted (Whitmore 1990).

The process of logging also affect the non-commercial species of trees, which results into changes in the forest ecosystems, hence reducing the bio-diversity of forest dependent plants and animal species. The impact of selective cutting of species in isolated populations will be much stronger, especially on species with specialised pollen and seed dispersal mechanisms (Kigomo 1999).

Some forest operations such as clear-cutting results into loss of elements, mostly the nitrate nitrogen which can easily be detected by measuring the amount contained in water of streams flowing through such an ecosystem. The process of clear - cutting of forests affects the flow of nitrogen due to the removal of transpiring surface. The increase in nitrate concentration is a clear indication of the occurrence of nitrification in the clear-felled ecosystems. Since an NH_4^+ substrate is required, the occurrence of nitrification indicates that, the soil C:N ratios are favoured for production of NH^+_4 in excess of heterotrophic needs (Bormann et al. 1997).

Human activities such as burning of the vegetation in the forest e.g. during the process of shifting cultivation, leads to changes in the soil characteristics such as rise in pH, reduced fertility etc. as a result of the ashes which are rich in exchangeable cations, including available phosphorous and calcium which cause the base saturation to increase (Saharjo 1997). This will also result into a loss of 60-85% of the litter nitrogen and 40-50% of the litter sulphur depending on the intensity of the fire. Ashes are beneficial to plants with superficial roots which absorbs the released nutrients (Drechsel & Zech 1993).

The significant decrease in nitrogen after burning, occurs due to the process of volatilisation which will happen at 200°c. Burning releases cations from the forest vegetation but also results into volatile loses of significant portion of ecosystem nitrogen and sulphur. The immediate effect of soil exposure after burning is the reduction in soil moisture, especially near the surface. In general frequently burned-over soils are drier near the surface than unburned soils. If a deep rooted vegetation composed of trees and shrubs is burned and replaced by a shallow rooted annuals, soil moisture content at the lower levels increases as a result of the burning. Besides destroying the litter layer, heat also destroy the soil invertebrates and micro-organisms which cause mixing of the soil (bioturbation), resulting into reduced soil porosity. Litter and organic matter have several benefits to the soil which includes development of soil structure and the aggregate granular soil particles thereby increasing the infiltration as compared to bare soils (Saharjo 1997).

Where bush fires are frequent, the shorter the interval between fires, the more open the resultant vegetation structure. When fires are more frequent than the period required for the juveniles of the woody species to reach maturity, the vegetation structure will become more and more open and after some decades without replacement of the old individuais, these species will tend to disappear. If fires are less frequent, woody species will be able to develop and regenerate (Pivello & Coutinho 1996).

2.4 Nutrients in forest ecosystems

Trees get nutrients by several processes and means e.g..input of nutrients from rainfall in solution as well as particulate aerosols, uptake from the soil, re-uptake after decomposition of litter, additions from weathering of the bed-rock and volcanic eruptions (Whitmore 1990).

Nutrient cycles in tropical forests are influenced by several factors which includes climate, species composition, succession status and soil fertility. Litter-fall, through-fall and stem-flow are the main fluxes for the return of most nutrients from the vegetation to the soil surface. Litter-fall is usually the most important of these fluxes for the return of most nutrients, the major exception to this generalisation being potassium (K). In forests, as much or even more K, reaches the forest floor in through-fall as or than in litter-fall due to the greater susceptability of leaves to leaching of K compared to other nutrients. Likewise, there is relatively low phosphorous returned through leaf-fall compared to other nutrients. Much of it is returned in reproductive structures (Herboln & Congdon 1997).

Litter-fall studies in forest stands have been conducted for a relatively longer time with the earlier studies concentrating more on fluctuations and composition of litter-fall distribution. Such investigations have been carried out in stands of indigenous and extrinsic tree species, in mono-cultural stands as well as in mixed stands with or without the under-storey vegetation . More recent studies have put emphasis upon ecosystem analysis, with litter-fall playing a central role of recycling nutrients in forests (Paderson & Hansen 1999).

Nutrient cycling in tropical forests is often characterised as „tight" or „efficient" when compared to the temperate forests. This efficiency could be seen in two ways i.e. either relatively large amounts of organic matter is fixed per unit of nutrient taken up (the resource utility i.e."within-stand cycling") or when most of the nutrients released from the trees are rapidly taken up by roots, mycorrhizae or decomposers and retained within the system i.e."within-system cycling „ (Vitousek 1984).

The former type of cycling is characterised by re-absorption of nutrients from the senescing parts and therefore low nutrients concentration in litter-fall, wood and root litter. The latter type is characterised by low nutrient loss from the system as a whole despite relatively large amounts of nutrients cycling between trees and the soil. Most trees vary in the efficiency with which they use nutrients. The existence of an efficient „within-stand" nutrient economy is an indication of the nutrient limitation to primary production, while an inefficient „within-system" nutrient economy indicates that the supply of that nutrient to trees is adequate or better. An efficient within-stand nutrients use results into an efficient within-system nutrients use as well (Vitousek 1984).

When the nutrient cycling is efficient, it is a type of "closed" cycle which occur in forests on deep soils where the weathering process.releases nutrients far deeper beyond the reach of the tree roots e.g. the central Amazonia. An inefficient nutrient cycling is more of an "open" cycle, which occur in forests on rugged and hilly terrain, where the soil is shallow ,and therefore weathering of the bedrock is able to provide a continuous replenishment of the nutrients in such ecosystems (Whitmore 1990).

Some forest ecosystems have evolved mechanisms whereby there occurs a closed circulation of nutrients within the living bio-mass e.g. the Amazon forests. The same nutrient molecules are recycled through generations of the living components of the forest. Special adaptations have been developed to reduce to a minimum the loss of nutrients by leaks from the cycles e.g. there is no appreciable humus layer and the root systems of trees is shallow, usually restricted to the uppermost 20 - 30 cm , and about three times as dense as that of temperate forests. This is an indication that the nutrients are never temporarily retained or stored in dead matter on top of the soil, from where they might easily be leached by the high rain fall but are rapidly reabsorbed from the forest litter as well as from the dropping and remains of animals after the rapid decomposition under the hot humid climatic conditions (Sioli 1997).

Comparisons of the chemical composition of the rain water falling through the canopies (through-fall), stem runoff (Stem-flow) and the ground water in the Amazon forest, showed that both the rain and ground water samples were chemically very poor in dissolved matter and nutrients whereas the through-fall and stem-flow were found to be very rich in dissolved matter including nutrients. This shows that the dense mat of roots of the forest trees, acts as a highly effective filter by retaining all the dissolved substances from the canopy and stem-flow water and immediately recycles them back into the living trees without losing some into the ground water, creeks and rivers which would eventually drain into the oceans, thus losing them from the forest ecosystem. Nutrients are one basis of constant biological productivity and their irreplaceable loss reduces and limits both the harvests and biological production (Sioli 1997).

Decomposition of organic matter is important because it affects the structural and functional aspects of terrestrial ecosystems. The supply and distribution of organic matter , and the consequent litter nutrient content return are important aspects of the dynamics of the ecosystems, the rate of nutrient release being fundamental to the way in which it occur. Following the death of a tree or plant, the retained elements return to the soil through mineralization and then become available for use in the ecosystem, if no leaching or volatilisation takes place. The pattern of decomposition and thus nutrients release are important determinant for the overall functioning of the ecosystem (Acenolaza & Lancho 1999).

Tropical forests contribute in many ways to maintain the present dynamical and chemical equilibrium of the atmosphere. Forests represents a carbon reservoir, both through their a-real and root systems as well as through the organic matter in the soil. Estimates show that tropical forests possesses a reserve of carbon equivalent to 1.5 -2.0 times the carbon stored in carbon-dioxide in the atmosphere. Therefore conversion of forests into other forms of land-use e.g pastures, agricultural fields etc will release carbon-dioxide from the biosphere into the atmosphere resulting into increased greenhouse effect/warming. Also this process of deforestation releases great quantities of particles and compound gases into the atmosphere which contribute to the changing chemical composition and energy balance of the atmosphere (Salati & Nobre 1997).

2.5. Carbon and Nitrogen in Forest Ecosystems

The carbon and nitrogen cycles are closely related in terrestrial ecosystems, where nitrogen exerts control over the rates of several carbon cycling processes including the Net primary production (NPP), which is the rate at which the vegetation in an area captures carbon from the atmosphere. Forests, which cover 43% of terrestrial biosphere, are potentially responsible for 72% of annual global NPP, which provides food, fuel, pulp/paper and fibre to Man (McGuire & Melillo 1995).

NPP is the difference between Gross primary production (GPP) which is the gross assimilation of carbon captured through photosynthesis and plant respiration (Ra), which is the energy cost of metabolic activities. Both GPP and Ra represent biochemical process that are catalysed by nitrogen rich enzymes and their rates depends to some extent on the nitrogen content of the plant tissue.

The production of new plant tissue requires Nitrogen in addition to Carbon. GPP thus depends on the Nitrogen status of the plant, which is influenced by the nitrogen stored in vegetation (Nv) and the supply of nitrogen to vegetation (Nuptake). The elevated Carbon dioxide reduces leave nitrogen by an average of 21%, but it has smaller effect on nitrogen concentration in the stems and fine roots. Contrary to this, higher soil nitrogen availability results into increased leaf nitrogen concentration.

Soil nitrogen availability is an important factor that often constrains the response of woody plant growth to elevated Carbon dioxide. Also increased Nitrogen availability and elevated Carbon-dioxide have opposite effects on the relative allocation of Carbon to above-ground and below-ground bio-mass (McGuire & Melillo 1995).

The most important consequence of deforestation is a substantial decrease(Over 50%) in total organic carbon in the deforested site, both below and above ground carbon. This decrease is caused by the removal through harvest, combustion of residue, increased decomposition rate, lack of replacement of organic carbon due to continued cultivation, loss due to erosion (Vitousek 1983).

Deforestation as well causes a decrease in the amount of organic Nitrogen on the site in form of losses due to harvest, volatilisation and leaching. Nitrate is produced in large amounts in some disturbed forests, and it is often the most important anion in agricultural soils. The nitrate anion is relatively mobile in the soil solution, and nitrate together with associated cations are thus easily leached through most soils. However some tropical soils can retain large amounts of nitrate by absorption (Vitousek 1983).

Decomposition of organic matter with a higher C:N i.e. those from nitrogen poor sites, results into an abundance of organic carbon (energy) relative to nitrogen (protein) to the decomposers. They release Co_2 but retain nitrogen within their bio-mass and also remove and incorporate available nitrogen from the soil. When the C:N ratio is lower, both of the elements are released by the decomposers (Vitousek 1983).

2.6 Heavy metals in the Ecosystems

Most of these are required by plants in very low quantities and so they are trace elements and becomes toxic if at higher contents in the soil. These includes Lead (Pb), Copper (Cu), Zinc (Zn), Nickel (Ni), Cadmium (Cd), Aluminium (Al) and Mercury (Hg), all of which cover a range of toxicity to necessity to plant metabolism and health. Others are Iron (Fe), Manganese (Mn), Boron (Bo), Molybdenum (Mb), Colbalt (Co) and Chlorine (Cl), which together with Zn and Cu are required by plants as trace elements (Friedland 1990).

From the above mentioned, Fe, Mn, Zn, Cu and Mb are often referred to as „Heavy metals". There are three major sources of these metals in terrestrial ecosystems i.e. parent bedrock material, the atmosphere and the biosphere.

Both chemical and mechanical weathering of the parent rock result into release of elements, including heavy metals into the environment. Volcanic eruptions, forest fires, and continental dust have been a natural input from the atmosphere to the soils and ecosystems. The biotic inputs includes those from the existing vegetation i.e. above ground bio-mass, roots and other below ground bio-mass and also from leaching and wash-off from leave surfaces. Animal inputs in form of manure from the domestic live-stocks is a significant source of Arsenic, Copper, Zinc etc. into some ecosystems (Friedland 1990).

Metal toxicity to cultivated crops/plants is usually as a result of low pH (acidic), which is brought about by increased availability of Al, Mn and Fe, all of which are abundant in the mineral soil. The increased availability of these metals in the soil is toxic to many species of plants which require application of lime to increase the pH, and thus reducing the toxicity level in the soil. However the effect's of the lime is only restricted to the upper soil but not into the subsoil layers.

Crops tolerance to some metals e.g. Al and Mn has been investigated extensively, and genetic variability have been found among cultivars. The various genetic systems that control metal tolerance in different taxonomic groups of plants could be completely different in their expressed morphological, anatomical, physiological and biochemical processes which have an effect on the uptake, translocation and accumulation of the basic ions (Aniola & Gustafson 1990).

Tolerance to metals toxicity by plants on basis of the above listed characteristic puts the tolerant plants into three major groups i.e. excluders, accumulators and avoiders. The excluders are those plants which are able to restrict the transport of the metallic ions e.g. all cereals and legumes tolerant to Al belong to this group, and they accumulate the ions in the roots with only a limited supply to the shoots.

Accumulators are the plants in which the metal content in the plant tissue is higher than in the soil. A good example is Tea (*Thea sinensis*), which collect large amounts of the metal in the leaves (see photo 1 below). Avoiders are plants which contain an efficient mechanism of preventing the entry of toxic metal ions into sensitive metabolic target or they are tolerant to a given metal ion in their metabolic activities.

The various types of metal tolerance observed in the different species of plants is an implication that, the genetic control of tolerance can be quite distinct. Metal accumulation and hence the tolerance is metal specific, suggesting the presence of different genes controlling the tolerance to different toxic metals. However, some plants have been found to have multi-metal tolerance and even cotolerance (Aniola & Gustafson 1990).

Photo 1 :Tea (*Thea sinensis*), an accumulator for Aluminum ions, which are toxic to many plants when in higher content in the soil, is growing in the area neighbouring the forest.

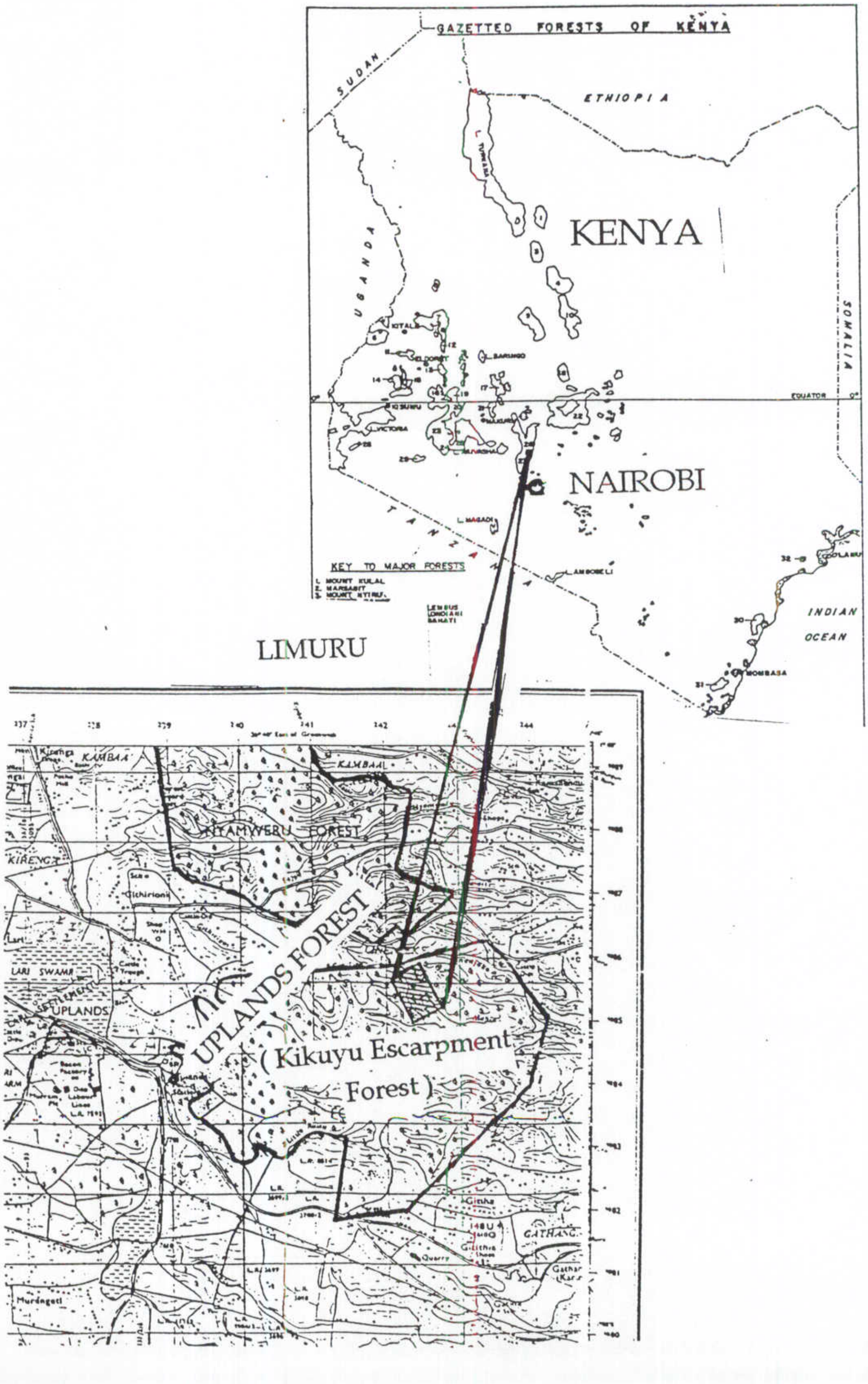
(CHAPTER 3)

3.0 Materials and Methods

3.1 Study Site

The following field research was carried out at Uplands forest in Kenya which is about 50 km to the North -West of Nairobi. The area is located between latitude 1°03'S and longtitude 36°39'E, within the central highlands. It covers the lower slopes of the Aberdares ranges/Mountains at an elevation of 2438m above sea level.

MAP 1



3.2 Climate

Rainfall is bimodal, with long rains falling from march to June with a peak in April and short rains from October to December, with an average annul mean of approximately 1400mm. Temperatures range from 5°C (minimum) to 21°C (maximum) daily means. The lowest temperatures are recorded in July while Jan./Feb. have the highest.

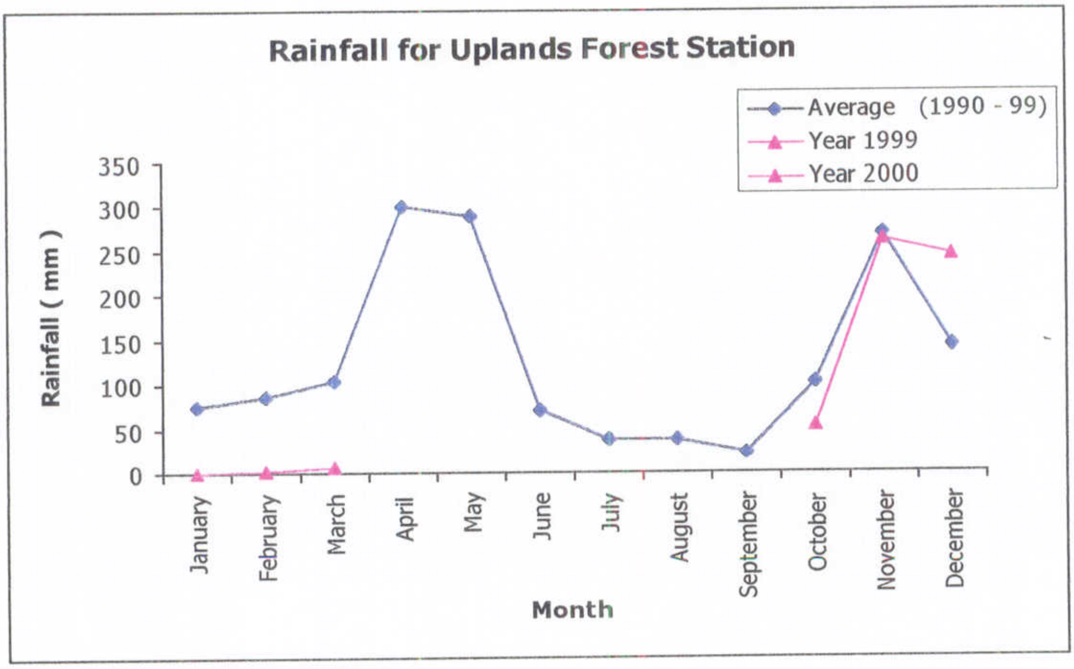


Figure 1(a).

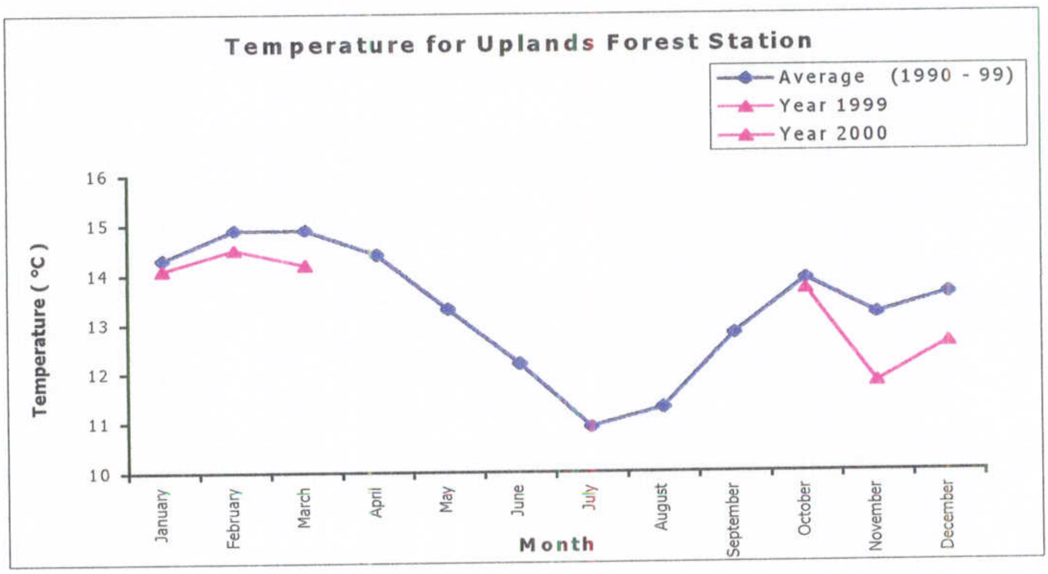


Figure 1(b).

3.3 Site selection

The study site was selected due the strategic situation of Uplands forest, as an "Island Forest", within farmlands and so pressure from the farming community is very intense. The Kwaregi beat, where the research plots were established offered the most suitable conditions for the research.

The is part of the Aberdares chain of forests, which are catchment areas for major rivers and streams in the central region of the country. Some of tributaries of Athi River which is the second largest in Kenya, have their source from this catchment. The area also is the watershed for L.Naivasha which support horticultural activities for exports.

