COMPARATIVE AUTECOLOGY OF SELECTED TREE SPECIES USING LEAF AND WOOD TRAITS WITHIN NINE FOREST FRAGMENTS OF THE TAITA HILLS

By

Felix Shikhuyu Abdalla

B.Sc. (Hons), University of Nairobi

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DECLARATION

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DEDICATION

To my beloved family Baraka and Mama Baraka, a new beginning for a blessed future.

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ABBREVIATIONS, ACRONYMS AND SYMBOLS

*	Significant at P = 0.05 (2 tailed)
**	Significant at P=0.01 (2 tailed)
≤	Less than or equal to
%	Percent
#	Number
Alt.	Altitude
ASL	Above Sea Level
Ca	Calcium
CITES	Convention on International Trade in Endangered Species
cm^2	Centimeter squared
DM	Dry Mass
EAWLS	East African Wildlife society
FM	Fresh Mass
Govt.	Government
G	Grams
G/cm3	Grams per centimeter cubed
IUCN	International Union for Conservation of Nature
ITCZ	Inter Tropical Convergence Zone
L.C.	Light Class
L.D.M.C.	Leaf dry mass content
L.T. / T	Leaf Thickness

Mg	Milligram
Mg/l	Milligram per liter
Ml	Milliliter
Mm	Millimeter
N	Nitrogen
ns	Not significant
P	Significant level
P	Phosphorus
PCA	Principal Component analysis
PC-Ord	Principal Component Ordination
P.L.	Petiole Length
r	Pearson Correlation Coefficient
rho	Spearman Rank Correlation Coefficient
r.p.m.	Revolutions per minute
s	Significant at 0.01 or 0.05 significant level.
Sp	Species
THBP	Taita Hills Biodiversity Project
W. D.	Wood Density

ABSTRACT

This study was aimed at associating the autecology of selected tree species in nine indigenous fragments of the Taita Hills forests, using their leaf and wood traits. Tree species (0.5 to 3.5) m, were selected due to their dominance and abundance in the forest. Understanding autecology of a forest would impact essential knowledge on what conservation measures to undertake e.g. when reclaiming such a habitat by a forestation or when managing forest gaps that may result in large scale fragmentation and eventual degradation of a habitat. Recently leaf and wood traits have proven to be effective in determining plant autecology from previous studies done.

Random collection of 10 leaf samples from each tree specimen for farther analysis was done. A total of 3000 leaf samples were collected. Position, altitude and light class was determined for each plant sampled using a GPS and an improvised densiometer. Leaf fresh and dry mass was obtained by weighing the leaves on a balance. Leaf petiole length was also measured using a vernier caliper while thickness was determined using a micrometer screw gauge. Leaf dry mass content was determined (by dividing the leaf dry weight and wet weight then multiplying this by 100%). Foliar N and P were determined using wet Kjedhal method and Spectral analysis. Wood density for samples collected was determined using the volume displacement method. Average values for variables were correlated and compared using multiple correlation, ordination (PCA) and cluster analysis.

Correlation coefficients (r & rho) for species together with correlations for the PCA and axis which they lay on identified the following species in respective functional groups:- *Maesa lanceolata*, *Tabernaemontana stapfiana* and *Milletia oblata* as edge species, *Macaranga capensis*, *Newtonia buchananii*, *Polyscias fulva* and *Prunus africana* as Pioneer/light species, *Phoenix reclinata, Rapanea melanophloes, Syzigium guinensee and schlerophyllum* as adaptive species able to adapt to changing conditions depending on the canopy cover. *Chrysophyllum gorungosanm*, *Craibia zimmermanii*, *Leptonychia usambarensis* and *Strombosia scheffleri* classified as shade species.

A cluster analysis done for fragments had a dendogram with two major clusters at 82% similarity; Vuria – Iyale fragments were on one side while the other fragments on another. Notably, all fragments had over 80% similarity. The cluster for species had *Phoenix reclinata* and other species at 69% similarity, while other species were differentially similar. The PCA established that fragments in the same locality and with similar species were grouped together.

It was concluded that for majority of the species, leaf and wood traits were indeed associated with altitude and light class for the species studies in the various fragments of the Taita hills forests. Altitude and canopy cover played a major role in defining the survival of these species.