It was possible to get to the field site on a daily basis given the limitation of resources required for the research. The selection of the sites was done by means of reconnaissance and expertise, which ensured the establishment of plots in the most representative parts of the forest.

3.4 Geology

Consists of volcanic rocks, which occur in association with the East African Rift Valley, formed in the plio-pleitocene-present period during the last 7 million years, and consists of Alkaline Basalts.

The parent rock have low potential for fertility, which is off-set in the mountainous region by higher than average rainfall , that enhances the rate of chemical weathering and sustains a prolific vegetation cover characteristic of the humid forests (Lovett & Wasser 1993).

3.5 Soils

These are Nitisols which are very deep (150cm and more), well drained, are dark reddish-brown to dark brown in appearance, are friable to firm and have humic top-soil layer in some places. The top soil has a moderate to strong sub-angular blocky structure underlain by a subsoil with a moderate angular blocky structure, which are porous throughout.

The organic matter content, cation exchange capacity (CEC) and percentage base saturation ranges from low to high. They are known to have high degree of phosphorous absorption (Kenya soil survey 1982).

These soils are found in approximately 250 million ha.worldwide, with more than half being in Africa especially in Ethiopia, Kenya, Zaire and Cameroon. In East Africa, they occur in uplands (at altitude of 1000m and above) under vegetation ranging from wooded grasslands to montane rain forests.(Driessen & Dudal 1991).

3.6 Vegetation sampling layout

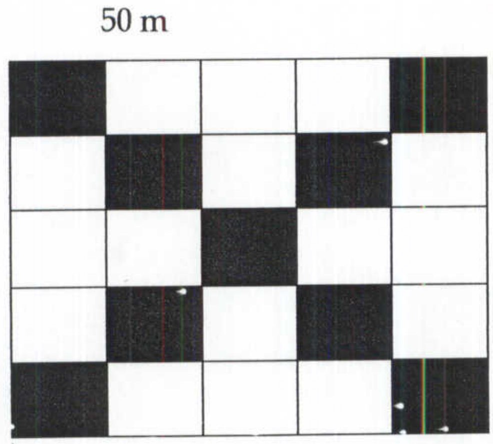
Sampling plots measuring 50 X 50 m were established in two distinct forest areas ie. some in relatively undisturbed and others in disturbed areas. Disturbance in this case to the forest ecosystem by man, the most recognisable being presence of tree stumps.

The plots were sub-divided into 10 X 10m sub-plots/Quadrats for the ease of assessing the vegetation as shown in the plot lay-out below.

All the trees and shrubs with a diameter at breast height (dbh) of 5.0 cm and over were recorded, thier species names, the canopy status ie. whether in the understorey,main or emergent canopies in all the quadrats. The tree stumps and species were also recorded as well as any other sign of disturbance eg. footpaths etc.

Data on saplings and seedlings were recorded in 9 out of 25 quadrats as shown in the plot lay-out . Seedlings are those less or equal to 1.5 m in height, and saplings are those more than 1.5m in height but less than 5.0 cm in diameter.

Diagram 1. PLOT LAYOUT



 - Quadrats where the seedlings & saplings were counted

NB: A total of 10 sample plots were established, 5 in each forest type and assessed as per the layout above.

Photo 2: Plot showing regeneration of *Tabernamomtana stapfiana,* in the fore ground, which is one of the pioneer species in the forest.

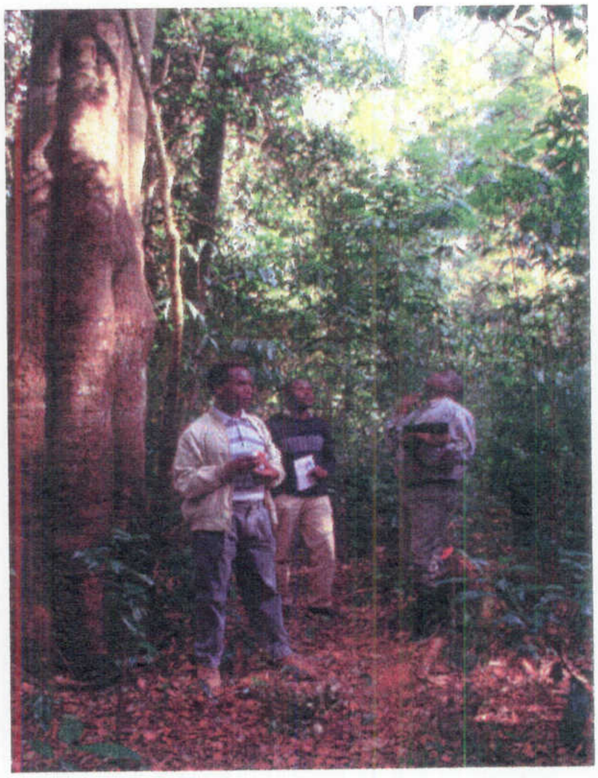


Photo 3: *Aningeria adolfi-frederecii*, a tree which is not regeneration in the forest. Also a liana and some regeneration of other species are seen in the fore-ground.

3.7 Vegetation and soil sampling for chemical analysis

Two plots were selected for the nutrients sampling and was done twice i.e. during the wet season (Decmber 1999) and the dry season (February 2000). These plots were Reference site 02 (RF 02) and Test site 03 (TT 03) Three tree species namely:-*Allophylus abyssinicus, Neoboutonia macrocalyx* and *Psychotria fractinervata* were selected due to their various uses and abundance as well as importance.

Leaves were harvested from 4 trees of each species per plot and 8 trees per species in the two plots. The heights and crown diameters for these trees were also measured.

Soil samples were taken from the two plots, during the dry season, from four points/sites per plot and three samples from each point. Twelve (12) samples were taken from each plot and twenty four (24) from both plots.

The three soil samples were taken from the top-most layer (Humus/Organic layer), the topsoil layer (A-horizon) and the sub-stratum/mineral layer (B-horizon)

The leaves and soil samples were dried at room temperatures in Kenya before they were transported to Tharandt/Germany, where they were further dried in the oven at 70°c, then milled for the digestion .

Photo 4:Forest destruction activities are evident in this test site plot As a result the continued export of resources out of the forest ecosystem., the humus and A-horizon layer were found to be very thin as compared to the reference site, where it was found to be about twice or more in thickness

3.8 Sample preparation for chemical analysis

(i) Leaves samples

Dry leaves were sorted-out ie. were separated using the Fritsch Rotary Divider (Laborette 27) for proper mixing after which the required sample was taken and milled using the Retsch Mill ZM 1000

(ii) Soil samples

Dry humus / Organic layer samples were milled using the Retsch Milling machine model ZM 1000 ,while the mineral soil layers (A & B horizons) were milled using the Fritsch Planatary Mill (Pulversisette 5)

The mineral layers were milled further to make the soil more fine,for the Nitrogen and Carbon testing, using the machine type Retsch RS100.

3.9 Measuring the ph of the Soil

Two sets of samples of the milled humus and mineral soil weighing 10 gms. each, were used for the PH tests. 50 ml.of distilled water were added to one set and an equivalent volume of Potassium chlorate (KCL 0,1 molar) were added to the other. Stirring of the solutions was done after 5 and 10 minutes for the H_2O and KCL repectively and thereafter every 45 minutes for 4 times before the PH values were taken using a microprocessor PH meter.

3.10 Digestions

(i) Approximately 200mg of the milled leaves powder was put into special vessels and the following reagents added:- 3mls Nitric acid, 2mls hydrogen peroxide and 25mls distilled water. 10 of these special vessels were put in the microwave pressure machine model MDS 2000 for a duration of 2 hours.

(ii) Approximately 300mg of the milled soil powder was put in the above said special vessels and the above reagents added as follows :- 7mls Nitric acid, 3mls Hydrogen peroxide and 50 mls distilled water. The vessels were put in the microwave pressure machine for a duration of 2 hours.

3.11 Statisical data analysis

The data on trees and shrubs was feed into the computer on the Excel spread-sheet for graphical presentation. Shannon-weaver diversity index as well as the Simpson index were calculated using the following formulae :-

(a) Shannon - wiener diversity index. $H' = - \Sigma (p_i \log p_i)$ Where (pi)- is the proportion of total sample that is composed of species i

(b) Simpsons diversity Index -for species dominance was culculated using below.

$$\lambda = \Sigma p_i^2 \text{ (pi as above).}$$

(c) The Jackknife estimate of species richness was culculated using the formula below

$$\hat{S} = s + \left(\frac{n-1}{n}\right)k$$

Where S - Jackknife estimate of species richness

s - observed total number of species in n quadrats

n - total number of quadrats sampled

k - number of unique species

((d) The Bootstrap estimate of species richness was calculated using the formula below

$$B(S) = S + \Sigma (1 - p_i)^n$$

NB: The above formulae for Shannon-wiener and Simpson's index are from the Biological diversity book by M.A.Houston (1994) Those on Jackknife and Bootstrap are found in the Ecological Methodology book by C.J.Krebs (1989).

(CHAPTER 4)

4.0 RESULTS

4.1. Species Composition

The study area i.e. Kwaregi beat which is found in the upper zone of Lari block, Uplands forest, in Kenya, is cooler and humid presenting conditions of a type of tropical moist montane forest. The species found includes *Ocotea usambarensis* (camphor), *Podocarpus latifolius* and *Aningeria adolfi-friedericii* as the climax species. Others found includes *Allophylus abyssinicus, Psychotria fractinervata, Neoboutonia macrocalyx, Macaranga kilimandscharica, Polyacias kikuyensis, Prunus africana, Nuxia cogesta, Syzygium guinensee, Dombeya goetzenii etc.*

The frequency of the said primary or climax species was found to be very low and some did not occur in some plots both in the natural or undisturbed and disturbed areas. *Clutia abyssinica* and *Rubus spp.* were frequently found in the disturbed areas and forest edges.

4.1.1. Species richness and species - curves

More species occurred in the Test site plots (40) than in the Reference site plots (36). The species area curves for the two sites are shown in Figure (2) below, and the species per area sampled in Appendix 12.

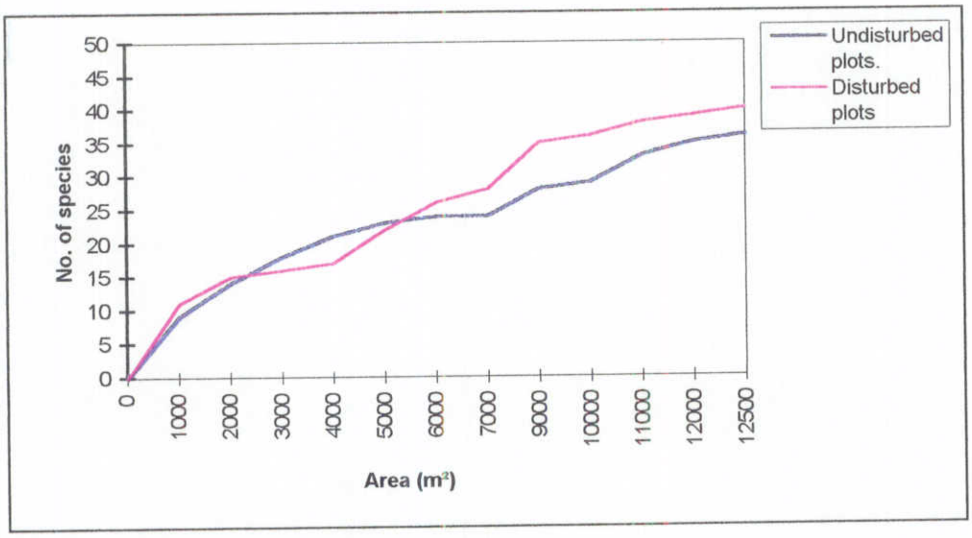


Figure 2 : Species-area curves for the two sites

In the Reference site, the 36 species falls into 25 families , with Rubiaceae having (4) species Euphorbiaceae (3) species and Sterculaceae, Araliaceae, Flacourtiaceae, Solanaceae, Caesalpiniaceae, Myrsinaceae all had (2) species each while 17 families had a single species.

In the Test site, the 40 species falls into 29 families, with both Rubiaceae and Euphorbiaceae having 4 species each, while Flacourtiaceae, Sterculiaceae, Meliaceae, Sapindaceae and Rutaceae had 2 species. 22 families had a single species each.

29 species occurred in both sites, 11 in the Test and 7 in the Reference site plots.

4.1.2 Ecosystem Functional Types

Forest Structure

Allophylus abyssinicus, Neoboutonia macrocalyx, Macaranga kilimandscharica, Polyacias kikuyensis, Ocotea usambarensis and *Aningeria adolfi-friederecii* occurred as emergents over the main forest canopy and they are the structure determinants (see photo 2 above).

N. macrocalyx, M. kilimandscharica and *P. kikuyensis* have got good regeneration while the rest have poor or none. *A. abyssinicus, N. macrocalyx* and *M. kilimandscharica* have higher frequencies in the plots as compared to the rest of species named above.

Psychotria fractinervata is the most abundant and frequent species in the forest and have the best regeneration

Photo 5: The general pysiognomy of Uplands forest, where *Allophylus abyssinicus, Neoboutonia macrocalyx, Macaranga kilimandscharica* and *Psychotria fractinervata* are the forest structure determinants.

Pioneers

Neoboutonia macrocalyx, Macaranga kilimandscharica and *Tabernamontana stapfiana* are the pioneer species which regenerate well in the disturbed sites. Their higher growth rate makes them more adapted to compete for the available space.

4.1.3 Stands vertical stratification

Allophylus abyssinicus, Polyacias kikuyensis, Aningeria adolfi-friederecii, Ocotea usambarensis and Macaranga kilimandscharica mostly occurred as emergents in the forest canopy.*Psychotria fractinervata, Neoboutonia macrocalyx, Rapanea melanophloeos, Prunus africana, Nuxia cogesta, Podocarpus latifolius, Croton macrostachys, Tabernamontana stapfiana and Casearia battiscombei* formed the canopy stratum. *Xymalos monospora, Galiniera coffeoides, Schefflera volkensii, Ochna spicata, Peddiea fischeri* etc. formed the understorey stratum.

4.1.4. Species Frequency

The frequency percentages of the most frequent species in both sites are shown in Table 1 (a) for the Reference and 1 (b) for the Test site plots , below :-

Table 1 (a) Species in Reference site plots.

Species	Frequency%				
Reference Site (RF) plots	RF 01	RF 02	RF 03	RF 04	RF 05
Psychotria fractinervata	92	56	80	88	88
Allophylus abyssinicus	60	68	56	56	16
Neoboutonia macrocalyx	52	40	44	68	4
Macaranga kilimandscharica	16	24	48	38	44
Rapanea melanophloeos	8	8	4	4	56
Polyacias kikuyensis	8	4	4	4	8
Clausena anisata	12	4	4	4	4
Galiniera coffeoides	0	40	20	4	76
Tabernamontana stapfiana	4	0	8	16	32
Nuxia cogesta	16	0	4	4	20

Lobelia gibberoa	4	4	12	20	0
Dombeya goetzenii	0	12	4	4	0
Casearia battiscombei	0	4	4	4	0
Solanum mauritianum	0	4	8	12	0
Dracaena afromontana	8	0	0	4	20

Table 1 (b) Frequent species in Test site plots

Spcies	Frequency %				
Test site (TT) plots	TT 01	TT 02	TT 03	TT 04	TT 05
Psychotria fractinervata	72	92	72	100	60
Neoboutonia macrocalyx	60	80	40	60	64
Allophylus abyssinicus	44	8	40	56	24
Macaranga kilimandscharica	16	60	32	28	32
Tabernamontana stapfiana	8	8	80	60	48
Galiniera coffeoides	4	8	48	36	28
Polyacias kikuyensis	24	4	20	20	12
Dracaena afromontana	0	24	32	12	32
Rapanea melanophloeos	12	0	20	32	20
Xymalos monospora	8	0	20	28	28
Lepidotrichilia volkensii	20	16	12	12	0
Ocotea usambarensis	0	0	20	28	16
Podocarpus latifolius	0	0	16	12	4
Lobelia gibberoa	0	12	4	0	4
Ochna spicata	0	4	0	8	4

Psychotria fractinervata was the most dominant species in both sites followed by *Allophylus abyssinicus, Neoboutonia macrocalyx, Macaranga kilimandscharica, Rapanea melanophloeos* and *Polyacias kikuyensis* in decending order in the undisturbed plots (Table 1 (a) above). In the Test site plots, *P. fractinervata* was followed by *Neoboutonia macrocalyx, Tabernamontana stapfiana, Macaranga kilimandscharica Allophylus abyssinicus* and *Galiniera coffeoides* in decending order.

Neoboutonia macrocalyx, Tabernamontana stapfiana, Dracaena afromontana and *Xymalos monospora* had increased frequencies in the Test site plots. In addition the three mentioned primary or climax species i.e. *Ocotea usambarensis, Podocarpus latifolius* and *Aningeria adolfi - friedericii* occurred among the 15 most frequent species in the disturbed site plots whereas they did not appear among those in the Reference site plots.

Nuxia cogesta, Clausena anisata, Dombeya goetzenii and *Solanum mauritianum* all of which had occurred among the 15 most frequent in the Reference did not appear among those in the Test site plots.

4.1.5 Species regeneration status

Pyschotria fractinervata, Polyacias kikuyuensis, Neoboutonia macrocalyx, Macaranga kilimandscharica, Rapanea melanophloeos and *Clausena anisata* had the highest number of seedlings and saplings in the natural site.

Psychotria fractinervata, Neoboutonia macrocalyx and *Macaranga kilimandscharica* also had the same trend in the disturbed site plots but *Polyacias kikuyuensis, Rapanea melanophloeos* and *Clusina anisata* showed reduced regeneration while *Tabernamontana stapfiana, Dombeya goetzenii, Podocarpus latifolius, Solanum mauritianum, Prunus africana* and *Dracaena afromontana* showed improved regeneration.

Allophylus abyssinicus and *Aningeria adolfi-friederecii* showed no regeneration at all. The highest number of seedlings and saplings was recorded in the Reference site plots as shown in Table 2 below.

Table 2 : Seedlings and saplings

Plot	RF 01	RF 02	RF 03	RF 04	RF 05
Reference site	Sd.871 Sp.377	Sd.1579 Sp.388	Sd.2266 Sp.573	Sd.1251 Sp.379	Sd.452 Sd.315
Plot	TT 01	TT 02	TT 03	TT 04	TT 05
Test site	sd.312 Sp.261	Sd.1448 Sp.521	Sd.618 sp.423	Sd.401 Sp.158	Sd.553 Sp.239

Key :- Sd- seedlings , Sp – saplings

4.1.6. Species Diversity

(i) Shannon - Wiener diversity index

This is the most known and popular diversity index, which is a measure of the order or disorder contained in an ecosystem/community. The Shannon-Wiener measure H', which is a measure of uncertainity in a community, increases with the increasing no of species. It can theoretically reach very high values, but practically it does not exceed 5.0 for biological communities.

(a) Reference site plots had a value = 0.9994

(b) Test site plots had a value =1.0264

(ii) Simpson's index of diversity- is the probability of picking two individuals at random that are from different species, which ranges from 0-1 (when 0 - the two picked don't belong to the same species, when 1- the two picked belong to the same species).

(a) Reference site plots had a value = 0.127462

(b) Test site plots had a value =0.11139

(iii) Jackknife estimate of species richness

This is an estimate of species richness based on the observed frequency of rare species in the community, when quadrats have been used for sampling.

	Richness	Variance
Reference site	33,815	3,840
Test Site	42,783	4,378
All quadrats	48,751	4,838

(iv) Bootstrap estimate of species richness

This is also an estimate of species richness based on the Jackknife principles on quadrats but requires a lot of simulations on a computer to get estimates

	Sample size 10		Sample size 20		Sample size 50		Sample size 100	
	Richn.	Var.	Richn.	Var.	Richn.	Var.	Richn.	Var.
Reference	53,788	3,389	49,835	3,659	44,100	2,253	40,896	1,177
Test site	72,749	5,497	67,884	3,690	62,849	1,965	59,574	0,972
All plots	81,615	7,529	75,626	5,010	66,439	3,922	60,672	3,302

4.2.0 Nutrients status of the forest ecosystem

Three most dorminant tree species were selected for study of the nutrients in the forest. Their description and distribution in Kenya are given and shown below.

(i) *Psychotria fractinervata*

This is the most frequent and dominant species in both sites. It is in the family Rubiaceae , has an average height of about 13 m , diameter at breast height of 20 cm and an average crown diameter of 7 m. and have got a very good regeneration.

It has a narrow distribution , restricted to the central and western highlands only.

Map 2 (KTSL 1994)

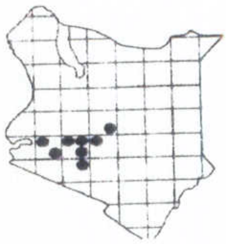


Photo 6 :*Psychotria fractinervata*, was found to be the most frequent and dominant species and also with good regeneration in the forest.

(ii) *Neoboutonia macrocalyx*

This is a fast growing pioneer tree, in places where forests have been disturbed or cleared. It is in the family Euphorbiaceae , has an average height of 19.5 m , diameter at breast height of 31 cm and a crown diameter of 8.5 m.

It's distribution is wider covering the central and western highlands and upto Mt.Kilimanjaro region in the southern part.

Map 3 (Source KTSL 1994)

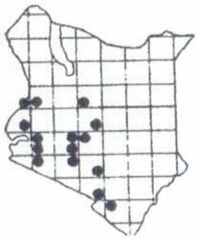


Photo 7: *Neoboutonia macrocalyx,* a pioneer species at Uplands was found to have a higher specific demand for both Nitrogen and Phosphorous.

(iii) *Allophylus abyssinicus*

This is the widely distributed of the three species, going to the far north to L. Turkana and south to Mt Kilimanjaro region.

It is in the family sapindaceae, has an average height of 21 m , diameter at breast height of 32 cm and a crown diameter of 9.5 m.

Map 4 (Source KTSL 1994)

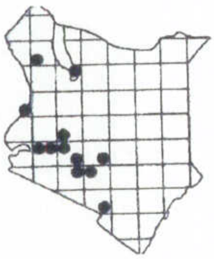


Photo 8 : *Allophylus abyssinicus,* a good tree for charcoal and without any regeneration in the forest.

4.2.1 Nutrient's content in plant tissue

4.2 2 Macronutrients (org.subs.)

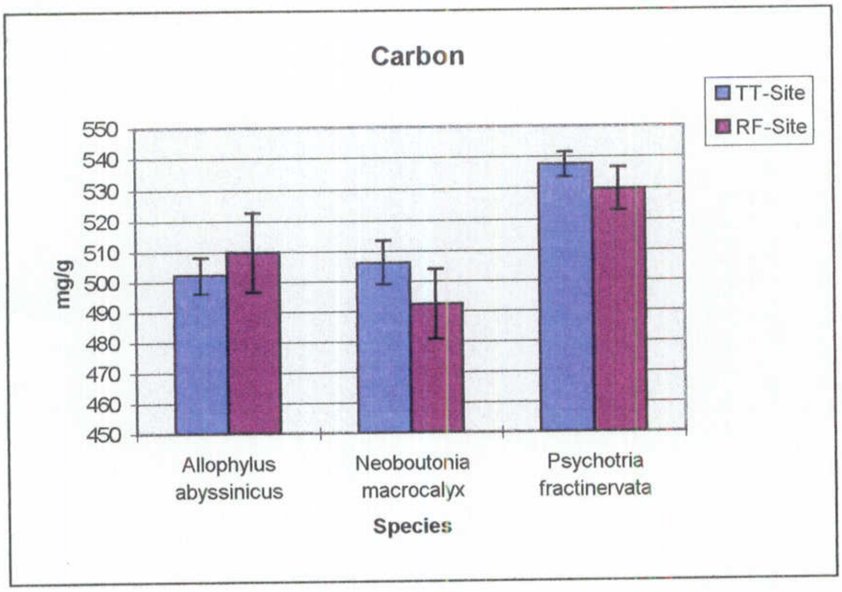
These are Carbon (C), Nitrogen (N), Sulphur (S) and Phosphorous (P). all of which are important in primary productivity and plant metabolic activities.

The above three tree species, all had higher contents of C where *Psychotria fractinervata* had the highest in both sites, then *Allophylus abyssinicus,* and *Neoboutonia macrocalyx* had the lowest in the two sites and especially so in the reference one. Also *P. fractinervata* had the highest content of S and the other two species followed the same trend as above.

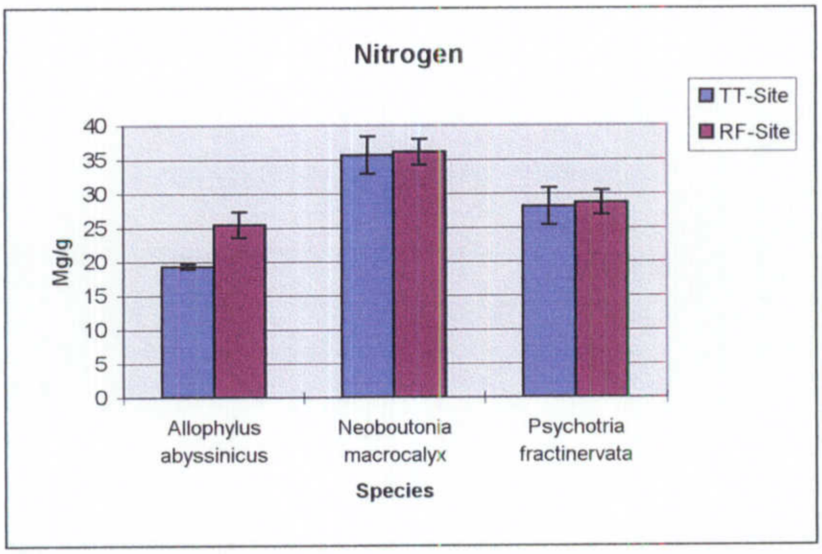
N. macrocalyx had the highest content of N in both sites, then *P. fractinervata* and *A. abyssinicus* had the lowest. Also *N. macrocalyx* had the highest content of P in both sites and the other two species followed the same trend as above.

(see graphs I – IV below for C, N , S and P respectively).

(I)

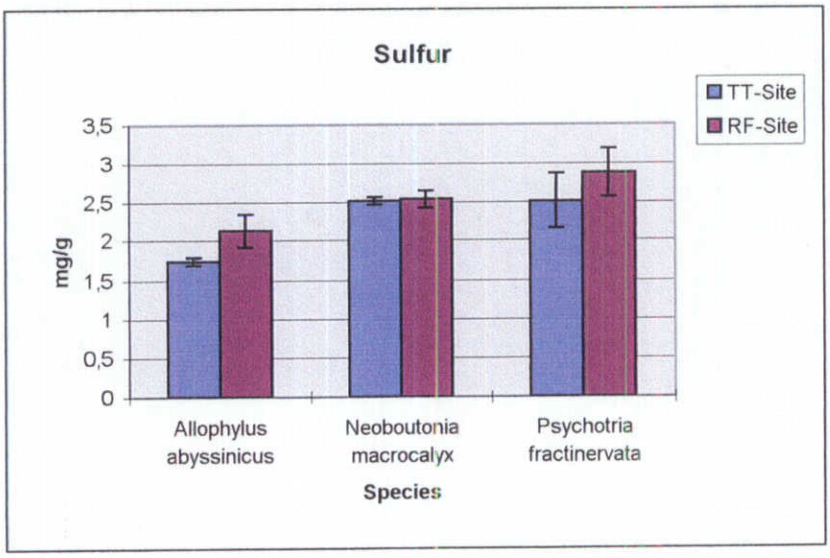


(II)



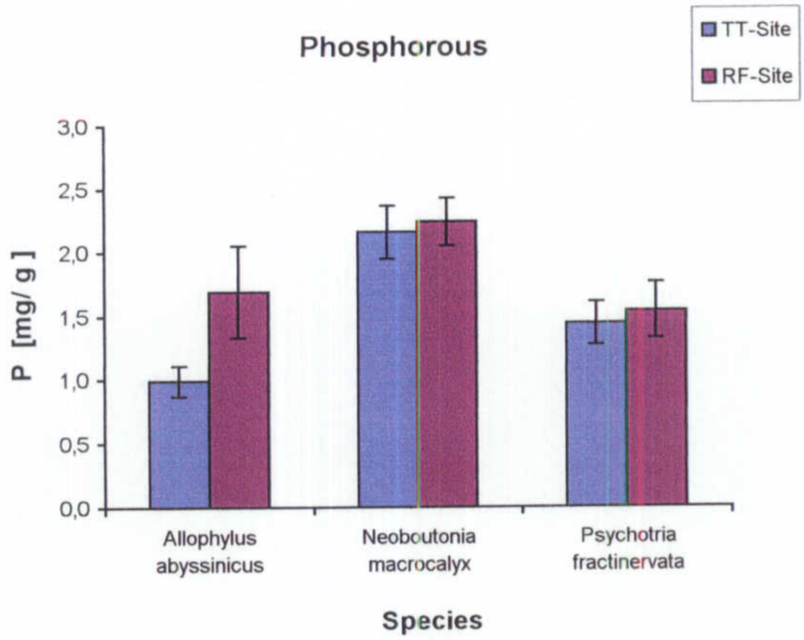
Nitrogen
TT-Site
RF-Site
40
35
30
25
20
15
10
5
0
Mg/g
Allophylus abyssinicus
Neoboutonia macrocalyx
Psychotria fractinervata
Species

(III)



Sulfur
TT-Site
RF-Site
3,5
3
2,5
2
1,5
1
0,5
0
mg/g
Allophylus abyssinicus
Neoboutonia macrocalyx
Psychotria fractinervata
Species

(IV)



4.2.3 Macronutrients (Alk.&Alki earth metals)

These are Potassium (K), Calcium (Ca), Magnesium (Mg) and Sodium (Na). These nutrients are also required for plant growth and development and are thus essential.

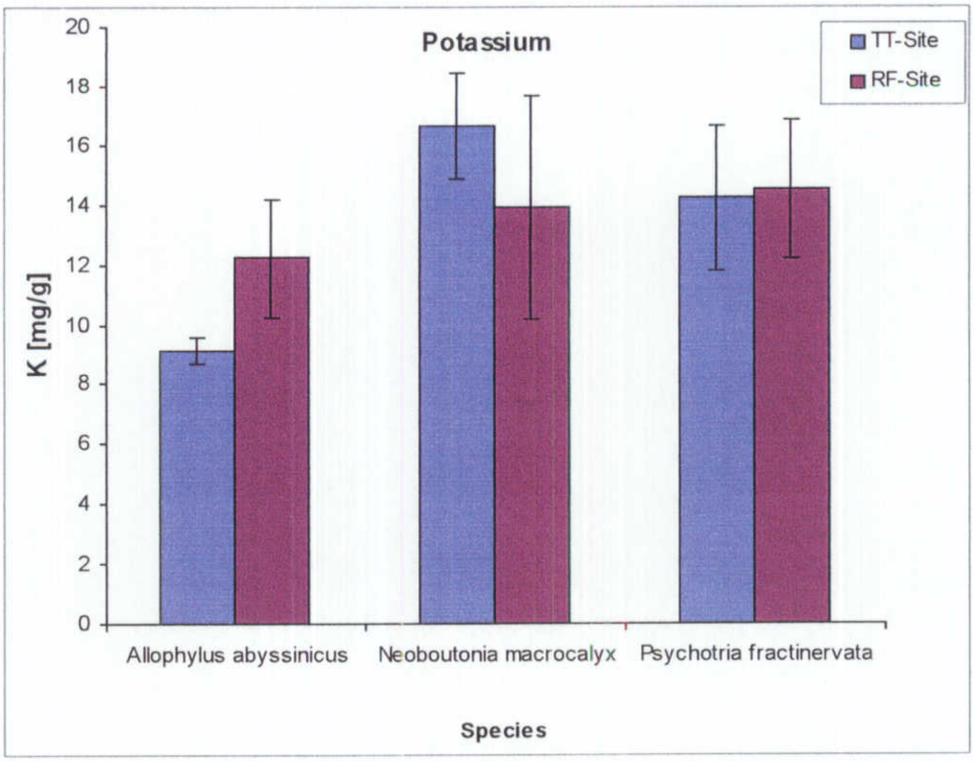
Neoboutonia macrocalyx had the highest content of K in the Test site, then *Psychotria fractinervata* and *Allophylus abyssinicus* had the lowest. In the Reference site *P. fractinervata* had the highest, followed by *N. macrocalyx* while *A. abyssinicus* had the lowest.

All the three tree species, had higher content of Ca in the Reference than in the Test site. *N. macrocalyx* had the highest content in both sites, followed by *A. abyssinicus* and *P. fractinervata* had the lowest in the reference, while it was *A. abyssinicus* that had the lowest in the test site.

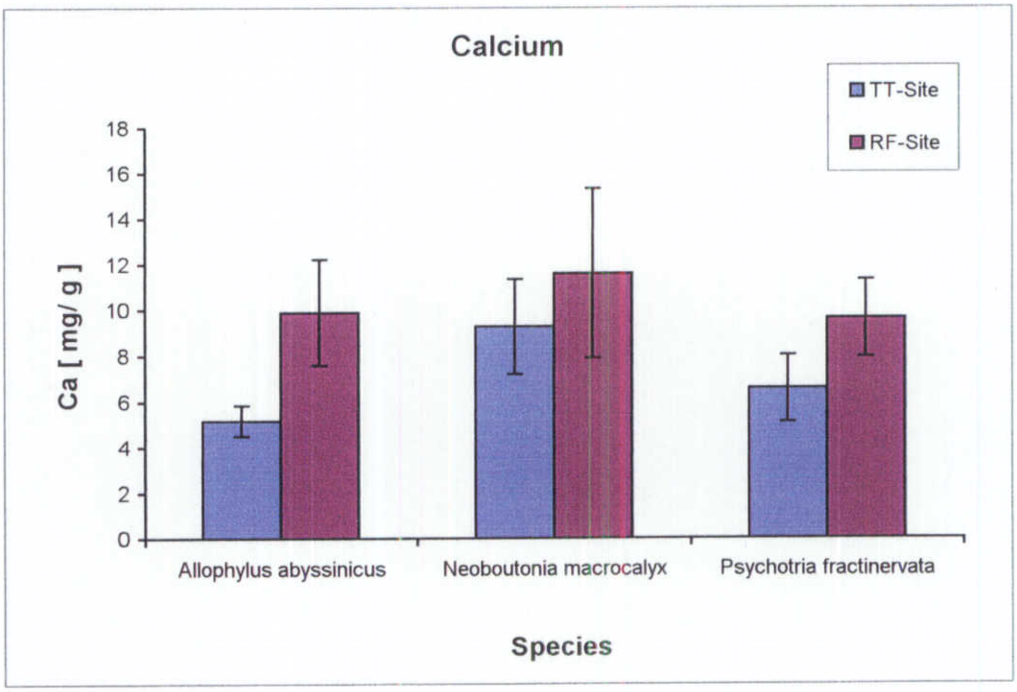
All the three tree species had higher content of Mg in the reference site where *A. abyssinicus* had the highest followed by *P. fractinervata* while *N. macrocalyx* had the lowest. In the test site, was a reverse of the above, where *P. fractinervata* had the highest followed by *N. macrocalyx* while *A. abyssinicus* had the lowest.

P. fractinervata had the highest content of Na in both sites, followed by A. abyssinicus and N. macrocalyx had the lowest. However P. fractinervata and N. macrocalyx had almost the same content in bothg sites but A. abyssinicus showed a significant difference between the sites, where it had higher content in the test site. The other two species had slightly higher content in the reference site. (see graphs V – VIII below for K, Ca, Mg and Na respectively).

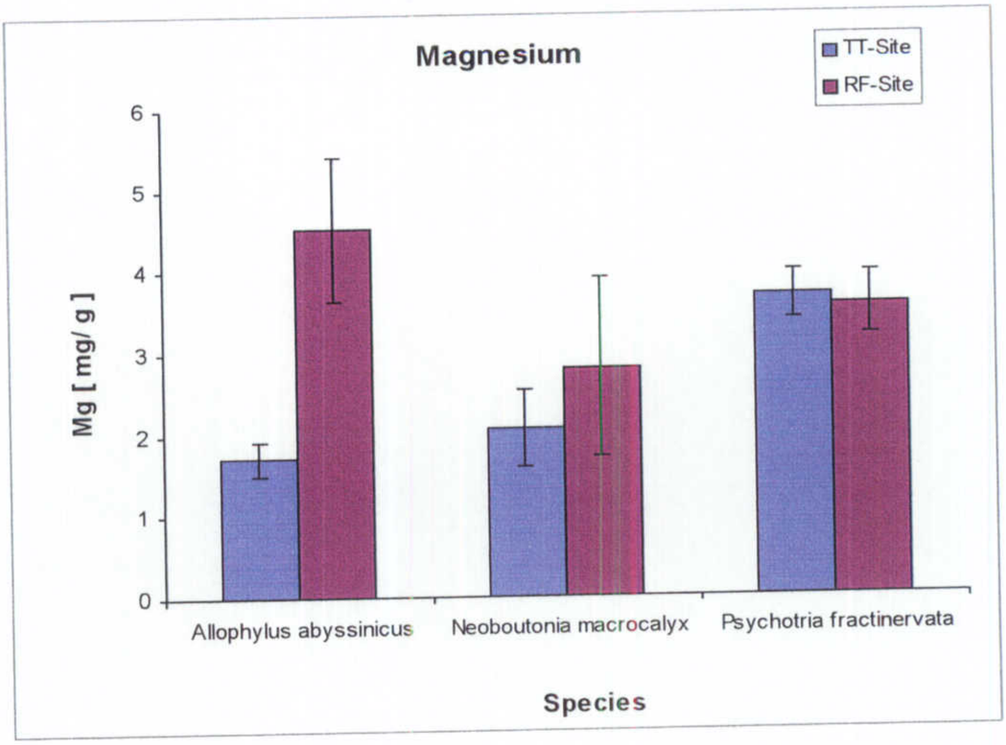
(V)



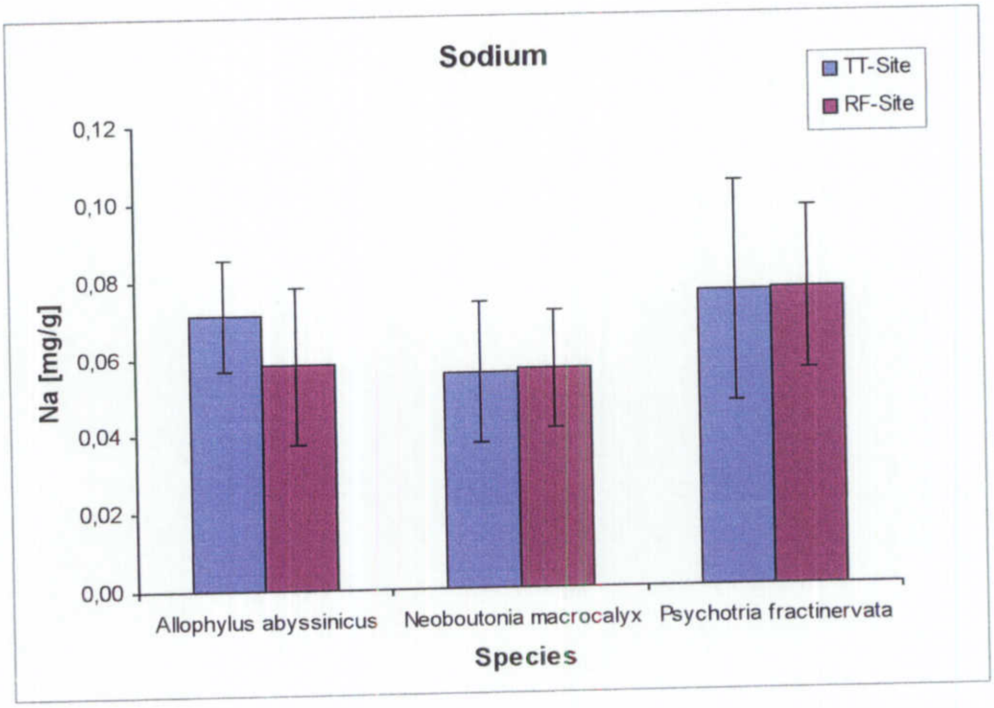
(VI)



(VII)


Magnesium
TT-Site
RF-Site
Mg [mg/ g]
0
1
2
3
4
5
6
Allophylus abyssinicus
Neoboutonia macrocalyx
Psychotria fractinervata
Species

(VIII)


Sodium
TT-Site
RF-Site
Na [mg/g]
0,00
0,02
0,04
0,06
0,08
0,10
0,12
Allophylus abyssinicus
Neoboutonia macrocalyx
Psychotria fractinervata
Species

4.2.4 Trace elements.

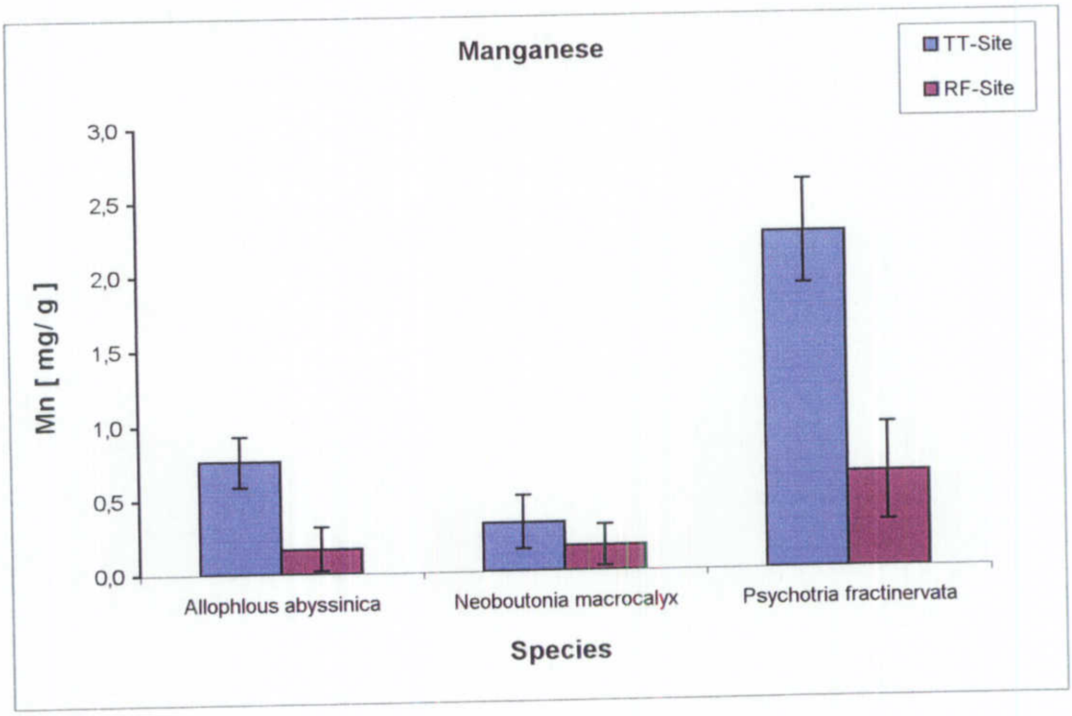
These includes Manganese (MN), Aluminum (Al) and Iron (Fe).

All the three species of trees had relatively higher contents of Mn in the test than reference site. *Psychotria fractinervata* had the highest content in both sites, followed by *Allophylus abyssinicus* and *Neoboutonia macrocalyx* had the lowest in the test site. Both *A.abyssinicus* and *N. macrocalyx* had almost equal level of content in the reference site.

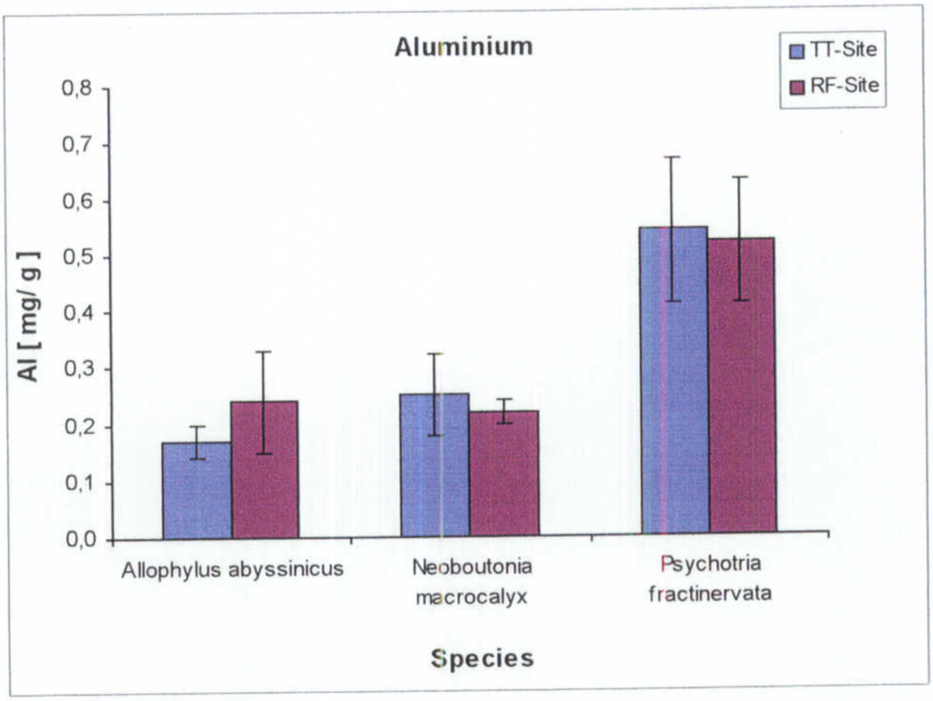
P. *fractinervata* had the highest content of Al in both sites, followed by *A. abyssinicus* while *N.macrocalyx* had the lowest in the reference, whereas it was *A. abyssinicus* which had the lowest in the test site.