Key Words: Autecology, Taita Hills Forests, leaf and wood traits.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Autecology is primarily experimental and deals with easily measured variables like light, humidity, and soil nutrients in an effort to understand the needs, life history and behavior of tree species. Research on forest ecology requires one to have knowledge on the role and functioning of every tree species in a habitat. Every species has its own response to environmental conditions and ecosystem processes. Therefore, every tree with its own unique characteristics will dynamically interact with other species and claim its own niche.

Empirical models (forest and landscape models) use species-specific characteristics and traits to predict forest succession; these characteristics also help in predicting distribution and abundance of tree species. Dynamic models in ecology utilize niche parameters of species to explore response to environmental conditions like altitude and radiation from the sun. As a result, knowledge obtained from such models is essential for gap modeling, a forestation, forest habitat reclamation and conservation.

Tree physiology data are often scarce or lacking, especially for tropical tree species, because the classical method to obtain this data is difficult and time consuming. Recently, simple leaf and tree variables have been put forward as a proxy of tree physiology and have effectively succeeded to reveal tree physiology data in previous studies. Key tree species physiological traits are difficult to measure (e.g. Photosynthetic capacity, response to light and altitude), but can be predicted from simple qualitative wood and leaf traits.

This thesis contains a detailed inventory of different tree traits (Leaf Petiole length, thickness, N, P, Fresh mass, Dry mass and Wood Density), for selected tree species. The traits were used to describe 'tree functional types' where by 'tree functional type' is defined as a group of trees with a similar response to environmental conditions (altitude/elevation and canopy cover/light class in this study) biota, and similar effects on dominant ecosystem processes.

The purpose of this study is to determine whether the leaf and wood variables for selected species and forest fragments are associated in relation to altitude and canopy cover in the Taita Hills forests.

1.2 Literature review

The Taita Hills forest is a cloud/mist forest that creates a small patch of green between dry savannah plains surrounding the region (Nickmans and Muys, 2011). The governing natural processes in the forest have created a unique composition of species with high endemism of both flora and fauna in the forest (Bennun and Njoroge, 1999; Beentje and Ndiang`ui, 1988; Myers *et al.,* 2000; Lovett, 1993).

Natural moist forests of the montane type have been known as *Ocotea* or *Podocarpous* forests (PROTA 2010; Greenway, 1973), because of the predominance and abundance of these two species in this ecosystem. Apart from the former and the latter *Prunus africana* is also known to be very important in these ecosystems as well (Lind and Morrison 1974). The Taita Hills forests have been subjected to human interference over the years resulting in fragmentation of the once continuous mist forest to 52 patches that are completely detached from each other. Comparing both the natural and planted forest, the fragments greatly vary in size with the smallest being Kulundu (0.08 ha) and the largest being Igho (2000 ha), (Taita Hills stakeholders workshop report 2005). In terms of the original afromontane mist/cloud forest, Aerts *et al.,* 2011 found that the largest fragment is Mbololo (220 ha) followed by Ngangao (120 ha) then Chawia (50 ha).

Use of wood for timber, land for agriculture, practises involving deforestation and shifting cultivation can cause forest fires that would destroy large areas within a small period of time (Swennen 2008). These among others may be some of the reasons or causes that may have resulted in further fragmentation of these forest fragments. According to (Fishpool, 2001), the total area of the East African Mountains (EAM) is about 3300km^2 with 400km^2 in the Taita Hills forests. This was also established by Madofe *et al.,* (2007) in a forest health monitoring project in EAM beginning the year 2000 where 43 permanent plots, 17 in the Taita Hills area were established; 11 in Ngangao forest and six in Chawia forest.

The indigenous fragments in the Taita hills the cover about 430 ha with the smallest fragments heavily fragmented **(**Adriaensen *et al.,* 2011). This may have resulted to presence and absence of individual species of trees that were present in the original habitat. Patches formed by individuals constituting a community are dynamically related to each other (Watt 1947). The regeneration complex may explain species absence in cases where they were present in the past. A mosaic of patches may have intergrading series repeated all over the area (Godwin and Conway1939). Due to human settlements and Agriculture, the once continuous mist forest is presently highly fragmented and comprise up to 52 patches completely detached from each other. Studies done in the forests indicate that they are heavily disturbed and the patches keep shrinking as time goes by.