A. abyssinicus had the highest content of Fe in the reference site, followed by *P. fractinervata* while *N. macrocalyx* had the lowest. In the test site it was *P. fractinervata* which had the highest and *A. abyssinicus* the lowest (see graphs (IX).(X) and (XI) below for Mn, Al and Fe respectively).

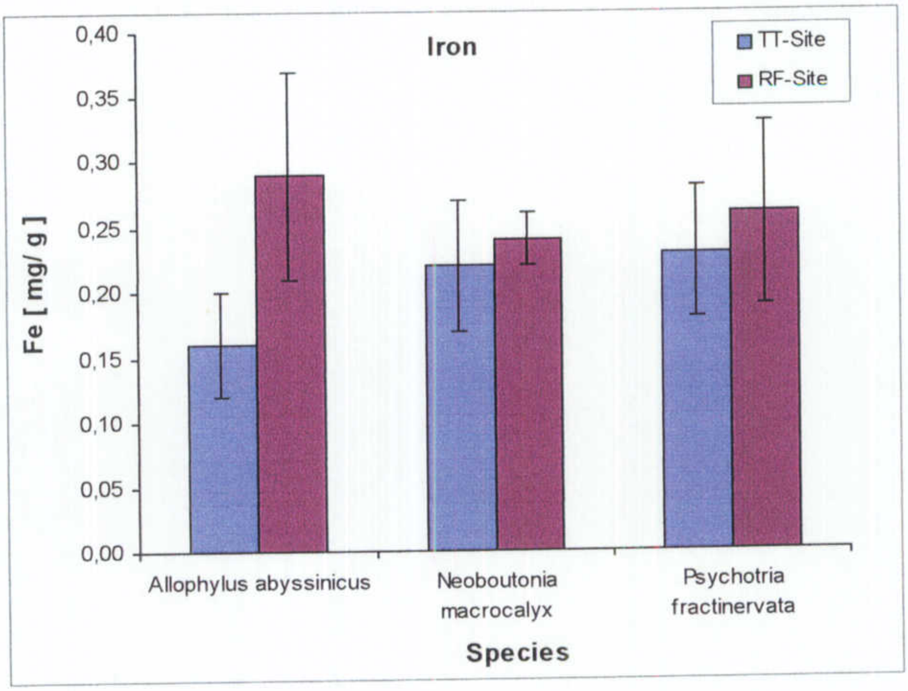
(IX)



(X)


Aluminium
TT-Site
RF-Site
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
Al [mg/ g]
Allophylus abyssinicus
Neoboutonia macrocalyx
Psychotria fractinervata
Species

(XI)


Iron
TT-Site
RF-Site
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
Fe [mg/ g]
Allophylus abyssinicus
Neoboutonia macrocalyx
Psychotria fractinervata
Species

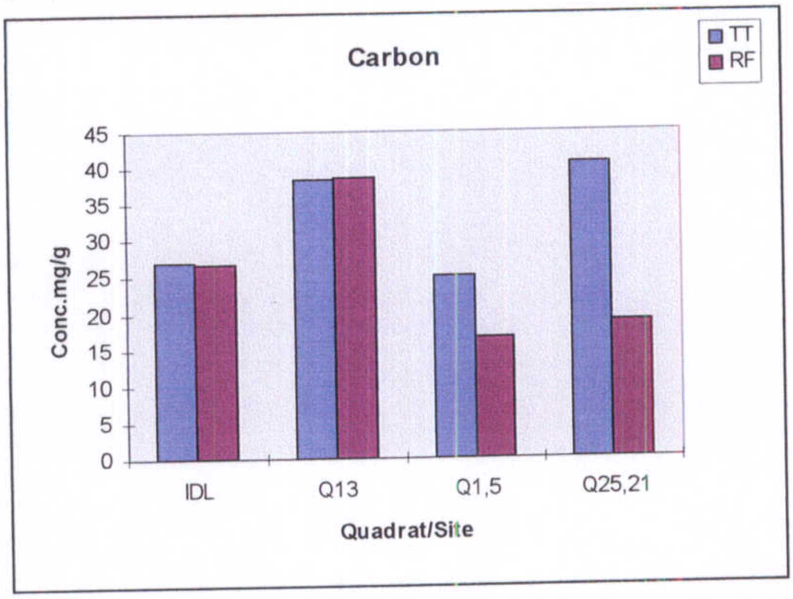
4.3.0 Nutrient's content in the soil

4.3.1 Macronutrients (Org./non-metallic).

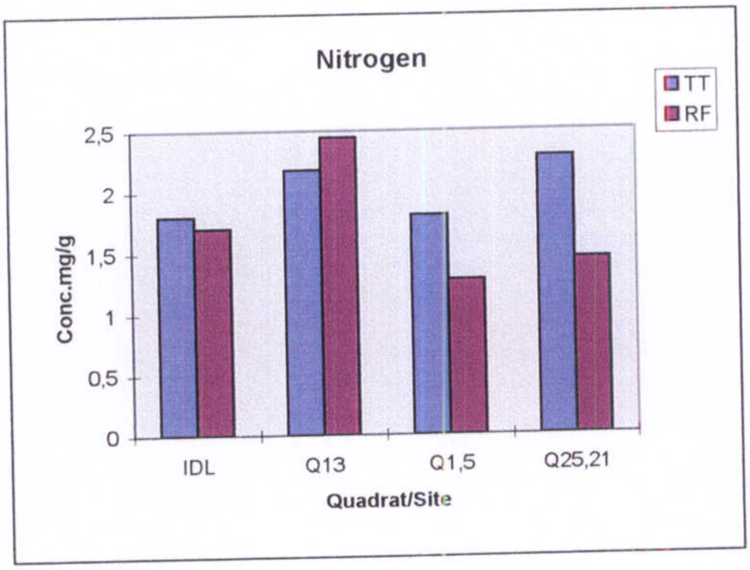
These are Carbon (C), Nitrogen (N) and Sulphur (S).

The content of C was almost equal in the two sites in some localities/quadrats within the sites whereas other localities showed higher contents in the test than in the reference site. N and S had a similar trend in both sites. The central quadrats in two sites showed slightly higher contents of N and S in the reference than in the test site (see graph (I), (II) and (III) below for C, N and S respectively).

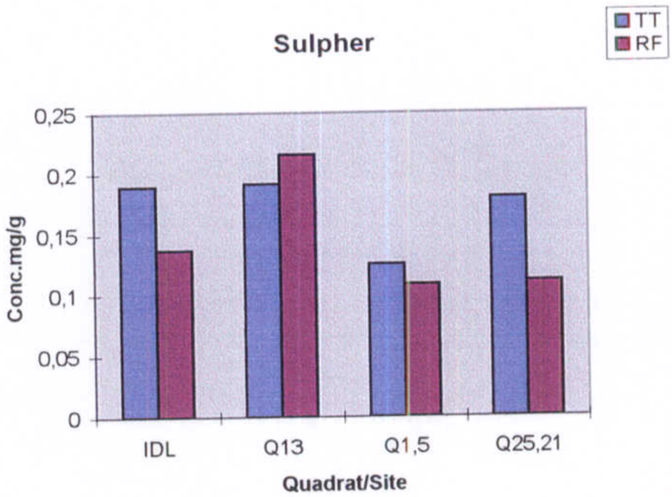
(XII)



(XIII)



(XIV)



4.3.2 Macronutrients (Alk.& Akli. earth metals).

These includes Calcium (Ca), Potassium (K), Magnesium (Mg) and Sodium (Na).

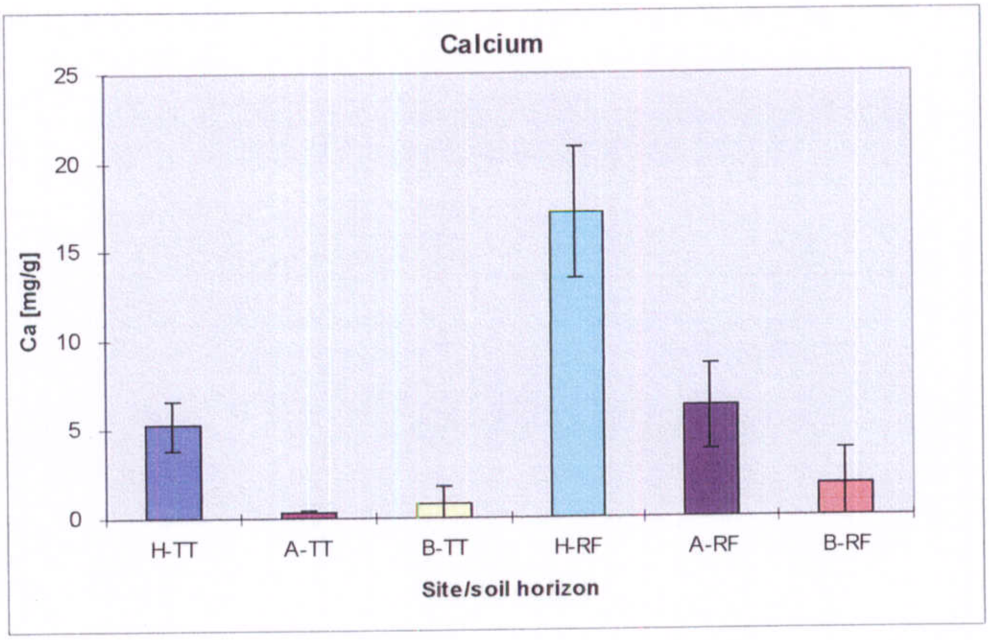
There was a significant difference in the content of Ca in the Reference where it was higher and the Test site where it was low in all the horizons comperatively. The humus had the highest content in both sites, then A-horizon and B-horizon had the lowest in the reference whereas it was A-horizon which had the lowest in the test site.

A-horizon had the highest content of K in the Reference, B- horizon in the Test, whereas it was the humus layer that had the lowest in both sites.

The content of Mg was directly opposite in the two sites, whereby it was highest in the humus layer followed by A-horizon and B-horizon had the lowest in the Reference. In the Test site Humus layer had the lowest while B-horizon had the highest.

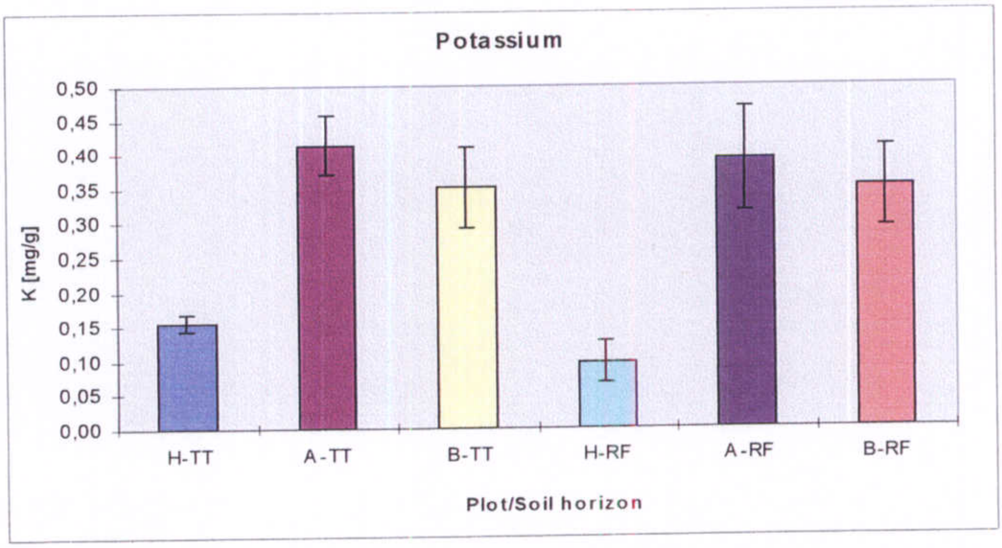
The content of Na showed the same trend in both sites, where A-horizon had the highest and humus the lowest. However slightly higher content occurred in the Test site (See graph (IV),(V),(VI) and (VII) below for Ca, K, Mg and Na respectively).

(XV)



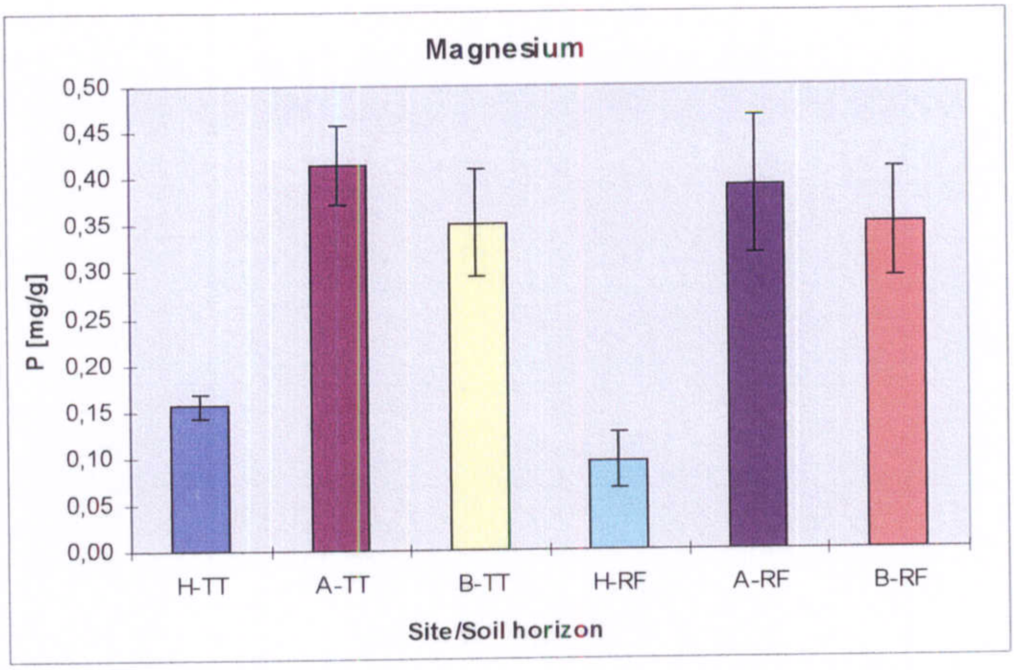
Calcium
Ca [mg/g]
25
20
15
10
5
0
H-TT
A-TT
B-TT
H-RF
A-RF
B-RF
Site/soil horizon

(XVI)



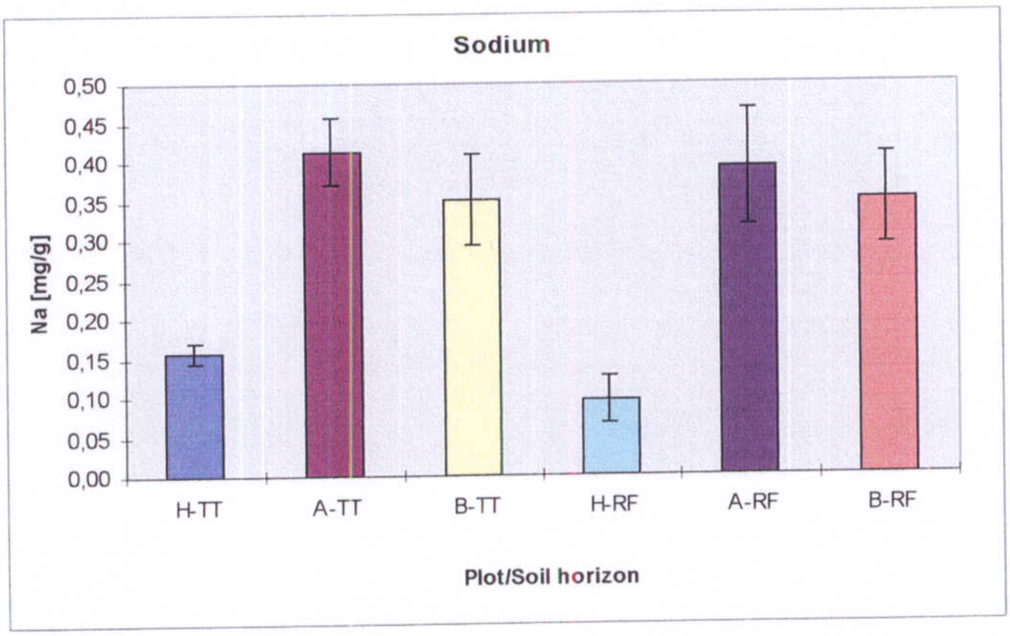
Potassium
K [mg/g]
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
H-TT
A-TT
B-TT
H-RF
A-RF
B-RF
Plot/Soil horizon

(XVII)



Magnesium
P [mg/g]
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
H-TT
A-TT
B-TT
H-RF
A-RF
B-RF
Site/Soil horizon

(XVIII)



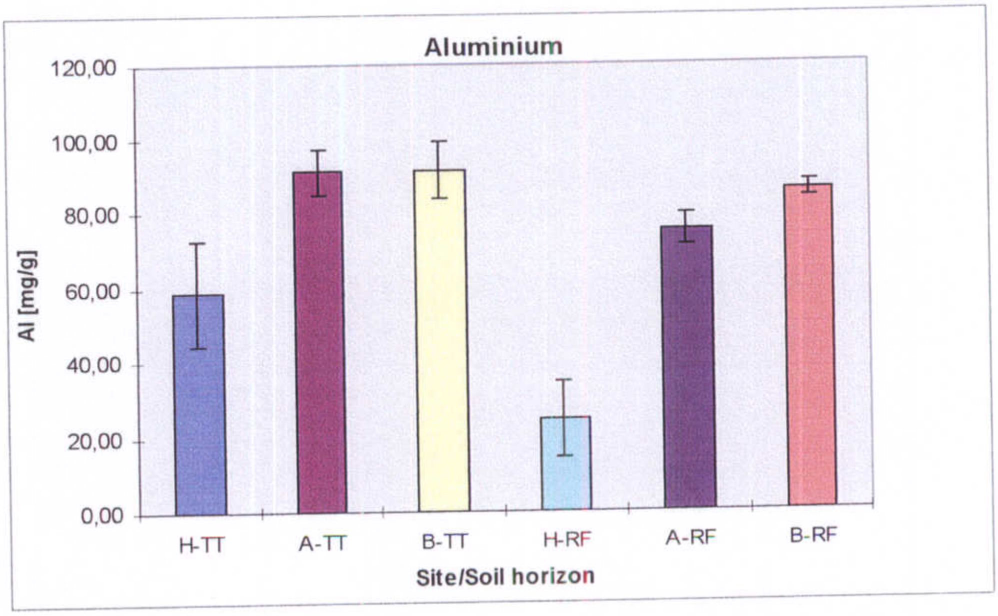
Sodium
Na [mg/g]
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
H-TT
A-TT
B-TT
H-RF
A-RF
B-RF
Plot/Soil horizon

4.3.3 Trace elements

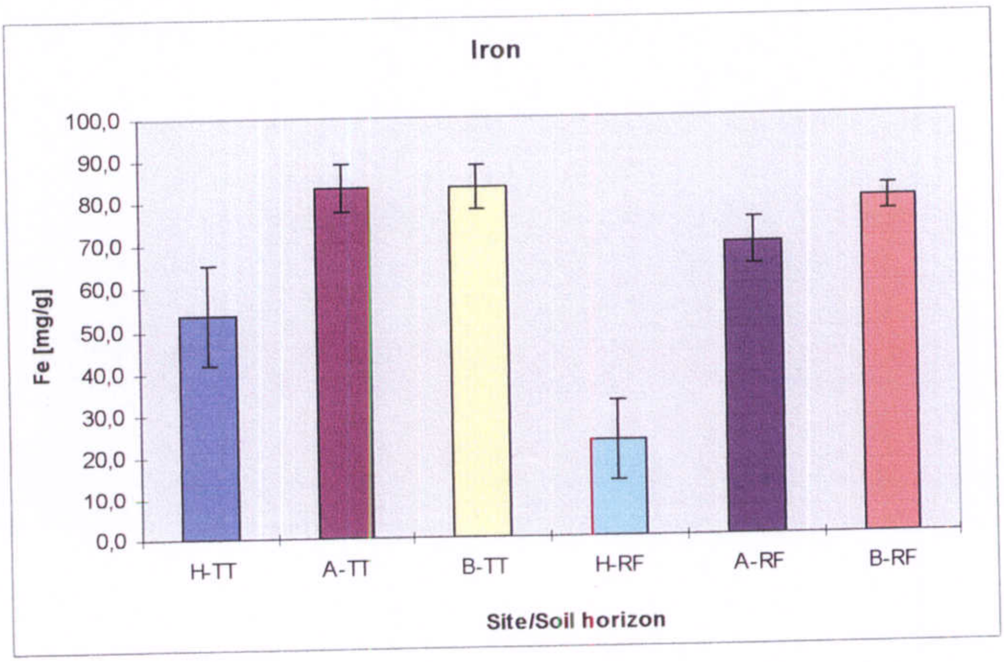
These are Aluminum (Al), Iron (Fe) and Manganese (Mn)

Al and Fe showed a similar trend in both sites, with higher contents occuring in the test site. For both elements, B-horizon had the highest content ,then A-horizon and the humus had the lowest. A and B-horizons had the highest content of Mn in the reference than in the test while the humus layer had lower content than in the test site (see graph (VIII), (IX), and (X) below for Al, Fe and Mn respectively).