Studies have been done e.g. by the Taita Biodiversity Project (THBP) to quantify the disturbance level for each of the forest fragments (Bytebier, 2001), with basic ecological parameters like vegetation stratification, plant density and size classes identified and studied. Indicators of destruction like cut trees and number of human trails (anthropogenic effect indicators in the forests) were also studied. These parameters were published earlier for Sagalla, Ronge, Mbololo, Ngangao, Chawia, Fururu, Vuria and Mwachora (Wilder *et al.,* 1998) but there is no data for four other forest fragments (Kichuchenyi, Macha, Iyale and Ndiwenyi).

Such missing knowledge and information is essential for conserving these small fragments and this research work had the four fragments covered, thus in a manner filling an existing knowledge gap. The remaining natural forest in the Eastern Arc Mountains is highly fragmented. The median patch size is 10.2 km^2, and the mean patch size is 58.0 km^2; (Newmark, 1998) also suggests that 77% of the forests have been lost over the last 2000 years with the presence of Iron Age sites in the Taita Hills indicating that humans have been altering the Eastern Arc forests for at least 2,000 years (Schmidt, 1989).

An understanding of the current coverage, composition, distribution and correlations of natural forest in the Taita Hills forests is critical for developing strategies to conserve its biological diversity. This study focused on distribution of selected species, correlation of physiological traits of these species and their relationship with aspects of their surroundings (light and altitude).

Studies by (Newmark, 1998) estimated the maximum total area of natural forest, open as well as closed forest, in the Eastern Arc Mountains to be 5,340 km2. The Udzungwa Mountains contain the largest area of natural forest followed by the Nguru, Uluguru, Rubeho, East Usambara, South Pare, West Usambara, Mahenge, Ukaguru, North Pare Mountains, and the Taita Hills (size of the EAM in descending order as per size). The Taita hills were indicated to have 6km^2 of Natural forest, about 13 patches of indigenous forest, 4km^2 of closed forests and it has suffered 98% loss of the original forest cover.

Autecology may have an influence on plants i.e. relation to elements of the weather like winds light and attitude that may affect or determine alignment of plants in a community in terms of e.g. unidirectional vegetation spread. Survival of a species will also depend on its attributes` interactions with the environmental factors (Schupp *et al*, 1989) with differential success in survival also being due to the function a species may play in that habitat. This is also known as ecological sorting, a probable reason for absence of species in patches of a once connected forest like the Taita Hills which may have had similar species that are now in some fragments only.

Studies by (Lamprecht 1989 and Mansourian 2005) have shown that autecological data for present species in the tree and herbaceous layer of tropical forests in Africa isn`t well known with the herbaceous layer often lacking. Thus this study`s focus on 18 species in the tree layer and forest floor of the Taita Hills forests in a bid to partly bridge this gap. A forest gap is an opening created in the forest canopy by artificial or natural causes (Watt, 1947). Gaps induce dynamics including the phenomena of forest regeneration i.e. gap dynamics (Van der Maarel, 1988). Determining tree autecological properties of would be a difficult task, as the trees in the forest need to be monitored in time and space over a period of time. Fortunately previous studies by (Poorter and Bongers, 2006a and 2006b; Markesteijn *et al.,* 2007) have shown links between traits of a tree and its autecological properties. Wood and leaf Traits are dependent on autecological properties, biotic and abiotic conditions of a tree stand. Trees adapt to environmental properties by investing their biomass in selected organs where by rapid growth would imply a fast build up of biomass and a fast allocation of resources to a given organ.

In tropical wet forests, light is considered to be a limiting factor for growth and survival thus light capitation will be a concern when a tree is to have fast growth. Environmental properties in a forest gap will have a given sequential pattern where the forest floor will be first exposed receiving high isolation with the occurrence of the gap.

Pioneer species will be advantaged and will invest more biomass in the leaves to enhance light interception, in this process they will harvest maximum light and hence increased photosynthesis (Poorter *et al.,* 2006). As a result the leaf area will increase and less biomass will be invested in the petioles.

Later the petiole will increase in length to support large leaves and will also function as energetically cheaper organs than branches by helping in positioning of leaves for light interception and prevention of self shading (Givnish, 1984; Valadares 1999; Galves and Pearcy, 2003). In this manner the tree then will postpone branching and will invest more in vertical growth (King, 1998; Poorter *et al.* 2006; Poorter and Bongers, 2006a; Sterck and Gelder, 2006). At maximum height the tree will focus on persistence with reduced and thickened leaf sizes that will shield them from excess irradiance and physical weathering. Overheating will also be reduced by the shape of leaves (shape factor) where slender leaves will have reduced boundary layer resistance (Markesteijn, 2007; Givnish, 1984).

The amount of adaptation of leaves at different positions in the canopy will be dependent on amount of irradiance at this location. This adaptation is known as plasticity or magnitude of acclimation a species will realize in response to differences in irradiance (Markesteijn, 2007). The crowns of the trees in the upper canopy will shade the under stories where shade tolerant species grow. The understory will have thinner leaves that will intercept all light filtering through the canopy (Evans and Poorter, 2001). The tree will invest more biomass in the leaves where carbon will be made available by decreasing inter node length in the plant (King, 1991; Poorter, 2001).

Thus from the previous explanation Nitrogen content, Phosphorus content, and leaf dry mass content (LDMC) are leaf traits that can be used as indicators for biomass growth rate when looked at on mass basis (Nickmans and Muys, 2011), leaf shape may also indicate temperature regulation as well. In looking at wood traits, the density of wood can have a consequence on mechanical properties of stems and branches (Niklas, 1993, Sterck and Bongers, 1998). These will have an effect on survival; architecture and growth in long term (Sterck *et al.,* 2001 Poorter *et al.,* 2006, King *et al.,* 2005, Alvarez-Clare, 2005). Higher wood density will be connected to a greater mechanical strength, lower tree growth rate, smaller leaf and twig size (Niklas, 1992; Loehle, 1988; Givnish, 1995; Enquist *et al.*, 1999; Muller-Landau, 2004 and Roderick, 2000).

As found out by (Nickmans and Muys, 2011 and Markesteijn *et al.,* 2007), it is expected that species in areas with high irradiation (lit areas) will have low foliar Nitrogen, Phosphorus and leaf area (however in this study leaf area was not determined).

These species will also have a high Leaf Dry Mass Content, longer petiole lengths and thicker leaves (to protect them from excess irradiation).Thus for these species Nitrogen and Phosphorus will be negatively correlated with LDMC, Petiole Length and leaf thickness (Poorter *et al.*,2006). Thickness increases with irradiance and is negatively correlated with foliar Nitrogen, while a low LDMC implies high allocation of photosynthetic tissue and thus a higher foliar Nitrogen content. Species occurring in xeric/sunny conditions have greater thickness, this being because plants can cope with mechanical damage by investing in resistant structures or allocations of resources to reserves that enable them replace the damaged tissue. Sun leaves have greater thickness and species mass than shade species as well.

Exposure of plants to less light results in elongated petioles, as a result of phototropism, a probable explanation for elongated petiole lengths in species to be studied. Gap colonizers have less tough leaves, with higher Nitrogen and water than shade tolerant species. Leaf thickness plays an important role in leaf and plant functioning and is related to species adaptation strategies to acquire and use resources, with negative relationships seen between leaf thickness, photosynthesis and growth (Nickmans and Muys, 2011). Phosphorus is an important factor in plant growth and is used in energy transfer reactions among other things explaining the positive correlation with Nitrogen given that both Nitrogen and Phosphorus are needed for photosynthesis, thus it is logical that low LDMC would imply higher N and P. Thus sun leaves a higher LDMC, lower N and P explaining negative correlations found (Sack *et al.,* 2003, Nickmans and Muys, 2011). High Nitrogen, Phosphorus and low leaf thickness indicates an investment in higher growth. According to (Ninemeets *et al.,* 2006), Petiole length if positively correlated with leaf area indicates the larger the leaf the longer the petiole length.