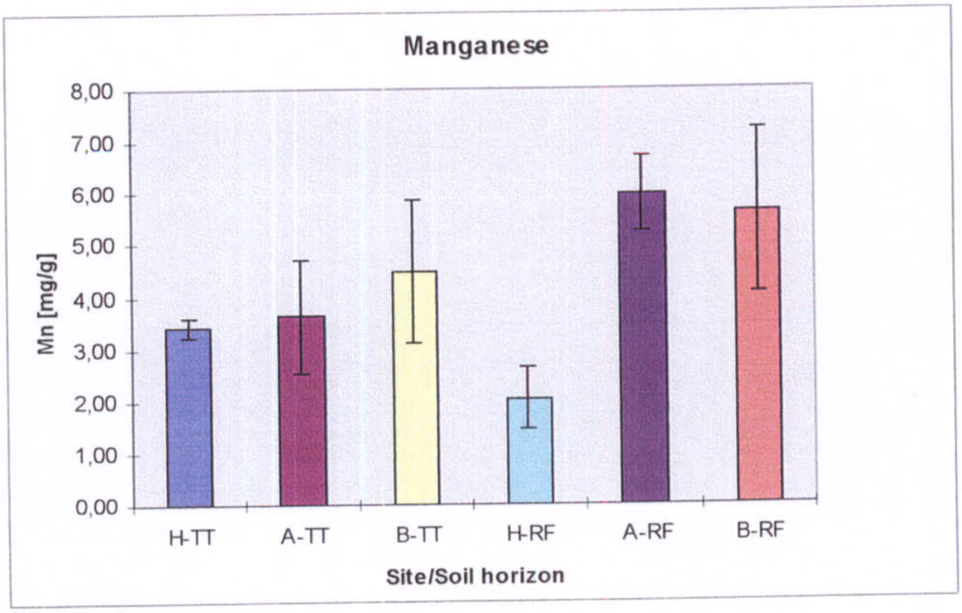
(XIX)



(XX)



(XXI)

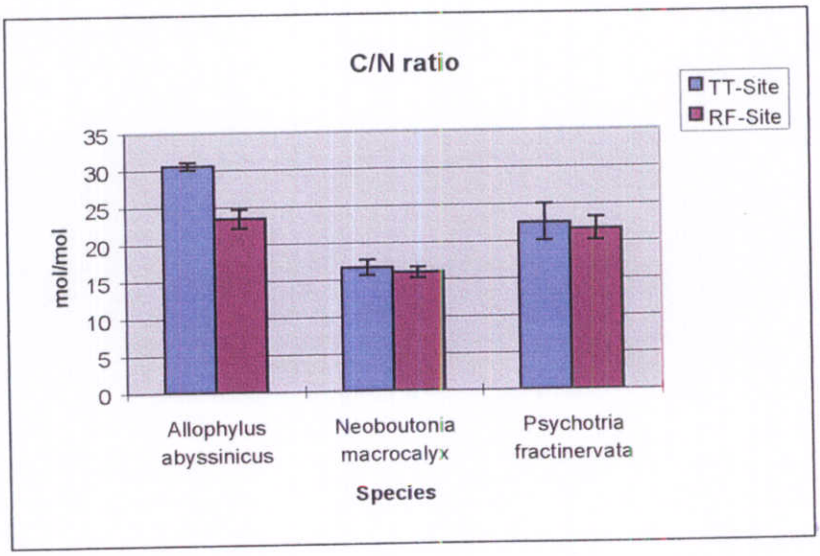


4.4.0 Carbon : Nitrogen Ratio

4.4.1 Plant tissue

Allophylus abyssinicus had significantly higher ratios in both sites with the test site being more higher than in the reference. The other two species had almost equal ratios in the two sites and it is Neoboutonia macrocalyx which had the lowest (see graph (XI) below).

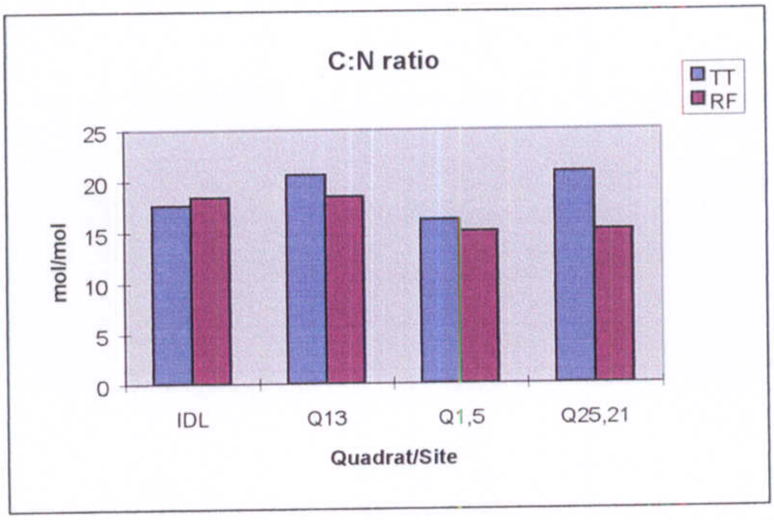
(XXII)



4.4.2 Soil

All the paired quadrats, apart from the peripheral ones, showed almost the equal ratios with those of the test site being slightly higher (see graph (XII) below).

(XXIII)

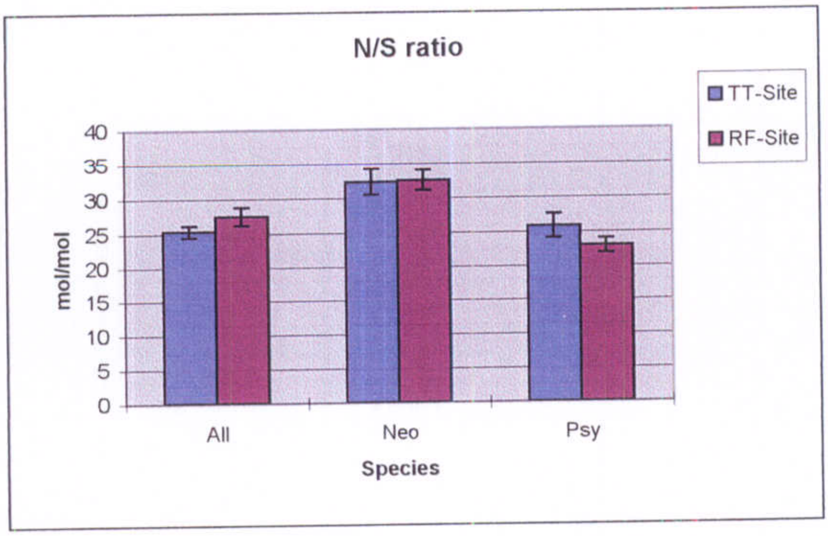


4.5.0 Nitrogen : Sulphur Ratio

4.5.1 Plant tissue

Neoboutonia macrocalyx had the highest and almost equal ratios in both sites. The other two species had slightly different ratios, wherby *Allophylus abyssinicus* had slightly higher ratio in the reference and *Psychotria fractinervata* in the test site. P. fractinervata had the lowest ratio in the reference and A. abyssinicus in the test site (see graph (XIII) below)

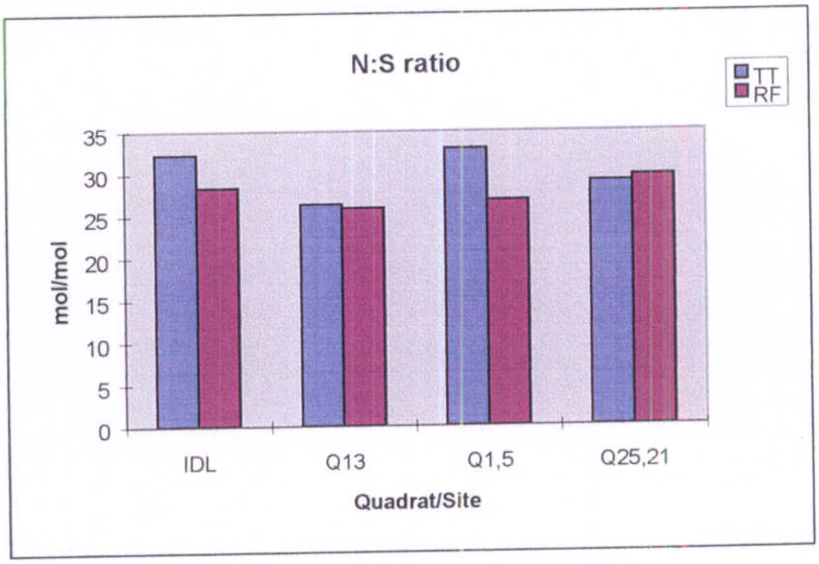
(XXIV)



4.5.2 Soil

Only one set of paired quadrats showed higher ratios in the test site, whereas the rest were almost uniform in the two sites (see graph (XIV) below)

(XXV)



(CHAPTER 5)

5.0 Discussion

5.1 Species composition

The management of the forest resources is guided by the national forest policy and supported by the forest act. The current forest policy, which became operational in 1968, have been revised to reflect the changes that has taken place since then, and the new Policy has a provision for conservation of bio-diversity as part of management of the natural forests, due to the recognition that, these forests need to be left to regenerate. Also, the exploitation of these forests for timber has been under a Presidential ban since mid 1980's ,and the management activities by the Forest Department have been largely restricted to the plantations, law enforcement to control illegal extraction, licensing for the extraction of the forest produce e.g. fuelwood, grazing of livestock, farming under the shamba system etc. (ODA & IUCN 1995).

The well known human activities in forests includes exploitation of the forest resources for timber, fuelwood, charcoal, herbal medicine etc. The intensity of exploitation will depend on the availability and accessibility to the resource, as well as the demand for the various products and services. Uplands forest which occur in a high potential and densely populated area, in central Kenya and closer to large urban centres e.g. Limuru, Kikuyu, and Nairobi, the capital city which is about 50 km away, is under excessive human pressure for the various products to supply the local and far away market demands.

The above mentioned human activities will affect the species composition in the forest, and mostly the exploitation of the commercial timber species. At Uplands Forest, such species includes *Ocotea usambarensis* and *Podocarpus latifolius* as the two mostly targeted species. Other known timber species in the forest are *Albizia gummifera, Aningeria adolfi-friedericii, Casearia battiscombei, Cassipourea malosana, Dombeya goetzenii, Ekebergia capensis, Olea capensis, Prunus africana, Syzgium guinensee* and *Teclea nobilis* (ODA & IUCN 1995).

The sawn timber of *Ocotea.usambarensis,* a hardwood species, are highly valued in the kenyan furniture industry and this species is also highly targeted in the forest, to supply the local and far away market demand for the products. *Podocarpus latifolius* , a softwood species, also is in high demand for it's timber which is easy to work on. Though the quality is not as good as that of the former, it is easy to work on this species during the process of sawing. Also it's growth characteritics is better in that it is often single-stemed and straight as opposed to the former which is rarely so.

Both *O. usambarensis* and *P. latifolius* have very low frequencies in the investigated forest as seen from Tables 1a and b. Their regeneration as well is very poor and especially so with the former species whose regeneration is in form of sprouts from the roots and stumps but not from seeds. Though the later species regenerates from seeds, the availlable seedlings and saplings in the forest are extremely few. *Olea capensis* and *Prunus africana* also have high quality timber for furniture but they have very low frequencies in the forest as well.

Charcoal burning is another activity being carried out in the forest, whereby *Allophylus abyssinicus* is the preferred species due to it's high density wood resulting into good charcoal. This is an activity especially practised by the youth to earn a living due to lack of better paying jobs/employment. Uplands being at high altitude and thus low temperatures, charcoal is a necessity in most homes for warming as well as cooking, especially in the local shopping centres. The demand for the product is high due to the high population in the area.

Fuelwood is another product in very high demand in the area, and though is permitted as dead wood collection, the amount of dead-wood in the forest can't cope with the demand. *Neoboutonia macrocalyx* and *Macaranga kilimandscharica* are preferred for fuelwood in absence of dead wood. Poles for construction and fencing are also got from the forest and the species cut include *Macaranga kilimandscharica, Neoboutonia macrocalyx* and *Ocotea usambarensis,* due to their good form i.e. are straight and upright. *Prunus africana, Polyacias kikuyensis* and *Olea capensis* are good candidates for the purpose as well.

The forest neighbouring community are involved in agricultural activities, where Tea (*Thea sinensis)* is the main cash crop. Due to the favourable climatic conditions for growth of vegetables, the inhabitants are actively involved in farming of vegetables such as cabbage, kales, carrots etc. to supply not only the local Limuru and Nairobi markets, but also as far as Mombasa and Malindi which are tourist destinations along the kenyan coast, a distance of about 600 km away. To support their farming activities, the forest acts as a source of tool handles, the species preferred being *Teclea nobilis* and *Ochna ovata,* due to their hard texture and therfore don't break easily.

Bark stripping is another activity carried out in the forest and *Podocarpus latifolius* is especially preferred for it's waterproofing covering for bee-hives because bee-keeping is an important activity carried out in the forest. Other species de-barked includes *Olea capensis* for stomach-ache remedies and other medicinal purposes (ODA & IUCN 1995). *Rapanea melanophloeos* is de-barked for treatment of elephantiasis while it's fruits are used against intestinal worms (Gachathi 1989).

Toddalia asiatica's roots are used for treatment of pneumonia, colds and fever while the stem is used for walking sticks and other related wood works. *Maytenus acuminata* is used for walking sticks and tool handles as well. *Clutia abyssinica,* which is a common shrub in the disturbed sites, has it folage used as fodder for livestock mostly sheep and goats. It's roots are used as medicine against diarrhoea and dysentry (Gachathi 1989).

Piper capense, which is a common herb in montane forests, and form much of the understorey vegetation in this forest is medicinal. It's stem is boiled and the concotion is used for treatment of sore throats and the roots are used for flavouring the soup. The roots of *Rubia cordifolia,* which is a common herb in disturbed sites, are used as medicine against dysentry. Also they contain a dye which is used for colouring leather belts, bag/busket handles etc. *Urtica massica* which have stinging hairs, is another common herb in disturbed sites, the leaves are used as vegetables and roots are medicinal (Gachathi 1989).

The main impact of the continued utilization of the forest by people to the species composition is shown by the increased frequencies of pioneer species, mostly *Neoboutonia macrocalyx, Macaranga kilimandscharica* and *Tabernamontana stapfiana* in the Test sites. These are the gap fillers in the forest and their quick establishment due to their fast growth rate, is an advantage over the other species. These species are more frequent in areas where harvesting for timber or otherwise has occurred in the montane forests in central Kenya (ODA & IUCN 1995).

The effect of canopy gaps as a result of the continued non-commercial utilization of the forest resources is clearly shown by the relatively higher number of species in the test as compared to those in the reference sites (See diagram 1 for the species- area curves). The various tests used for species diversity have also shown it to be higher in the test than in the Reference sites. However more trees were found in the reference than in the test sites. The opening of the canopy improves the regeneration of tree species, mostly the broad leaved pioneers and which are light-demanders,the so called "gap opportunists" or nomadic species (Lamprecht 1989).

Three tree species which occur in the forest i.e. *Polycias kikuyensis, Prunus africana* and *Ochna ovata* have been categorized as rare or venerable. *P. kikuyensis,* which is a wet montane forest tree endemic to central Kenya, is good for timber and is used for making of traditional beehives, mole traps etc. *Prunus africana* is an excellent timber tree for furniture and flooring and is now famous for the pharmaceutical research for prostate gland curing drug and therefore making the species even more endangered than before. Extracts from the bark of Prunus africana are being used for the treatment of benign prostatic hyperplasia and prostate gland hypertrophy, both of which are ailments suffered by about 60% of men in Europe and U.S.A. (Garnick 1994). *Ochna ovata,* which is an understorey species in the forest, is used for making tool handles and walking sticks (KTSL 1994, IUCN 1998).

All of the above three rare species, were not frequent in the forest, although *P. kikuyensis* occurred more frequently in the Reference while *O. ovata* was more frequent in the Test sites. *Prunus africana* did not appear among the 15 most frequent species in either site (see Tables 1a&b). These species will therefore require conservation efforts maybe in-situ conservation to maintain and increase their populations in this and other forests as well.

Two species i.e. *Allophylus abyssinicus* and *Aningeria adolfi-friederecii* showed no regeneration at all in both sites. This could probably be due to lack of seeds or germination failures or higher loss of seedlings due to herbivory or could even be drought induced seedling mortality as was found in the Amazonia forest (Nepstad et al. 1996). This is likely to have emerged from the constantly changing climatic conditions at Uplands, which have become more drier and warmer than it was a couple of decades ago. This and the likelyhood that, is often the mother or seed-bearing trees which are mostly harvested, could easily be taken to explain the prevailing condition on regeneration of these two species and a few others as well in the forest.

Human activities do not only cause destruction of habitats, but coupled with the climatic change can also lead to spread of species beyond their natural range of occurrence.The presence of *Grevellia robusta,* which is not indigenous to Kenya, though now has been naturalised, show the effects of human activities to introducing alien species. If such species are favoured by the prevailing environmental conditions, they can easily end up changing the species composition, though after a long period of time (den Nijs et al. 1999).

5.2 Nutrients

In general, the long undisturbed development under high temperatures and rainfall conditions in the tropics, have led to intensive weathering and leaching of nutrients to deeper layers. This leaves the upper soil layers without the essential minerals required for regeneration of species, and are most composed of Iron (Fe) and Aluminium(Al) oxides

(Lamprecht 1989). This situation was evident especially in the Test site, where there was no substantial humus layer as compared to the Reference site, making the mineral soil layers to be more exposed in the former than in the later site.

Nutrients are important for the growth of trees and they are stored in both the above and below ground components of trees in the forest ecosystem (Whitmore 1990). There three dominant tree species at Uplands forest showed higher contents of carbon (490 - 535 mg/g) in both sites.*Psychotria fractinervata* had the highest content in both sites. It was followed by *Neoboutonia macrocalyx* and *Allophylus abyssinicus* had the lowest in the Test, whereas it was *N. macrocalyx* which had the lowest in the Reference site. Nitrogen ranged from appro. 20-38 mg/g, where *N. macrocalyx* had the highest content in both sites, then *P. fractinervata* and *A. abyssinicus* had the lowest. The content of Sulphur (1.7 - 2.8 mg/g) was higher in *P. fractinervata,* then *N. macrocalyx* and it was *A. abyssinica* that had the lowest. in both sites. That of Phosphorous ranged from 1.0 - 2.3 mg/g, and it was *N. macrocalyx* which had the highest content in both sites, then P. fractinervata while *A. abyssinicus* had the lowest.

The C:N ratio ranged from 15 - 30 m/m and *A. abyssinicus* had the highest ratios with a significant difference between the sites, then *P. fractinervata* and *N. macrocalyx* had the lowest. The N:S ratios were relatively higher ranging from 23 - 32 m/m and *N. macrocalyx* had the highest in both sites, then *A. abyssinicus* and *P. fractinervata* had the lowest. *N. macrocalyx* did not show any difference between the sites but the other two species had some slight differences in content between the sites, whereby *A. abyssinicus* had slightly higher in the Reference and *P. fractinervata* in the Test site.

The content of the above four main or macronutrients in the soil did not show much variation between the sites. Carbon ranged from 15 - 40 mg/g, with only some slight differences in some peripheral localities, where it was higher in the Test site. Nitrogen which ranged from 1.4 - 2.5 mg/g, showed the same trend as Sulphur which had a range of between 0.1 - 0.4 mg/g. Where Nitrogen was higher, it was in those same localities or Quadrats that Sulphur was higher which would suggest a correlation in their functioning as well as uptake by plants. The two elements were found to have a constant ratio of 0.030 in Pinus radiata's foliage and seeds, where they occur in organic form and are required for protein synthesis (Kelly & Lambert 1972).

When the content of total nitrogen is known, organic sulphur can be estimated by multiplying the constant ratio with the available nitrogen i.e. 0.030 x total-N, which is the level of organic sulphur actually required for complete constitution of the plant material. When sulphur is in excess of this basic requirement, the extra will be in form of sulphate –S, which is an indication that S is probably adequate. When total-S is not greater than organic-N, then a true sulphur defficiency probably exists. Nitrogen is taken up at the rate at which S is available, and therefore protein formation will be limited to the availability of nitrogen (Kelly & Lambert 1972).

The C:N ratios ranged from 15 - 20 mol/mol with less variation between the sites. The N:S ratios were higher ranging from 25 - 34 mol/mol having the variation as stated for Nitrogen and Sulphur above. These ratios are important indicators to show the amount or quantity of the nutrient which is gained by the soil from decomposition of the biomass. It will as well give an indication of how much of the nutrient is exported out of the ecosystem in form of bio-mass (Singh & Singh 1991).

Potassium (K^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}) and Sodium (Na^+) are micronutrients, which belong to the most basic cations in the soil. All except Na, are essential bioelements, which accumulate in large quantities in the vegetation (Furch 1997). *Neoboutonia macrocalyx* had the highest content (13 - 17 mg/g) , of K^+ in both sites, with the highest in the Test site, then *Psychotria fractinervata* (13 - 13.5 mg/g) and *Allophylus abyssinicus* had the lowest (9 - 12 mg/g). Both *N. macrocalyx* and *A. abyssinicus* had some variation between the sites whereby the former species had higher content in the Test while the later had the highest in the Reference site.

All the three species, had higher content of Ca^{2+} in the Reference site and there was a significant difference between the sites, especially for *A. abyssinicus. N. macrocalyx* had the highest content (9 - 12 mg/g) in both sites, while *A. abyssinicus* (5 - 10 mg/g) and *P. fractinervata* (6 - 9 mg/g) had almost equal contents with slight differences. Both *A. abyssinicus* and *N. macrocalyx* had slightly higher content of Mg^{2+} in the Reference (2 - 4.5 and 2 - 3 mg/g, respectively) while *P. fractinervata* had slightly higher content (3.6 -3.4 mg/g) in the Test site. Both *N. macrocalyx* and *P. fractinervata* had almost equal contents of Na^+ in the two sites,although the former had the highest (0.54 - 0.56 and 0.75 - 0.77 mg/g respectively) but *A. abyssinicus* had a signicant difference (0.5 - 0.7 mg/g) the higher being for the Test site unlike the other two species.

There was a remarkable difference in the content of Ca^{2+} in the two sites, whereby it was far much higher in the reference than in the test site. The humus layer had the highest content, then A-horizon and B-horizon had the lowest in the reference (17, 8 and 3 mg/g for the humus, A-and B- horizons respectively). In the test site, the values were quite low comparatively (5, 1 and 2 mg/g respectively for the soil layers above).

The content of K^+, Mg^{2+} and Na^+ had a similar trend in the two sites where, humus had the lowest and A-horizon the highest, but slightly higher contents occurred in the test site (0.15, 0.42 and 0.35 mg/g, respectively for the humus, A- and B- horizons) and in the reference (0.10, 0.37 and 0.33 mg/g for the respective layers as above). The results show higher content of these four elements in the plant tissue than found in the soil.

Manganese (Mn), Aluminum (Al) and Iron (Fe) all of which are classified as heavy metals (Shaw 1990), were present in relatively higher concentrations in both sites. *P. fractinervata* and *A. abyssinicus* had higher content of Mn (2.3 - 0.6 and 0.2 - 0.8 mg/g respectively), the former higher content in the Test and the later in the Reference site. The site difference was more significant in these species than in *P. fractinervata* which had 0.3 - 0.2 mg/g, in the Test and Reference site respectively. *P. fractinervata* and *N. macrocalyx* had more content of Al in the Test (0.55 - 0.52 and 0.25 - 0.20 mg/g respectively), than in the Reference which was a reverse for *A. abyssinicus,* which had more in the Reference site (0.18 - 0.25 mg/g). All the three species had higher content of Fe in the Reference than in the Test site. However, it was *A. abyssinicus* that showed a significant difference between the sites but the other two did not (0.15 - 0.3, 0.21 - 0.24 and 0.23 - 0.26 mg/g respectively for *A. abyssinicus, N. macrocalyx* and *P. fractinervata* in the Test and Reference sites).