(Roderick 2000) found that a higher wood density will indicate a slower growth rate and hence the negative correlations seen; Pioneer species hence will be expected to have a low density with longer petiole lengths and leaf areas for faster growth (Pooter *et al.,* 2006; Nickmans and Muys 2011). (Alvarez Clare S, 2005) also found that shade tolerant species had higher wood density to cope with mechanical damage in the understory. Leaf fresh and dry mass being positively correlated probably indicates similar water content for the species (Nickmans and Muys, 2011). These species were sampled in indigenous mist/cloud afromontane forests which depended mostly on water from the mist on the hill tops of the Taita Hills forests. Thus for the correlations, concentration will not be on all variables analyzed but on few variables that give logical interpretation and have evidence in literature as above; e.g. thickness, light Class, LDMC, Petiole Length, Nitrogen, Phosphorus and wood density.

Altitude and Light class were the two independent variables among the other variables analyzed. It is observed that these two greatly had effect on the decisions to be made since their effect on a variable would have implications on conclusions made e.g. as stated earlier; increase in light is expected to result in thicker leaves high LDMC and longer petiole length.

Habitat loss and climate change pose increasing threats for biological communities worldwide (Thomas *et al*. 2004). In particular, forests are at stake: from the year 2000 to 2005 the continent lost about 4 million hectares of forest annually, close to one-third of the area deforested globally (FAO, 2009). Plant communities and their associated fauna and ecosystem services in forests have been lost at a high rate over this period as well (Lewis, 2009). Deforestation affects biological forest communities in various ways; it reduces the amount of habitat, isolates the remaining patches (habitat fragmentation) and alters the local or regional microclimate (Lawton *et al.*, 2001; Fahrig 2003). In remaining forest fragments, selective logging (Berry *et al.*, 2008; Ruger *et al.*, 2008) and the subsequent invasion of alien or early-succession species (Devlaeminck *et al.*, 2005; Heckmann *et al.*, 2008) further degrade habitat quality. Consequently, biological communities in fragmented forests are expected to differ from the original, pre-fragmentation situation (temporal effect). They are also expected to vary between and within remaining forest patches

Restoration can be applied in managing such a forest resource that has been affected by negative anthropogenic interference in helping the resource evolve back to itself (Mansourian, 2005; Nickmans and Muys, 2011). In deciding on which restoration strategy to apply successfully in a given ecological system, it will be necessary to have knowledge and information on the site characteristics, soil, climate, vegetation dynamics, vertical and horizontal structure of vegetation with autecology of present species.

1.2.1 Primary productivity of Taita Hills Forest

Energy flow through any ecosystem starts with fixation of Carbon dioxide using sunlight energy by plants and other autotrophic organisms (photosynthesis and chemosynthesis). In this way plants accumulate energy matter forming primary production (Pennings *et al.*, 2005).

The Taita Hills forest is a mist forest and the rate at which organic matter is produced, or radiant energy is bound, through photosynthesis per unit area per unit time (g m^{-2} yr^{-1} or g m^{-2} d^{-1}) will be expected to be high. The Taita Hills forest are part of Africa`s mist forests that are also part of the tropical forest biome. The biome concept organizes large-scale ecological variation. Terrestrial biomes are distinguished primarily by their predominant vegetation, and are mainly determined by temperature and rainfall (www.nature.com accessed on 10/07/2012; 11:33 a.m.).

The high primary production in these forests has been attributed to various reasons including the following (www.rainforestconservation.org accessed on 10/07/2012; 11:40 a.m.):-

- Tropical forests are thought to be the oldest on earth, thus their age has allowed for accumulation of many species that have adapted and evolved over time. Large areas covered by such forests (despite the current fragmentation e.g. as in the Taita Hills), resulted in geographical isolation, endemism and speciation.

- Heterogeneity of the internal forest environment, environmental processes, biogeochemical cycles, numerous food chains and food webs resulting in various trophic levels and energy transfers with high productivity.

In comparison with tropical lowland rainforests, these forests have a low aboveground net primary productivity, a small standing biomass and a small leaf area index (LAI) with stunted growth form of the trees. Estimates of gross primary productivity of cloud forests are scarce, and there are uncertainties in what factors are most important in controlling their productivity (Van de Weg *et al.*, 2012).