The content of Mn is higher in the soil in the Reference and Fe in the Test site but the content of these two nutrients was contrary in the plant tissue. They all had higher content of Mn in the Test and Fe in the Reference site, suggesting the existence of special adaptation mechanism to control the absorption of the various elements according to their physiological requirements. *P. fractinervata* appears to be an accumulator for Mn and *A. abyssinicus* for Fe. Both *N. macrocalyx* and *P. fractinervata* did not show much difference in the Al content between the sites since they had higher content in the Test site where it was more in the soil, but *A. abyssinicus* had more in the Reference site. However *P. fractinervata* seems to be an accumulator for Al going by the higher content in both sites.

The higher content of these metals, especially Mn and Al is the main cause of the low soil pH and thus higher acidity in the two sites and especially in the Test site. Though the low soil pH could be more of geological background due to the weathering of the parent bedrock and the base cation effect, which could be deduced from the fact that, their content is higher in the A and B-horizons than in the Humus, the export of bio-mass out of the forest ecosystem, and hence loss of alkaline and alkaline earth elements has to be blamed for lack of protection cover to the soil.

These two heavy metals, are known to be toxic to plants at higher concentrations in the soil solution e.g. Al is known to displacing both Mg and Ca from the cortex cell wall, which in turn results into a chain of other reactions e.g. decreased CO_2 uptake due to decrease in chlorophyll etc (Godbold 1994). Tea (*Thea sinensis*), a main cash crop in Kenya and a known accumulators of Al ions, is grown in the forest neighbourhood of the study area. Other crops growing there includes Maize (*Zea mays*) and Potatoes (*Solanum tuberosum*), both of which are the main staple.food crops in the area as well as the whole of central Kenya.

(CHAPTER 6)

6.0. Conclusion and Recommendations

6.1. Conclusion

The research study have revealed that, any form of forest utilisation which involves harvesting or cutting of some trees, and therefore forming gaps in the forest canopy, will affect the species composition whether commercial or non-commercial, by creating micro-habitats favourable to particularly the pioneer species. However the effects of non-commercial are less severe as compared to commercial in terms of forest destruction and depletion of the resources.

Psychotria fractinervata was the most dominant and frequent species in the forest in terms of stem numbers and very good regeneration in both the Test and Reference site. It is a species which should be seen as of ecological importance in this forest.

The pioneer species i.e. *Neoboutonia macrocalyx, Macaranga kilimandscharica* and *Tabernamontana stapfiana* were found to be more frequent in the Test site plots. They are the gap fillers in this and other montane forests in central part of Kenya.

More species of trees were found in the Test than in the Reference, although more stems occurred in the Reference site plots.

Three rare and endangered species were also found in the forest i.e. *Polyacias kikuyensis, Prunus africana* and *Ochna ovata* and two species were found not to be regenerating in the forest i.e. *Allophylus abyssinicus* and *Aningeria adolfi-freiderecii.*

Charcoal burning was found to be the most destructive activity carried out in the forest. This results in loss of nutrients contained in the wood biomass, as well as destruction of the soil and the organic matter.

Extraction for timber is almost as equally destructive given the fact that it is focused on two species only i.e. *Ocotea usambarensis* and *Podocarpus latifolius.*

A total of 57 species of trees, shrubs and lianas were found occurring in the Kwaregi Beat of Uplands Forest. A few others could be found as well beyond the area covered by this study.

The nutrient status of the forest is depleted when bio-mass is taken out of the forest in form of timber, fuel-wood, fodder etc. because the wood exported out contains nutrients as well as the foliage

Tree species were found to have higher specific demand and/or stronger limitation to productivity by some elements e.g. *Allophylus abyssinicus* was seen as having such for Mg^{2+} and Fe^{+} ions, *Neoboutonia macrocalyx* for N, P and K^{+} and *Psychotria fractinervata* for S, Mn and Al.

The content of Nitrogen and Sulphur in both the plant tissue and soil, were found to have a corelation suggesting a similar relationship in the use of these two elements.

Neoboutonia macrocalyx, a fast growing pioneer tree species and and the results showed it to have specific demand for Nitrogen, is a good candidate for the agroforestry systems. It does not have dense shedding effects and with pruning can provide a good source of Nitrogen to the soil/food crops and also can serve the function of windbreak in agricultural fields.

The higher content of Mn, Al and Fe ions in the soil are the major cause of the low ph i.e. acidic conditions especially in the test site.

6.2. Recommendations

A combination of strategies such as In-situ conservation and Enrichment planting can be put in place to maintain and even increase the population of the above three mentioned rare and endangered species plus the two other which are not regenerating in the forest.

Any form of harvesting of resources from this and other forests should be sensitive to conservation of species diversity e.g. substitution of species like *Ochna ovata* and *Teclea nobilis* can be substituted with *Xymalos monospora* which is often multi-stemed and can make tool handles of equally good form as the two species. This will be done as a form of pruning the extra stems and leaving the main one to continue growing instead of removing the often single-stemed *O. ovata* or *T. nobilis.*

The forest neighbouring community should make diversification in their use of the forest resources, they can subsititute *Allophylus abbyssinicus,* which is not regenerating with other species e.g. *Tabernamontana stapfiana* etc, which does not have such a problem and maybe can make charcoal of equally high quality and also make more use of the tree resources out of the forest estate.

Charcoal burning result into complete destruction and therefore loss of nutrients from the forest ecosystem because of the process of carbonization of the wood into charcoal. It also deprives the soil of the decomposing organic matter as well as destroying the micro-organisms e.g. fungi and bacteria which are important for the process of decomposition and hence recycling of nutrients.

In order to conserve the nutrients in the forest ecosystem, it is necessary to de-bark the trees as well as de-limbing in the forest because these are the parts with high contents of nutrients and if they are left to decompose in the forest, the recycling will not be most affected by what is taken out of the forest.

In areas where there is real depletion and hence lack of nutrients due to exportation in form of bio-mass, it is necessary to apply Ash, Organic or Mineral fertilizer to replenish the lost nutrients and this will ensure continued productivity of the forest.

However, legal use of the forest resources is highly recommended and this will ensure a source of income to the Forest Department as well as continued services to the community by the forest. The people should consider themselves as the beneficiaries from the forest and take a protective stand instead of the current destructive one.

The continued existence and conservation of this forest should be viewed as beneficial to both the forest neighbouring community as well as the Forest Department, who are the custodian of the forest resources due to the importance of the bio-diversity contained therein and other services provided by the forest especially to the local community.

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Appedix 1a.

Plot UD01 Trees/shrubs

Species / Quadrat No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Totals
Psychotria fractineruata	4	2	2	1	1	1	2	5	1	2	1	1	2	1	2	1	5	2	3	0	2	4	1	1	0	47
Neoboutonia macrocalyx	0	0	1	0	1	1	0	1	0	1	0	0	0	2	0	8	1	0	2	2	6	2	0	0	5	33
Allophyllus abyssinicus	3	0	1	1	0	2	3	0	3	3	2	0	1	1	0	3	2	1	0	1	0	0	0	3	0	30
Lepidotrichilia volkensii	0	0	0	0	0	0	2	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	6
Clausena anisata	0	0	0	0	0	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Macaranga kilimandscharica	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	4
Nuxia cogesta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	4
Prunus africana	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	3
Polyacias kikuyuensis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Dovyalis abyssinica	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Dracaena afromontana	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Rapanea melanophloeos	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	3
Xymalos monospora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
Tabernamontana stapfiana	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lobelia gibberoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Pauridiantha holstii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Totals per quadrat	8	2	5	3	2	4	9	7	5	8	5	3	6	4	5	13	9	4	7	4	9	7	4	4	6	**145**

Appedix 1b
Plot UD01 Trees & Shrubs

Species Name	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Psychotria fractineruata	23	0,242	-0,616	-0,149	0,05861
Neoboutonia macrocalyx	13	0,137	-0,864	-0,118	0,01873
Allophyllus abyssinicus	15	0,158	-0,802	-0,127	0,02493
Lepidotrichilia volkensii	12	0,126	-0,899	-0,114	0,01596
Clausena anisata	3	0,032	-1,501	-0,047	0,00100
Macaranga kilimandscharica	11	0,116	-0,936	-0,108	0,01341
Nuxia cogesta	2	0,021	-1,677	-0,035	0,00044
Prunus africana	3	0,032	-1,501	-0,047	0,00100
Polyacias kikuyuensis	2	0,021	-1,677	-0,035	0,00044
Dovyalis abyssinica	2	0,021	-1,677	-0,035	0,00044
Dracaena afromontana	2	0,021	-1,677	-0,035	0,00044
Rapanea melanophloeos	2	0,021	-1,677	-0,035	0,00044
Xymalos monospora	2	0,021	-1,677	-0,035	0,00044
Tabernamontana stapfiana	1	0,011	-1,978	-0,021	0,00011
Lobelia gibberoa	1	0,011	-1,978	-0,021	0,00011
Pauridiantha holstii	1	0,011	-1,978	-0,021	0,00011
Total	**95**			**-0,985**	**0,13662**

Appedix 1c

Plot UD01 Sd. & Sp.

Species name / Quadrat No.	1		5		7		9		13		17		19		21		25		Total	
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	52	18	106	38	38	9	87	11	22	13	35	21	116	57	28	19	45	13	529	199
Clausena anisata	12	4	12	1	14	6	15	3	10	4	7	8	9	2	21	3	3	1	103	32
Polyacias kikuyuensis	33	9	13	4	12	0	4	3	8	6	5	4	8	3	2	0	4	0	89	29
Neoboutonia macrocalyx	8	0	0	0	0	0	1	2	0	0	22	9	1	2	5	12	5	8	42	33
Canthium oligocarpum	6	2	4	0	0	0	4	6	0	0	1	2	7	3	6	4	0	0	28	17
Macaranga kilimandscharica	0	0	6	0	0	0	8	9	0	0	5	3	0	0	4	3	0	0	23	15
Scutia mrytina	6	8	3	0	0	0	5	2	0	0	1	6	0	0	0	0	0	0	15	16
Prunus africana	3	0	5	0	0	0	0	0	0	0	0	0	3	1	0	1	0	2	11	4
Rapanea melanophloeos	0	0	0	0	0	1	2	1	1	2	0	0	5	2	0	0	0	0	8	6
Tabernamontana stapfiana	0	0	0	0	0	0	1	0	2	1	0	1	2	4	0	0	2	0	7	6
Xymalos monospora	0	0	0	0	0	0	0	0	2	0	0	0	3	1	0	0	0	0	5	1
Todallia asiatica	0	0	0	0	0	0	4	6	0	0	0	0	0	0	0	0	0	0	4	6
Dracaena afromontana	0	0	0	0	1	0	0	0	1	0	0	0	2	0	0	0	0	0	4	1
Ochna spicata	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	1	7
Cola greenwayi	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Podocarpus latifolius	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Teclea nobilis	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	3
Solanum mauritianum	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
TOTALS	120	41	149	43	66	24	133	43	46	26	76	54	156	80	66	42	59	24	871	377

Plot UD02 Trees & Shrubs

Appedix 2a
Plot UD02 Trees & Shrubs

Species name/ Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Psychotriafractinervata	3	0	0	1	1	0	0	5	4	5	3	0	4	5	2	1	0	1	0	1	0	1	0	0	0	40
Allophylus abyssinicus	2	0	0	2	1	0	1	3	4	1	1	0	2	1	2	1	1	0	2	0	2	1	0	1	0	28
Neoboutonia macrocalyx	2	1	1	0	0	2	1	0	0	0	0	3	0	0	2	0	0	0	0	3	1	0	0	0	1	20
Galiniera coffeoides	2	0	0	3	2	0	0	2	0	1	0	1	0	1	1	0	0	0	0	0	3	0	0	0	1	18
Macaranga kilimandscharica	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	2	1	0	0	0	0	0	0	0	1	7
Dombeya goetzenii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	4
Pterolobium stellatum	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	3
Rapanea melanophloeos	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Polyacias kikuyuensis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Dovyalis abyssinicus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Clausena anisata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Toddalia asiatica	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Casearia battiscombei	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Lobelia gibberoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Solanum mauritianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Total per quadrat	12	2	2	7	5	2	2	10	10	7	4	5	8	7	7	4	3	2	3	4	6	3	2	3	4	**132**

Appedix 2b
Plot UD02 Trees & Shrubs

Species name/ Quadrat No.	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Psychotriafractinervata	14	0,203	-0,693	-0,141	0,04117
Allophylus abyssinicus	17	0,233	-0,633	-0,147	0,05423
Neoboutonia macrocalyx	10	0,137	-0,863	-0,118	0,01877
Galiniera coffeoides	10	0,137	-0,863	-0,118	0,01877
Macaranga kilimandscharica	6	0,082	-1,085	-0,089	0,00676
Dombeya goetzenii	3	0,041	-1,386	-0,057	0,00169
Pterolobium stellatum	3	0,041	-1,386	-0,057	0,00169
Rapanea melanophloeos	2	0,027	-1,562	-0,043	0,00075
Polyacias kikuyuensis	2	0,027	-1,562	-0,043	0,00075
Dovyalis abyssinicus	1	0,014	-1,863	-0,026	0,00019
Clausena anisata	1	0,014	-1,863	-0,026	0,00019
Toddalia asiatica	1	0,014	-1,863	-0,026	0,00019
Casearia battiscombei	1	0,014	-1,863	-0,026	0,00019
Lobelia gibberoa	1	0,014	-1,863	-0,026	0,00019
Solanum mauritianum	1	0,014	-1,863	-0,026	0,00019
Total per quadrat	**73**			**-0,966**	**0,14569**

Appedix 2c: UD02 Sd.& Sp.

Species name	Quadrat Nos.																		Total	
	1		5		7		9		13		17		19		21		25			
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	75	27	185	37	199	30	173	34	164	15	106	17	133	30	103	29	173	62	1311	281
Polyacias kikuyensis	7	2	14	2	8	3	14	5	45	3	4	1	6	1	11	3	5	2	114	22
Clausena anisata	21	5	0	0	3	2	5	0	0	0	2	0	8	3	9	2	0	0	48	12
Neoboutonia macrocalyx	2	3	6	2	1	0	0	0	3	1	0	0	0	0	6	4	8	6	26	16
Rapanea melanophloeos	7	4	0	0	4	1	0	1	1	1	0	0	3	1	0	0	0	0	15	8
Macaranga kilimandscharica	1	0	2	0	1	1	0	1	4	1	3	2	0	2	0	0	2	1	13	8
Canthium oligocarpum	0	0	4	0	3	1	6	2	0	0	0	0	0	0	0	0	0	0	13	3
Teclea nobilis	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3
Scutia myrtina	0	0	0	0	4	0	3	0	0	0	0	0	0	0	0	0	0	0	7	0
Dracaena afromontana	0	0	0	0	0	0	0	0	0	0	3	3	2	1	0	0	0	0	5	4
Solanum mauritianum	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	5	0
Toddalia asiatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	3	1
Lobelia gibberoa	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	2	3
Crotolaria natalitia	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	2	2
Tabernamontana stapfiana	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
Lepidotrichilia volkensii	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
Xymalos monospora	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Dombeya goetzenii	0	0	0	8	0	1	0	0	0	0	1	7	0	0	0	1	0	1	1	18
Ochna ovata	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	5
Podocarpus latifolius	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
Total number per Quadrat	**123**	**45**	**211**	**50**	**223**	**39**	**201**	**45**	**219**	**25**	**125**	**32**	**152**	**39**	**133**	**39**	**192**	**75**	**1579**	**389**

Appedix 3a
Plot UD03 Trees and shrubs

Species name/Quadrat.Nos	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Psychotria fractinervata	8	4	1	1	0	0	0	2	3	0	4	1	0	5	1	1	2	1	3	3	1	3	4	4	3	55
Neoboutonia macrocalyx	0	0	2	7	17	1	1	2	0	1	0	0	2	0	1	0	0	0	0	0	2	0	2	0	0	38
Allophylus abyssinicus	2	5	0	1	0	0	1	0	4	1	1	0	0	0	0	0	2	1	1	2	2	1	0	0	1	24
Macaranga kilimandscharica	0	1	0	0	0	2	0	1	2	0	1	2	0	1	0	0	2	0	1	0	1	0	0	3	1	18
Galiniera coffeoides	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	5
Solanum mauritianum	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3
Lobelia gibberoa	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3
Tabernamontana stapfiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	2
Prunus africana	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nuxia cogesta	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Peddiea fischeri	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Polyacias kikuyensis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Dombeya goetzenii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Rapanea melanophloeos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Casearia battiscombei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Cola greenwayi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Clausena anisata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total number per Quadrat	11	11	3	9	20	3	4	5	9	3	6	4	2	7	4	2	8	2	6	7	5	4	7	9	5	157

Appedix 3b
Plot UD03 Trees & Shrubs

Species name	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Psychotria fractinervata	14	0,179	-0,746	-0,134	0,03222
Neoboutonia macrocalyx	20	0,256	-0,591	-0,152	0,06575
Allophylus abyssinicus	1	0,013	-1,892	-0,024	0,00016
Macaranga kilimandscharica	12	0,154	-0,813	-0,125	0,02367
Galiniera coffeoides	1	0,013	-1,892	-0,024	0,00016
Solanum mauritianum	11	0,141	-0,851	-0,120	0,01989
Lobelia gibberoa	2	0,026	-1,591	-0,041	0,00066
Tabernamontana stapfiana	3	0,038	-1,415	-0,054	0,00148
Prunus africana	1	0,013	-1,892	-0,024	0,00016
Nuxia cogesta	5	0,064	-1,193	-0,076	0,00411
Peddiea fischeri	1	0,013	-1,892	-0,024	0,00016
Polyacias kikuyensis	1	0,013	-1,892	-0,024	0,00016
Dombeya goetzenii	2	0,026	-1,591	-0,041	0,00066
Rapanea melanophloeos	1	0,013	-1,892	-0,024	0,00016
Casearia battiscombei	1	0,013	-1,892	-0,024	0,00016
Cola greenwayi	1	0,013	-1,892	-0,024	0,00016
Clausena anisata	1	0,013	-1,892	-0,024	0,00016
Total	**78**			**-0,961**	**0,14990**

Appedix 3c: UD03 Sd.& Sp.

Species name	Quadrat Nos.																		Total	
	1		5		7		9		13		17		19		21		25			
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	167	29	72	13	306	51	368	56	376	82	167	70	172	56	181	38	249	47	2058	442
Polyacias kikuyensis	18	2	6	3	2	3	3	2	8	2	8	2	6	0	15	6	7	1	73	21
Clausena anisata	17	1	1	1	3	2	4	0	5	3	0	0	6	3	1	1	5	1	42	12
Neobotonia macrocalyx	0	0	4	37	4	5	0	0	0	0	5	2	7	1	4	1	1	1	25	47
Lobelia gibberoa	0	0	14	7	1	0	0	0	1	1	4	2	0	0	0	0	0	0	20	10
Macaranga kilimandscharica	0	0	5	4	3	0	0	0	1	2	4	0	0	0	0	1	2	1	15	8
Dombeya goetzenii	0	0	4	1	0	0	0	0	0	0	0	0	0	0	3	4	0	0	7	5
Tabernamontana stapfiana	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	3	8	6	11
Scutia myrtina	2	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	5	0
Canthium oligocarpum	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	4	1
Prunus africana	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	4	0
Podocarpus latifolius	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	3	1
Solanum mauritianum	0	0	2	9	0	4	0	0	0	0	0	0	0	0	0	0	0	0	2	13
Rapanea melanophloeos	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	2	1
Ochna ovata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total number per Quadrat	**206**	**32**	**108**	**75**	**320**	**67**	**375**	**58**	**394**	**90**	**190**	**76**	**197**	**64**	**207**	**51**	**269**	**60**	**2266**	**573**

Appedix 4a
PLOT UD04 / Trees&shrubs

Species name / Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Psychotria fractinervata	4	3	2	6	1	3	3	0	1	0	0	2	2	3	2	3	2	2	1	6	1	1	3	4	6	60
Neoboutonia macrocalyx	1	1	3	1	1	2	5	0	1	0	0	0	0	1	1	6	0	0	1	0	2	3	1	2	2	34
Allophylus abyssinicus	0	1	1	0	0	0	1	1	0	0	0	1	3	1	0	3	2	3	0	1	0	0	1	3	3	25
Solanum mauritianum	0	0	0	0	2	0	0	0	0	7	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	12
Macaranga kilimandscharica	0	0	0	2	1	0	0	1	0	2	1	0	0	1	0	0	1	0	0	0	1	1	0	0	0	11
Lobelia gibberoa	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2	0	0	0	0	1	0	0	1	0	0	6
Tabernamontana stapfiana	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	2	5
Maesa lanceolata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Canthium oligocarpum	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Rapanea melanophloeos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Xymalos monospora	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Cassia occidentalis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nuxia cogesta	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Solanacea / Lycium spp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Clausena anisata	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Dracaena afromontana	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Galiniera coffeoides	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Podocarpus latifolius	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Polyacias kikuyensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Casearia battiscombei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Dombeya goetzenii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total number per Quadrat	5	5	6	9	7	5	12	2	4	8	2	5	6	8	9	13	6	5	3	9	4	5	6	11	15	171

Appedix 4b
Plot UD04 Trees & Shrubs

Species name	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Psychotria fractinervata	22	0,242	-0,617	-0,149	0,05845
Neoboutonia macrocalyx	17	0,187	-0,729	-0,136	0,03490
Allophylus abyssinicus	14	0,154	-0,813	-0,125	0,02367
Solanum mauritianum	3	0,033	-1,482	-0,049	0,00109
Macaranga kilimandscharica	8	0,088	-1,056	-0,093	0,00773
Lobelia gibberoa	5	0,055	-1,260	-0,069	0,00302
Tabernamontana stapfiana	4	0,044	-1,357	-0,060	0,00193
Maesa lanceolata	2	0,022	-1,658	-0,036	0,00048
Canthium oligocarpum	2	0,022	-1,658	-0,036	0,00048
Rapanea melanophloeos	1	0,011	-1,959	-0,022	0,00012
Xymalos monospora	2	0,022	-1,658	-0,036	0,00048
Cassia occidentalis	1	0,011	-1,959	-0,022	0,00012
Nuxia cogesta	2	0,022	-1,658	-0,036	0,00048
Solanacea / Lycium spp.	1	0,011	-1,959	-0,022	0,00012
Clausena anisata	1	0,011	-1,959	-0,022	0,00012
Dracaena afromontana	1	0,011	-1,959	-0,022	0,00012
Galiniera coffeoides	1	0,011	-1,959	-0,022	0,00012
Podocarpus latifolius	1	0,011	-1,959	-0,022	0,00012
Polyacias kikuyensis	1	0,011	-1,959	-0,022	0,00012
Casearia battiscombei	1	0,011	-1,959	-0,022	0,00012
Dombeya goetzenii	1	0,011	-1,959	-0,022	0,00012
Total	**91**			**-0,956**	**0,13344**

Appedix 4c: UD04 Sd.& Sp.

Species name	Quadrat Nos.																		Total	
	1		5		7		9		13		17		19		21		25			
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	57	28	28	5	103	32	88	23	168	78	112	27	92	12	112	35	126	35	886	275
Polyacias kikuyensis	17	0	11	0	11	2	8	0	5	0	8	1	0	1	6	1	15	3	81	8
Clausena anisata	5	0	12	0	9	1	7	0	11	1	0	0	7	0	4	1	8	2	63	5
Scutia myrtina	9	1	7	0	3	0	4	0	3	1	0	0	4	0	3	0	1	2	34	4
Rapanea melanophloeos	2	0	0	0	6	0	2	0	6	0	2	1	4	1	9	0	3	1	34	3
Macaranga kilimandscharica	0	0	6	1	0	0	4	2	6	5	3	1	0	0	2	1	3	0	24	10
Dracaena afromontana	2	0	0	0	6	0	0	3	1	0	4	1	0	0	0	0	9	4	22	8
Canthium oligocarpum	5	0	2	0	0	0	3	1	5	0	2	1	0	0	0	0	3	0	20	2
Dombeya goetzenii	0	1	0	4	1	0	11	0	2	1	0	0	0	0	5	5	0	0	19	11
Solanum mauritianum	0	3	3	1	1	1	3	7	1	4	5	1	0	0	0	0	4	0	17	17
Neoboutonia macrocalyx	0	0	8	5	0	1	0	3	0	1	0	0	0	2	6	2	0	1	14	15
Crotolaria natalitia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	2	0	0	13	2
Prunus africana	4	0	0	0	3	4	0	0	0	0	0	1	0	0	2	1	1	0	10	6
Tabernamontana stapfiana	0	0	4	1	0	0	0	0	0	0	0	1	0	0	1	0	0	3	5	5
Ochna ovata	0	0	2	0	0	0	0	0	0	2	2	0	1	0	0	0	0	1	5	3
Lobelia gibberoa	0	0	1	3	0	0	0	0	0	0	0	0	1	0	0	0	1	0	3	3
Teclea nobilis	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1
Galiniera coffeoides	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Allophylus abyssinicus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Total number per Quadrat	**101**	**33**	**84**	**20**	**143**	**41**	**130**	**39**	**208**	**93**	**140**	**37**	**109**	**16**	**163**	**48**	**174**	**52**	**1252**	**379**

Appedix 5a

PLOT UD05 / Trees & Shrubs

Species name / Quadrat No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Canthium oligocarpum	1	1	1	5	4	2	2	1	4	2	1	1	2	0	3	1	2	3	1	2	2	3	3	3	2	52
Galiniera coffeoides	5	2	3	7	3	2	1	4	3	2	4	1	1	0	3	1	0	0	0	0	1	1	3	0	1	48
Psychotria fractinervata	2	3	2	1	2	4	2	0	1	1	1	1	1	0	4	2	1	4	2	3	1	3	0	2	4	47
Syzygium guinense	2	2	4	0	2	0	1	5	1	2	2	0	0	1	1	0	2	0	0	1	0	1	0	1	2	30
Drypetes gerradii	0	1	1	0	3	1	2	1	1	0	1	4	1	1	1	1	2	1	0	0	3	1	0	1	0	27
Macaranga kilimandscharica	0	0	1	2	0	0	0	1	1	0	1	0	2	9	0	1	0	2	1	1	0	0	0	0	0	22
Podocarpus latifolius	0	0	0	3	1	1	0	1	2	1	1	1	0	2	3	0	1	0	0	0	0	2	1	2	1	23
Rapanea melanophloeos	1	1	1	2	1	2	0	2	1	0	0	0	1	0	2	1	0	2	0	1	0	0	0	2	0	20
Peddiea fischeri	0	0	1	0	0	0	0	0	1	1	2	1	1	1	1	0	0	0	0	1	2	1	1	0	0	14
Olea capensis	0	2	1	1	1	0	1	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	1	11
Tabernamontana stapfiana	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	2	0	1	0	1	1	0	1	9
Ocotea usambarensis	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	2	0	0	1	0	1	0	0	1	0	9
Dracaena afromontana	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	1	2	1	0	0	0	0	0	7
Allophylus abyssinicus	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	1	0	0	1	0	0	0	0	5
Nuxia cogesta	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	5
Xymalos monospora	0	0	0	2	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	5
Polyacias kikuyensis	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Ochna spicata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
Cola greenwayi	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Maytenus acuminata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lepidotrichilia volkensii	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Schefflera volkensii	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Neoboutonia macrocalyx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Clausena anisata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Total per Quadrat	12	13	17	23	20	12	9	16	18	10	17	12	10	23	19	10	11	18	11	12	12	15	12	12	12	357

Appedix 5b
Plot UD05 Trees & Shrubs

Species name	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Canthium oligocarpum	24	0,118	-0,929	-0,109	0,01384
Galiniera coffeoides	19	0,093	-1,031	-0,096	0,00867
Psychotria fractinervata	22	0,108	-0,967	-0,104	0,01163
Syzygium guinense	16	0,078	-1,106	-0,087	0,00615
Drypetes gerradii	18	0,088	-1,054	-0,093	0,00779
Macaranga kilimandscharica	11	0,054	-1,268	-0,068	0,00291
Podocarpus latifolius	15	0,074	-1,134	-0,083	0,00541
Rapanea melanophloeos	14	0,069	-1,164	-0,080	0,00471
Peddiea fischeri	12	0,059	-1,230	-0,072	0,00346
Olea capensis	9	0,044	-1,355	-0,060	0,00195
Tabernamontana stapfiana	8	0,039	-1,407	-0,055	0,00154
Ocotea usambarensis	8	0,039	-1,407	-0,055	0,00154
Dracaena afromontana	5	0,025	-1,611	-0,039	0,00060
Allophylus abyssinicus	4	0,020	-1,708	-0,033	0,00038
Nuxia cogesta	5	0,025	-1,611	-0,039	0,00060
Xymalos monospora	4	0,020	-1,708	-0,033	0,00038
Polyacias kikuyensis	2	0,010	-2,009	-0,020	0,00010
Ochna spicata	2	0,010	-2,009	-0,020	0,00010
Cola greenwayi	1	0,005	-2,310	-0,011	0,00002
Maytenus acuminata	1	0,005	-2,310	-0,011	0,00002
Lepidotrichilia volkensii	1	0,005	-2,310	-0,011	0,00002
Schefflera volkensii	1	0,005	-2,310	-0,011	0,00002
Neoboutonia macrocalyx	1	0,005	-2,310	-0,011	0,00002
Clausena anisata	1	0,005	-2,310	-0,011	0,00002
Total	**204**			**-1,129**	**0,07166**

Appedix 5c: UD05 Sd.&Sp.

Species name	Quadrat Nos.																		Total	
	1		5		7		9		13		17		19		21		25			
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	29	27	17	3	26	5	12	6	15	3	11	2	3	1	15	8	5	1	133	56
Galiniera coffeoides	8	15	8	14	13	17	5	19	12	17	11	28	9	11	3	8	6	13	75	142
Dracaena afromontana	0	0	2	0	0	0	1	1	6	0	13	5	16	5	2	0	3	2	43	13
Tabernamontana stapfiana	6	2	8	0	6	1	3	0	3	2	0	0	1	2	0	0	2	1	29	8
Xymalos monospora	1	5	4	2	2	1	3	0	1	2	2	0	0	3	6	0	9	2	28	15
Canthium oligocarpum	8	6	4	0	5	0	1	0	5	0	0	0	3	0	0	0	1	0	27	6
Podocarpus latifolius	0	0	3	1	5	1	2	0	5	2	0	1	0	0	3	0	2	1	20	6
Peddiea fischeri	1	2	2	1	4	2	1	0	2	2	4	1	2	0	2	0	1	3	19	11
Macaranga kilimandscharica	2	2	2	1	1	3	12	25	0	1	0	0	0	1	0	0	0	0	17	33
Teclea nobilis	1	2	3	0	0	0	1	0	1	1	1	0	3	1	2	1	2	0	14	5
Rapanea melanophloeos	1	1	4	1	1	0	2	0	2	0	0	0	1	0	2	0	0	0	13	2
Ochna ovata	1	1	2	0	0	1	0	0	0	1	1	0	2	1	2	0	0	1	8	5
Lobelia gibberoa	0	0	0	0	0	0	7	2	0	1	0	0	0	0	0	0	0	0	7	3
Neoboutonia macrocalyx	0	0	0	1	0	0	0	1	0	0	2	2	0	0	3	1	0	0	5	5
Polyacias kikuyensis	0	0	0	0	0	0	1	0	0	0	1	2	0	0	2	0	1	1	5	3
Scutia myrtina	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Ocotea usambarensis	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	0	2	2
Total number per Quadrat	**62**	**63**	**59**	**24**	**64**	**31**	**51**	**55**	**52**	**32**	**47**	**41**	**40**	**25**	**43**	**19**	**32**	**25**	**450**	**315**

PLOT DD01 /Trees & Shrubs

Appedix 6 a: Trees & Shrubs

Species name / Quadrat Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Psychotria fractinervata	0	1	1	2	1	2	3	0	0	0	0	1	1	0	2	4	5	2	1	1	1	0	4	1	1	34
Neoboutonia macrocalyx	5	0	1	4	2	1	4	0	2	2	0	0	0	1	0	4	1	0	0	1	0	1	1	0	3	31
Allophylus abyssinicus	0	0	0	0	1	1	1	0	0	0	1	0	0	1	1	0	1	2	1	0	3	0	1	0	1	13
Lepidotrichilia volkensii	0	3	0	1	0	0	1	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	8
Polyacias kikuyensis	0	1	0	2	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	7
Macaranga kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	1	0	1	0	0	4
Tabermontana stapfiana	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3
Xymalos monospora	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3
Rapanea melanophloeos	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	3
Dombeya goetzenii	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Scutia myrtina	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Pauridiantha holstii	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Oncoba routledgei	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Allophylus ferrugineus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Teclea nobilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Galiniera coffeoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Total per Quadrat	5	6	2	10	4	8	10	0	2	3	2	2	4	2	3	8	10	4	4	3	6	2	7	3	5	**115**

Appedix 6b : Trees & Shrubs

Species name	N.P.P	Pi	log Pi	Pi * Log Pi	Pi^2
Psychotria fractinervata	18	0,231	-0,637	-0,147	0,05325
Neoboutonia macrocalyx	15	0,192	-0,716	-0,138	0,03698
Allophylus abyssinicus	11	0,141	-0,851	-0,120	0,01989
Lepidotrichilia volkensii	8	0,103	-0,989	-0,101	0,01052
Polyacias kikuyensis	6	0,077	-1,114	-0,086	0,00592
Macaranga kilimandscharica	4	0,051	-1,290	-0,066	0,00263
Tabermontana stapfiana	2	0,026	-1,591	-0,041	0,00066
Xymalos monospora	2	0,026	-1,591	-0,041	0,00066
Rapanea melanophloeos	3	0,038	-1,415	-0,054	0,00148
Dombeya goetzenii	2	0,026	-1,591	-0,041	0,00066
Scutia myrtina	2	0,026	-1,591	-0,041	0,00066
Pauridiantha holstii	1	0,013	-1,892	-0,024	0,00016
Oncoba routledgei	1	0,013	-1,892	-0,024	0,00016
Allophylus ferrugineus	1	0,013	-1,892	-0,024	0,00016
Teclea nobilis	1	0,013	-1,892	-0,024	0,00016
Galiniera coffeoides	1	0,013	-1,892	-0,024	0,00016
Total	**78**			**-0,997**	**0,13412**

Appedix 6c : DD01 Sd. & Sp.

Species name	Quadrat Nos.																		Total	
	1		5		7		9		13		17		19		21		25			
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	0	0	21	15	0	0	9	13	10	18	15	6	5	3	23	12	33	25	116	92
Dombeya goetzenii	46	15	4	10	15	7	5	11	0	0	3	1	0	0	12	8	12	4	97	56
Neoboutonia macrocalyx	4	11	1	13	0	0	3	19	1	3	9	3	2	3	15	3	0	0	35	55
Polyacias kikuyensis	0	0	2	10	4	12	2	0	6	1	10	2	0	0	6	1	4	2	34	28
Tabernamontana stapfiana	12	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	9
Rapanea melanophloeos	0	0	2	0	0	0	0	0	0	0	0	0	1	2	3	1	3	1	9	4
Solanum mauritianum	3	4	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	3	8
Canthium oligocarpum	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
Prunus africana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0
Teclea nobilis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1
Xymalos monospora	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Crotalaria natalitia	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Total number per Quadrat	**67**	**46**	**30**	**48**	**20**	**21**	**19**	**43**	**17**	**26**	**37**	**12**	**8**	**8**	**59**	**25**	**55**	**32**	**312**	**261**

Appedix 7a : Trees & Shrubs

Species name/Quadrat Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Psychotria fractinervata	2	2	1	2	2	2	1	4	4	0	1	1	1	2	2	2	1	0	3	6	2	1	1	1	5	49
Neoboutonia macrocalyx	3	3	2	1	1	1	2	3	0	2	4	1	2	1	3	0	1	1	4	0	0	1	0	2	2	40
Macaranga kilimandscharica	3	1	2	1	1	2	1	0	1	0	0	3	1	1	2	0	1	0	0	0	1	0	0	0	1	22
Dracaena afromontana	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	1	0	0	1	1	0	0	7
Lepidotrichilia volkensii	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	6
Lobelia gibberoa	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	6
Allophylus abyssinicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	4
Polyacias kikuyensis	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Galiniera coffeoides	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3
Dombeya goetzenii	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Tabernamontana stapfiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	2
Clausena anisata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Aningeria aldof-fredrecii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Grevellia robusta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Teclea nobilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Ochna spicata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Olinia rochetiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Pauridiantha holstii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total number per Quadrat	8	6	6	7	4	6	6	8	10	2	5	5	8	4	9	5	3	3	9	6	4	10	2	7	8	152

Appedix 7b : Trees & Shrubs

Species name	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Psychotria fractinervata	23	0,264	-0,578	-0,153	0,06989
Neoboutonia macrocalyx	20	0,230	-0,638	-0,147	0,05285
Macaranga kilimandscharica	15	0,172	-0,763	-0,132	0,02973
Dracaena afromontana	6	0,069	-1,161	-0,080	0,00476
Lepidotrichilia volkensii	4	0,046	-1,337	-0,061	0,00211
Lobelia gibberoa	3	0,034	-1,462	-0,050	0,00119
Allophylus abyssinicus	2	0,023	-1,638	-0,038	0,00053
Polyacias kikuyensis	1	0,011	-1,940	-0,022	0,00013
Galiniera coffeoides	2	0,023	-1,638	-0,038	0,00053
Dombeya goetzenii	2	0,023	-1,638	-0,038	0,00053
Tabernamontana stapfiana	2	0,023	-1,638	-0,038	0,00053
Clausena anisata	1	0,011	-1,940	-0,022	0,00013
Aningeria aldof-fredrecii	1	0,011	-1,940	-0,022	0,00013
Grevellia robusta	1	0,011	-1,940	-0,022	0,00013
Teclea nobilis	1	0,011	-1,940	-0,022	0,00013
Ochna spicata	1	0,011	-1,940	-0,022	0,00013
Olinia rochetiana	1	0,011	-1,940	-0,022	0,00013
Pauridiantha holstii	1	0,011	-1,940	-0,022	0,00013
Total	**87**			**-0,930**	**0,16356**

Appedix 7c : DD02 Sd.& Sp.

Species name	Quadrat Nos.																		Total	
	1		5		7		9		13		17		19		21		25			
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	220	46	192	82	245	29	72	16	151	49	65	27	56	22	72	16	169	33	1242	320
Clausena anisata	11	6	11	3	4	3	6	4	6	5	4	2	14	7	5	3	16	2	77	35
Polyacias kikuyensis	12	3	2	9	1	3	3	5	4	3	2	0	4	1	0	0	4	0	32	24
Canthium oligocarpum	3	0	5	8	10	2	2	0	0	0	1	0	4	0	0	0	2	1	27	11
Macaranga kilimandscharica	1	1	1	0	0	1	0	0	0	0	8	11	1	1	0	1	0	0	11	15
Prunus africana	5	1	0	0	0	2	0	0	0	0	1	0	2	0	1	0	2	0	11	3
Dombeya goetzenii	4	6	0	2	3	14	0	0	0	0	1	8	0	1	2	6	0	0	10	37
Dracaena afromontana	0	0	0	0	0	0	0	0	4	1	0	3	3	4	3	1	0	8	10	17
Neoboutonia macrocalyx	3	9	0	0	0	0	0	6	0	0	2	6	0	0	3	9	0	0	8	30
Tabernamontana stapfiana	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	0	4	1	6	3
Solanum mauritianum	0	0	0	0	3	2	0	0	2	4	0	2	0	0	0	0	0	1	5	9
Ptelelobium stellatum	2	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	5	0
Lobelia gibberoa	0	0	1	2	1	1	2	6	0	0	0	0	0	1	0	0	0	0	4	10
Galiniera coffeoides	0	0	0	0	0	4	0	0	0	0	0	0	0	1	0	0	0	0	0	5
Ochna ovata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Teclea nobilis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Total number per Quadrat	**261**	**72**	**213**	**108**	**269**	**61**	**85**	**37**	**168**	**62**	**85**	**60**	**84**	**39**	**86**	**36**	**197**	**46**	**1448**	**521**

Appedix 8a : Trees & Shrubs

Species name/Quadrat Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Tabernamontana stapfiana	1	0	2	1	1	1	0	0	5	5	3	3	0	1	4	3	1	1	2	2	0	3	1	1	4	45
Psychotria fractinervata	2	4	1	1	2	0	1	3	0	2	0	3	2	2	0	3	1	4	0	2	4	4	0	1	0	42
Galiniera coffeoides	1	0	1	0	1	0	0	2	4	0	0	1	0	0	1	1	2	1	1	0	1	1	1	0	0	16
Dracaena afromontana	1	3	0	0	0	0	0	1	0	0	1	0	0	1	2	1	1	0	0	0	0	0	0	0	0	11
Neoboutonia macrocalyx	0	0	1	1	0	0	1	0	0	0	0	0	1	0	0	0	2	0	3	0	2	2	3	0	1	17
Allophylus abyssinicus	1	0	0	3	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	0	12
Rapanea melanophloeos	0	0	0	0	0	0	3	0	2	0	1	1	2	0	2	0	0	0	0	1	0	0	0	0	0	12
Macaranga kilimandscharica	0	1	0	0	0	1	0	1	1	3	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	10
Syzygium quinensee	0	0	0	0	2	0	2	0	0	1	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	9
Allophylus ferrugineus	1	0	0	1	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0	0	6
Xymalos monospora	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	2	0	6
Casearia battiscombei	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	1	0	1	1	0	0	0	0	6
Polyacias kikuyensis	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	5
Podocarpus latifolius	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	4
Solanum mauritianum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	4
Scutia myrtina	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4
Ocotea usambarensis	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
Lepidotrichilia volkensii	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
Croton macrostachys	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	3
Cola greenwayi	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Lobelia gibberoa	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Aningeria aldolfi-fredrecii	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total number per Quadrat	9	11	5	10	13	5	8	11	13	16	9	13	9	9	10	11	7	8	8	8	15	13	8	7	7	232

Appedix 8b : Trees & Shrubs

Species name/Quadrat Nos.	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Tabernamontana stapfiana	20	0,149	-0,826	-0,123	0,02228
Psychotria fractinervata	18	0,134	-0,872	-0,117	0,01804
Galiniera coffeoides	12	0,090	-1,048	-0,094	0,00802
Dracaena afromontana	8	0,060	-1,224	-0,073	0,00356
Neoboutonia macrocalyx	10		#ZAHL!	#ZAHL!	0,00000
Allophylus abyssinicus	10		#ZAHL!	#ZAHL!	0,00557
Rapanea melanophloeos		0,075	-1,127	#BEZUG!	#BEZUG!
Macaranga kilimandscharica	8	0,060	-1,224	-0,073	0,00356
Syzygium quinensee	5	0,037	-1,428	-0,053	0,00139
Allophylus ferrugineus	5	0,037	-1,428	-0,053	0,00139
Xymalos monospora	5	0,037	-1,428	-0,053	0,00139
Casearia battiscombei	5	0,037	-1,428	-0,053	0,00139
Polyacias kikuyensis	5	0,037	-1,428	-0,053	0,00139
Podocarpus latifolius	4	0,030	-1,525	-0,046	0,00089
Solanum mauritianum	3	0,022	-1,650	-0,037	0,00050
Scutia myrtina	3	0,022	-1,650	-0,037	0,00050
Ocotea usambarensis	3	0,022	-1,650	-0,037	0,00050
Lepidotrichilia volkensii	3	0,022	-1,650	-0,037	0,00050
Croton macrostachys	3	0,022	-1,650	-0,037	0,00050
Cola greenwayi	2	0,015	-1,826	-0,027	0,00022
Lobelia gibberoa	1	0,007	-2,127	-0,016	0,00006
Aningeria aldolfi-fredrecii	1	0,007	-2,127	-0,016	0,00006
Total number per Quadrat	**134**		#ZAHL!	**#ZAHL!**	**#BEZUG!**

Appedix 8c: DD03 Sd.&Sp.