1.2.2 Land use in the Taita hills

The land use of the areas surrounding the forests fragments in the Taita Hills is mainly subsistence farmland that is evidenced by peasant farmers growing food crops and rearing domestic animals (as illustrated on Plates 1.1 and 1.2).

Some farms run just at the border of forests where it is expected that the edge effect will arise with some species that are favored with disturbance growing here; these being herbs and shrubs as opposed to trees. In cases where domestic animals are reared and tethered on the forest borders to graze (see Plate 1.2) e.g. donkeys, sheep and goats; it also occurs that the animals feed selectively on some species promoting the growth of others and in this way enhancing the edge effect, this reduces the forest edge cover in eventually.

Other areas in the Taita Hills are covered by plantations of exotic tree species e.g. *Eucalyptus* sp. and *Acacia* sp., the Sisal plantations in the lowlands like Mwatate and the gazetted Tsavo national park plains.

(a) (b)

Plate 1.1a: Sheep tethered and grazing at the edge of the Ngangao forest

Plate 1.1b: Maize farm bordering the edge of the Ngangao forest in the Taita Hills Forests.[Scare crow put up by a farmer to scare monkeys from the forest from invading the crops (A source of Human wildlife conflict)].

1.3 Justification of the study problems

This study was part of ongoing work in the Taita hills forest in an attempt to make a statement on the selected tree species of the Taita Hills Kenya which were found to be the most dominant from plots established by Thijs K.W. in a field study done in 2010.

This could help in description of dynamics that occur in a forest gap as a probable proxy for dynamics governing the whole ecosystem using tree traits as an alternative method since determination of ecosystem dynamics may be a long and costly operation.

Results of leaf and wood variables of individual species were compared between fragments to establish whether there is a relationship or not. Such knowledge would help in forest conservation, management and restoration. This will bridge a Knowledge gap since such a study has only been carried out in Mbololo and Ngangao before, without extending to other fragments.

The Taita Hills forests are heavily fragmented with only 12 indigenous patches. Ornithologists have revealed that this fragmentation has diminished the genetic diversity of several bird species and that morphological differences emerged for specimens of different fragments. It`s not clearly known if fragmentation has also had an effect on plants, thus one of the reasons for this study.

1.4 Overall Objective of the Study

The overall objective of this study was to assess the effect of altitude and light class on leaf and wood traits of eighteen tree species in the Taita Hills forests.

1.4.1 Specific Objectives:

i. To determine whether the leaf and wood traits of 18 tree species in nine fragments of the Taita Hills forest have similar growth response to light and altitude.

ii. To identify the functional groups of 18 tree species in nine fragments of the Taita Hills forest using simple wood and leaf traits.

iii. To analyze the correlation of leaf and wood traits of 18 tree species in nine indigenous forest fragments of the Taita Hills forest

1.4.2 Hypothesis

Tree growth in areas with similar altitude and light environment in the Taita Hills forests fragments has resulted in similar trends of leaf and wood traits.

CHAPTER TWO

STUDY AREA

2.0 Study area locality

Taita Hills form the northernmost part of the Eastern Arc Mountains, a crescent-shaped geological formation that runs through most of eastern Tanzania and ends in south eastern Kenya. The area is divided into three distinct isolates. Sagalla Hill (also known as Ndara) lies due south of the town of Voi, Mbololo massif (also known as Mraru, Wangonya or Ndi) in the noth east.

Dabida is the main hill complex, comprising the majority of the forest fragments studied and lies north of Mwatate, 50 km to the south-east lies Mt Kasigau (1,500 m above sea level), which is reported to have biogeographical similarities with the Taita Hills. Part of the Taita Taveta massif is also divided into two (2) by the Paranga Valley which is 900m deep, (Kolu, 2012).

2.1 Environment of Taita Hills Forest

The Taita Hills were formed about 180–290 million years ago by block-faulting of basement. Rocks in the Mozambique Belt (Vogt and Wiesenhutter, 2000). The Taita Hills are in south-eastern Kenya at 03°20'S, 38°15'E, about 150 km inland from the coast, with an area of about 250 km^2. They are surrounded by dry plains with dry bush land running up into the lower slopes of the hills, grading into moist forest, farmland and plantation at 1,200 m.