Species name	Quadrat Nos.																		Total	
	1		5		7		9		13		17		19		21		25			
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	6	2	7	4	31	15	25	6	50	12	48	9	26	16	30	12	39	19	262	95
Tabernamontana stapfiana	16	2	5	1	18	13	8	4	7	0	13	14	4	3	9	3	2	3	82	43
Macaranga kilimandscharica	0	1	13	3	40	1	2	0	1	0	10	20	0	0	0	1	4	8	70	34
Neoboutonia macrocalyx	0	2	4	8	5	14	5	7	7	8	4	13	5	1	0	0	2	4	32	57
Solanum mauritianum	0	0	17	36	2	2	1	3	0	0	5	4	0	0	7	1	0	4	32	50
Clausena anisata	6	10	2	0	0	0	7	0	6	4	0	0	3	3	3	4	4	0	31	21
Canthium oligocarpum	3	2	2	0	6	3	0	0	2	2	2	6	8	0	3	4	1	0	27	17
Galiniera coffeoides	0	3	1	4	2	8	0	1	3	4	4	6	3	5	0	2	11	4	24	37
Ochna ovata	2	6	2	4	2	4	2	4	2	3	1	4	4	1	0	4	1	0	16	30
Prunus africana	12	2	0	1	1	0	1	0	0	0	0	1	0	0	0	1	0	0	14	5
Podocarpus latifolius	1	1	0	0	2	0	1	0	0	1	1	0	0	1	2	0	0	1	7	4
Bersama abyssinica	2	0	0	0	1	1	0	0	2	0	0	1	0	0	1	0	0	0	6	2
Rapanea melanophloeos	0	0	0	0	0	0	0	1	2	0	0	0	2	0	0	0	0	0	4	1
Lobelia gibberoa	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	3	1	4	4
Scutia myrtina	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	1	1	2	4	4
Casaeria battiscombei	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4
Dracaena afromontana	0	0	0	2	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	7
Lepidotrichilia volkensii	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	7
Dombeya goetzenii	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Polyacias kikuyensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Total number per Quadrat	**51**	**35**	**53**	**64**	**110**	**61**	**52**	**26**	**82**	**34**	**89**	**89**	**55**	**35**	**58**	**33**	**68**	**48**	**618**	**425**

Appedix 9a : Trees & Shrubs

Species name/Quadrat Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Psychotria fractinervata	3	4	4	2	1	4	1	2	6	2	1	3	3	2	3	4	1	2	2	1	4	2	2	3	1	63
Dracaena afromontana	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	5
Neoboutonia macrocalyx	1	1	0	1	3	0	0	1	1	0	2	1	1	1	3	10	0	3	0	2	1	0	0	0	0	32
Tabernamontana stapfiana	0	0	2	2	1	0	1	0	0	3	2	1	0	1	0	1	1	1	1	1	0	0	2	2	0	22
Allophylus abyssinicus	1	1	0	1	1	1	2	0	1	0	2	0	0	1	0	0	1	2	0	0	1	3	2	0	0	20
Macaranga kilimandscharica	0	0	0	0	3	0	0	0	2	1	0	0	0	0	0	0	1	0	0	0	0	4	2	0	2	15
Galiniera coffeoides	0	0	0	1	0	0	0	0	1	0	0	1	0	0	2	0	1	0	0	1	0	2	0	1	1	11
Rapanea melanoploeos	0	0	1	1	1	1	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	1	1	10
Xymalos monospora	1	1	0	2	0	2	2	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Podocarpus latifolius	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Nuxia cogesta	0	0	0	0	0	0	0	2	1	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	6
Prunus africana	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5
Polyacias kikuyensis	0	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	5
Syzygium quinensee	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Drypetes gerradii	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	0	0	0	0	0	4
Peddiea fischeri	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	3
Schefflera volkensii	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Lepidotrichilia volkensii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	3
Ochna spicata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Dalbergia lactea	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Aningeria aldolfi-fredericii	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Maytenus acuminata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cola greenwayi	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Clausena anisata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Casearia battiscombei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Total number per Quadrat	7	10	13	12	11	12	10	6	14	9	9	9	5	10	12	16	6	9	6	10	7	11	8	11	7	240

Appedix 9b : Trees & shrubs

Species name	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Psychotria fractinervata	25	0,174	-0,760	-0,132	0,03014
Dracaena afromontana	3	0,021	-1,681	-0,035	0,00043
Neoboutonia macrocalyx	15	0,104	-0,982	-0,102	0,01085
Tabernamontana stafiana	15	0,104	-0,982	-0,102	0,01085
Allophylus abyssinicus	14	0,097	-1,012	-0,098	0,00945
Macaranga kilimandscharica	7	0,049	-1,313	-0,064	0,00236
Galiniera coffeoides	9	0,063	-1,204	-0,075	0,00391
Rapanea melanoploeos	8	0,056	-1,255	-0,070	0,00309
Xymalos monospora	7	0,049	-1,313	-0,064	0,00236
Podocarpus latifolius	3	0,021	-1,681	-0,035	0,00043
Nuxia cogesta	5	0,035	-1,459	-0,051	0,00121
Prunus africana	4	0,028	-1,556	-0,043	0,00077
Polyacias kikuyensis	5	0,035	-1,459	-0,051	0,00121
Syzygium quinensee	2	0,014	-1,857	-0,026	0,00019
Drypetes gerradii	3	0,021	-1,681	-0,035	0,00043
Peddiea fischeri	3	0,021	-1,681	-0,035	0,00043
Schefflera volkensii	3	0,021	-1,681	-0,035	0,00043
Lepidotrichilia volkensii	3	0,021	-1,681	-0,035	0,00043
Ochna spicata	2	0,014	-1,857	-0,026	0,00019
Dalbergia lactea	2	0,014	-1,857	-0,026	0,00019
Aningeria aldolfi-fredericii	1	0,007	-2,158	-0,015	0,00005
Maytenus acuminata	1	0,010	-2,004	-0,020	0,00010
Cola greenwayi	2	0,014	-1,857	-0,026	0,00019
Clausena anisata	1	0,007	-2,158	-0,015	0,00005
Casearia battiscombei	1	0,007	-2,158	-0,015	0,00005
Total	**144**			**-1,053**	**0,07856**

Appedix 9c : DD04 Sd.&Sp.

Species name	Quadrat Nos.																		Total	
	1		5		7		9		13		17		19		21		25			
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	33	15	25	13	0	0	21	7	9	2	14	5	9	4	6	3	12	2	129	51
Dracaena afromontana	7	1	2	2	3	2	2	9	2	2	2	0	2	1	8	3	7	5	35	25
Neoboutonia macrocalyx	3	1	15	4	0	0	0	0	0	0	6	2	0	0	3	3	0	1	27	11
Macaranga kilimandscharica	0	0	2	7	0	0	0	0	11	1	9	2	1	0	0	0	2	0	25	10
Podocarpus latifolius	2	1	2	0	4	1	10	3	4	1	0	0	2	0	0	0	0	0	24	6
Galiniera coffeoides	0	0	3	1	1	1	5	1	6	4	2	2	1	2	3	1	2	0	23	12
Canthium oligocarpum	1	0	5	3	2	0	8	0	4	0	0	0	2	0	0	1	0	0	22	4
Tabernamontana stapfiana	0	0	0	0	0	0	6	2	0	0	12	3	2	0	0	0	1	2	21	7
Rapanea melanophloeos	3	0	5	2	2	1	3	0	2	0	1	0	0	0	1	0	0	0	17	3
Solanum mauritianum	0	0	0	0	1	0	0	0	4	0	11	3	0	0	0	0	1	1	17	4
Ochna ovata	5	1	2	1	1	0	0	0	2	1	2	0	2	0	0	0	0	0	14	3
Teclea nobilis	3	3	8	5	0	0	0	0	0	0	0	0	1	2	0	0	1	0	13	10
Prunus africana	0	0	0	0	0	0	1	1	4	0	1	0	0	0	0	0	1	0	7	1
Peddiea fischeri	2	4	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	6	4
Cola greenwayi	2	2	0	0	4	1	0	0	0	0	0	0	0	1	0	0	0	0	6	4
Albizzia gummifera	0	0	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	6	0
Lobelia gibberoa	0	0	0	0	0	0	0	0	2	1	1	1	0	0	0	0	0	1	3	3
Polyacias kikuyensis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	3	0
Clausena anisata	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
Ocotea usambarensis	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Total number per Quadrat	**61**	**28**	**70**	**38**	**19**	**6**	**62**	**23**	**50**	**12**	**64**	**18**	**25**	**10**	**23**	**11**	**27**	**12**	**401**	**158**

PLOT DD05 / Trees & Shrubs

Appedix 10a : Trees & Shrubs

Species name / Quadrat Nos.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Psychotria fractinervata	3	6	4	3	0	1	8	0	1	2	1	1	0	2	0	4	0	0	2	0	2	0	0	0	1	41
Dracaena afromontana	0	0	0	0	1	0	0	2	2	2	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	11
Tabernamontana stapfiana	7	2	2	0	1	0	1	1	0	2	0	2	0	0	0	2	0	0	2	0	0	2	0	0	1	25
Neoboutonia macrocalyx	0	2	0	1	0	1	0	1	0	1	1	1	1	1	1	0	0	3	1	2	0	0	3	3	1	24
Macaranga kilimandscharica	0	1	0	0	0	1	0	0	5	0	1	1	0	0	0	0	2	0	0	0	0	1	0	1	0	13
Galiniera coffeoides	2	0	0	0	0	2	0	0	0	1	1	0	0	1	0	0	0	2	0	0	3	0	0	0	0	12
Allophylus abyssinicus	0	0	5	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1	0	10
Ocotea usambarensis	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	4
Xymalos monospora	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	3	1	0	0	9
Rapanea melanophloeos	1	0	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6
Syzygium guinensee	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	5
Peddiea fischeri	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	6
Drypetes gerradii	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	4
Canthium oligocarpum	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3
Polyacias kikuyensis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	3
Ekbergia capensis	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
Scheffleria abyssinica	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Ochna spicata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Podocarpus latifolius	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nuxia cogesta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2
Prunus africana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Lobelia gibberoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Solanum mauritianum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Crotalaria natalitia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Cola greenwayi	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Bersama abyssinica	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total numbers per Quadrat	28	19	15	16	6	14	11	5	9	13	8	8	7	11	4	12	5	9	8	2	11	6	4	5	4	188

Appedix 10b : Trees & Shrubs

Species name	N.P.P	Pi	log Pi	Pi * Log Pi	Pi²
Psychotria fractinervata	15	0,125	-0,903	-0,113	0,01563
Dracaena afromontana	8	0,067	-1,176	-0,078	0,00444
Tabernamontana stapfiana	12	0,100	-1,000	-0,100	0,01000
Neoboutonia macrocalyx	16	0,133	-0,875	-0,117	0,01778
Macaranga kilimandscharica	8	0,067	-1,176	-0,078	0,00444
Galiniera coffeoides	7	0,058	-1,234	-0,072	0,00340
Allophylus abyssinicus	6	0,050	-1,301	-0,065	0,00250
Ocotea usambarensis	4	0,033	-1,477	-0,049	0,00111
Xymalos monospora	7	0,058	-1,234	-0,072	0,00340
Rapanea melanophloeos	5	0,042	-1,380	-0,058	0,00174
Syzygium guinensee	5	0,042	-1,380	-0,058	0,00174
Peddiea fischeri	3	0,025	-1,602	-0,040	0,00063
Drypetes gerradii	4	0,033	-1,477	-0,049	0,00111
Canthium oligocarpum	3	0,025	-1,602	-0,040	0,00063
Polyacias kikuyensis	3	0,025	-1,602	-0,040	0,00063
Ekbergia capensis	3	0,025	-1,602	-0,040	0,00063
Scheffleria abyssinica	1	0,008	-2,079	-0,017	0,00007
Ochna spicata	1	0,008	-2,079	-0,017	0,00007
Podocarpus latifolius	1	0,008	-2,079	-0,017	0,00007
Nuxia cogesta	2	0,017	-1,778	-0,030	0,00028
Prunus africana	1	0,008	-2,079	-0,017	0,00007
Lobelia gibberoa	1	0,008	-2,079	-0,017	0,00007
Solanum mauritianum	1	0,008	-2,079	-0,017	0,00007
Crotalaria natalitia	1	0,008	-2,079	-0,017	0,00007
Cola greenwayi	1	0,008	-2,079	-0,017	0,00007
Bersama abyssinica	1	0,008	-2,079	-0,017	0,00007
Total	**120**			**-1,086**	**0,06986**

Appedix 10c: DD05 Sd.& Sp.

Species name	Quadrat Nos. 1		5		7		9		13		17		19		21		25		Total	
	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp	Sd	Sp
Psychotria fractinervata	4	1	19	5	1	0	7	5	10	4	18	9	15	7	12	3	25	9	111	43
Dracaena afromontana	7	1	12	4	4	11	11	5	14	7	9	5	6	8	0	0	0	0	63	41
Neoboutonia macrocalyx	7	1	6	3	10	4	3	4	13	2	13	0	7	2	0	0	3	4	62	20
Rapanea melanophloeos	12	0	0	0	5	1	5	0	4	0	0	0	2	1	9	1	8	0	45	3
Galiniera coffeoides	17	19	3	2	2	2	2	3	0	0	5	4	2	2	11	4	0	3	42	39
Macaranga kilimandscharica	8	0	18	7	0	0	4	7	1	0	0	0	0	0	0	0	0	0	31	14
Tabernamontana stapfiana	2	4	5	7	7	3	2	4	0	0	0	0	0	0	9	0	2	0	27	18
Dombeya goetzenii	0	0	0	0	0	0	0	2	27	3	0	0	0	0	0	2	0	0	27	7
Clausena anisata	3	0	0	0	2	0	1	1	3	1	3	0	2	0	6	2	1	1	22	5
Crotolaria natalitia	4	0	2	0	0	0	4	7	3	0	0	0	1	0	2	0	2	1	18	8
Polyacias kikuyensis	6	2	0	0	0	0	4	0	0	0	0	0	3	1	4	2	1	0	18	5
Podocarpus latifolius	8	1	5	2	4	0	0	0	0	0	0	0	0	0	1	0	0	0	18	3
Canthium oligocarpum	7	1	2	0	0	0	0	0	0	0	3	0	0	0	3	0	1	0	16	1
Xymalos monospora	1	0	0	0	0	0	0	0	0	0	10	3	0	1	4	0	0	0	15	4
Ochna ovata	6	1	0	1	0	0	0	0	0	0	1	0	1	0	4	1	0	1	12	4
Albizia gummifera	0	0	0	0	0	0	0	0	0	0	2	0	1	0	6	1	0	1	9	2
Solanum mauritianum	2	0	3	2	0	0	0	0	0	0	0	0	1	0	0	0	2	4	8	6
Ocotea usambarensis	0	1	3	10	0	0	1	1	0	0	0	0	1	1	1	0	0	0	6	13
Teclea nobilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	2	2
Scutia myrtina	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	2	1
Total number per Quadrat	**94**	**32**	**78**	**43**	**35**	**21**	**44**	**39**	**75**	**17**	**65**	**22**	**42**	**23**	**75**	**18**	**45**	**24**	**553**	**239**

Appendix 11

SPECIES LIST FOR UPLANDS FOREST, KWAREGI BEAT
Trees , Shrubs and Lianas

SPECIES NAME	FAMILY
Albizzia gummifera (JFGmel.) C.A.Sm.	Mimosaceae
Allophylus abyssinicus(Hochst.) Radlk.	Sapindaceae
Allophylus ferrugineus Taub	Sapindaceae
Aningeria aldolfi-friedericii(Engl.) Robyns&Gilb	Sapotaceae
Bersama abyssinica Fries	Melianthaceae
Canthium oligonocarpum Hiern ssp.friesiorum	Rubiaceae
Casaeria battiscombei R.E.Fries	Flacourticeae
Cassipourea malosana (Bak.) Alston	Rhizophoraceae
Cola greenwayi Brenan	Sterculaceae
Combretum peniculatum Vent.ssp.paniculatum	Combretaceae
Clausena anisata (Willd.) Benth.	Rutaceae
Clematis brachiata Thunb	Ranunculaceae
Clematis hirsuta Perr. & Guill.	Ranunculaceae
Clutia abyssinica Jaub.& Spach	Euphorbiaceae
Croton macrostachyus Del.	Euphorbiaceae
Crotolaria agastifolia Schweinf.	Papilionaceae
Crotolaria natalitia Meissn.	Papilionaceae
Dalbergia lactea Vatke	Papilionaceae
Deinbollia kilimandscharica Taub.	Sapindaceae
Dracaena afromontana Mildbr.	Dracaenaceae
Drypetes gerradii Hutch.	Euphorbiaceae
Dombeya goetzenii K. Schum	Sterculaceae
Dovyalis abyssinica (A.Rich.) Warb.	Flacourtiaceae
Ekbergia capensis Sparrm.	Meliaceae
Galiniera coffeoides Del.	Rubiaceae
Grevellia robusta	Proteaceae
Hippocratea africana (Willd.) Loes.	Celastraceae
Landolphia buchananii (Hall.f.) Stapf.	Apocynaceae
Lobelia gibberoa Hemsl.	Lobeliaceae
Lepidotrichilia volkensii (Guerke) Leroy	Meliaceae
Macaranga kilimandscharica Pax	Euphorbiaceae
Maesa lanceolata Forssk.	Myrsinaceae
Maytenus acuminata (L.f.) loes.	Celastraceae
Neoboutonia macrocalyx Pax	Euphorbiaceae
Nuxia cogesta Fres.	Loganaceae
Ochna ovata F.Hoffm.	Ochnaceae
Ocotea usambarensis Engl.	Lauraceae
Olea capensis L.	Oleaceae
Olinia rochetiana A. Juss	Oliniaceae
Oncoba routledgei Sprague	Flacourtiaceae
Pauridiantha holstii (K.Schum.) Brem.	Rubiaceae
Peddiea fischeri Engl.	Thymeleaceae
Podocarpus latifolius (Thunb.) Mirb	Podocarpaceae
Polyacious kikuyuensis Summerh.	Araliaceae

Psychotria fractinervata Petit	Rubiaceae
Prunus africana (Hook.f.) Kalkm.	Rosaceae
Ptelelobium stellatum (Forssk.) Brenan	Caesalpiniaceae
Rapanea melanophloeos (L.) Mez.	Myrsinaceae
Schefflera volkensii (Engl.) Harms	Araliaceae
Scutia myrtina (Burm.f.) Kurz	Rhamnaceae
Solanacea/lycium sp.? L.	Solanaceae
Solanum mauritianum Scop.	Solanaceae
Syzygium guinensee (Willd.) DC.	Myrtaceae
Tabernamontana stapfiana Britten	Apocynaceae
Teclea nobilis Del.	Rutaceae
Toddalia asiatica (L.) Lam.	Rutaceae
Xymalos monospora (Harv.) Warb.	Monimiaceae

Appedix 12: No. of species per area sampled

Area (m²)	Reference site plots.	Test site plots
0	0	0
1000	9	11
2000	14	15
3000	18	16
4000	21	17
5000	23	22
6000	24	26
7000	24	28
9000	28	35
10000	29	36
11000	33	38
12000	35	39
12500	36	40

Appedix 13

Jackknife estimate of species richness an richness variance

Plot 1	14,885	2,534
Plot 2	15,783	4,378
Plot 3	16,693	5,530
Plot 4	20,638	9,754
Plot 5	23,783	4,378
Plot 6	16,815	3,840
Plot 7	18,721	10,982
Plot 8	22,922	1,766
Plot 9	25,849	3,226
Plot 10	24,693	9,370
Region UD (first 5 plots):	33,815	3,840
Region DD (second 5 plots):	42,783	4,378
all quadrats	48,751	4,838
Formula no. In Krebs:	10.3 richness	10.4 variance

Appedix 14

Bootstrap estimate of species richness and richness variance

	sample size 10		sample size 20		sample size 50		sample size 100	
Plot 1	23,388	0,725	22,041	0,922				
Plot 2	23,664	1,031	22,015	0,899				
Plot 3	25,944	0,881	24,416	0,780				
Plot 4	28,958	0,857	27,778	0,552				
Plot 5	38,051	4,404	36,176	4,595				
Plot 6	26,190	1,139	24,908	0,869				
Plot 7	26,843	0,445	25,875	0,215				
Plot 8	34,433	1,743	32,253	1,174				
Plot 9	39,010	2,588	36,512	2,022				
Plot 10	42,412	2,079	39,914	2,195				
RF plots	53,788	3,389	49,835	3,659	44,100	2,253	40,896	1,177
TT plots	72,749	5,497	67,884	3,690	62,849	1,965	59,574	0,972
all plots	81,615	7,529	75,626	5,010	66,439	3,922	60,672	3,302

The bootstrap richness is the mean of 200 samples of the mentioned size.
The single bootstrap richness values are calculated by the formula (10.6) at page 339 in Krebs.
The richness variance is the variance of the 200 richness values.

Appendix 15: Soil pH					
Sample	Site	50ml.H2O	50 ml.HCL	Average	Range
KS 1 H-Fine	RF	5.12.	4.91.	5.0	0.6
KS 3	RF	5.48.	5.29.	5.4.	
KS 5	RF	5.65.	5.44.	5.6.	
KS 8	RF	5.05.	4.86.	5.0	
KS 2	TT	4.23.	3.96.	4.1.	0.3
KS 4	TT	4.55.	4.30.	4.4.	
KS 6	TT	4.43.	4.16.	4.3.	
KS 7	TT	4.53.	4.28.	4.4.	
KS 17 A-Fine	RF	5.84.	5.45.	5.7.	0.5
KS 19	RF	5.93.	5.66.	5.8.	
KS 21	RF	6.33.	6.00	6.2.	
KS 22	RF	5.95.	5.56.	5.8.	
KS 18	TT	4.45.	4.10.	4.3.	0.2
KS 20	TT	4.48.	4.14.	4.3.	
KS 23	TT	4.45.	4.10.	4.3.	
KS 24	TT	4.64.	4.28.	4.5.	
KS 17 A-coarse	RF	5.86.	5.44.	5.7.	0.5
KS 19	RF	5.95.	5.63.	5.8.	
KS 21	RF	6.33.	6.02.	6.2.	
KS 22	RF	5.93.	5.52.	5.7.	
KS 18	TT	4.36.	4.10.	4.2.	0.2
KS 20	TT	4.35.	4.07.	4.2.	
KS 23	TT	4.36.	4.10.	4.2.	
KS 24	TT	4.56.	4.26.	4.4.	
KS 10 B-Fine	RF	5.25.	4.72.	5.0	1.2.
KS 11	RF	5.44.	4.91.	5.2.	
KS 15	RF	5.88.	5.46.	5.7.	
KS 16	RF	6.35.	6.00	6.2.	
KS 9	TT	4.56.	4.07.	4.3.	0.2
KS 12	TT	4.67.	4.26.	4.5.	
KS 13	TT	4.44.	4.12.	4.3.	
KS 14	TT	4.48.	4.12.	4.3.	
KS 10 B-Coarse	RF	5.30.	4.70.	5.0.	1.2.
KS 11	RF	5.40.	4.90.	5.2.	
KS 15	RF	5.95.	5.47.	5.7.	
KS 16	RF	6.41.	6.03.	6.2.	
KS 9	TT	4.53.	4.08.	4.3.	0.1
KS 12	TT	4.57.	4.22.	4.4.	
KS 13	TT	4.42.	4.10.	4.3.	
KS 14	TT	4.48.	4.11.	4.3.	

DECLARATION

I **Simon Ndungu Wairungu** declare that the thesis entitled „ The effects of non-commercial utilisation of forest resources at Uplands, Kenya " is my original work based on the data I collected during the field research phase of the Master of science degree course in tropical forestry.

Apart from the literature sited in the document, I have done the rest under the guidance of my supervisors. It have never been presented to any other academic institution for an award of a degree or an other purpose.

Signature:

Date: 18/10/00