2.1.1 Climate

According to (Teel, 1984) climatic division derived from a soil survey in 1983, Taita Hills is part of Migori and Limuru climate type (Agro climatic zones II, II and IV). This was also evidenced by data collected from a Voi weather station (Lehouck *et al.,* 2009).

The climate here partly depends on the ITCZ which lies parallel to the equator. Mean rainfall in Wundanyi Town (at 1,200 m) is 1,329 mm per year (that in the hilltop forests probably exceeds 1,500 mm per year), with rainfall peaks in April and November (Beentje, 1987; Brooks *et al.,* 1998). The prevailing climatic conditions in southeastern Kenya are of the savanna type with two dry seasons (Koppen, 1923). The seasonal pattern is dominated by three airstreams (Ojany and Ogendo, 1973). The Arabian/Indian northeast trade winds, forming the northeast monsoon and prevail during the period of November to March giving rise to a short wet season. The area has bimodal rainfall resulting from movement of the ITCZ as the sun`s insolation moves to and away from the equator, as a result the wet season occurs in March-May and November-December with mist precipitation occurring throughout the year.

Tropical montane cloud forests capture water from clouds directly, hence the forests` ability to grow at the mountain peaks and this is in addition to the rain that falls; process called horizontal precipitation (Bruijnzeel and Proctor, 1995). The rainy season is followed by a long dry season. The southeast trade winds from the southeast monsoon. They start to influence the weather by about the month of April giving rise to the main wet season which is followed by a dry or transitional season starting during July. These hills form the first barrier for moisture-laden air masses that blow in from the Kenyan coast, with orographic rains occuring and being of great significance to the area (Beentje and Ndiangui, 1988). The eastern and southeastern slopes receive more rain from these humid southeast trade winds than do the western and northern slopes that are in the rain shadow area (Vogt & Wiesenhutter 2000). Altitude also has an influence on the rainfall pattern: higher areas get more rain than lower areas.

2.1.2 Drainage, Soils and Topography

They are composed of soft metamorphic rocks overlain by a quartzite cap (Beentje, 1987). Mainly rocks of migmatic and granulitic gneisses with minerals, e.g. garnet, biotite, placioglace, quartz and amphibole.

The alignment of the Taita Hills from north to south relates the hills tectonically to the evolution of the East African Rift System (Vogt and Wiesenhutter, 2000). Surrounding plains are mainly covered by Recent and Pleistocene red-brown sandy soils and calcareous crustal deposits overlying undifferentiated basement rocks consisting of crystalline limestone and gneisses (Were and Soper, 1986). The dominant soils on the Taita Hills are young soils, cambisols, which are of moderate fertility. In the upland areas cambisols are found together with highly weathered ferralsols with low natural fertility. Other soils developed on the Taita Hills are acrisols, rankers and rendzinas, which are common in the south-eastern part of the Taita Hills (Were and Soper, 1986).

Studies by (Sombroek *et al.,* 1982) revealed extensive saline and alkaline soils in the region. The soils having developed from Plio-Pleistocene parent rock bay sediments (Marafa beds). The deposits were believed to have been derived from local reworking of Pliocene bay sediments (Saggerson and Baker, 1965).

The drainage system of the Taita Hills consists of 2 major drainage basins: The Voi-Goshi/Vitengeni–Rare basin which includes Voi River which flows from the Taita

Hills and the Mwatate- Puma-Pemba basin that consists of Mwatate River (Oosterom, 1988). Several rivers drain from the Taita Hills catchment areas; The Voi River drains from near Werugha to the east, while the Mwatate and Bura rivers drain to the south. Although these rivers are perennial at their headwaters, none of them carries any permanent flow far into the Plains, (Were and Soper, 1986; Vogt and Wiesenhutter, 2000).

Tropical montane forests are distinguished by an altitude that is above 1 kilometer (KM) above sea level (A.S.L.). In isolated peaks especially near seas or oceans they occur at lower altitudes, a phenomenon known as the Massenerhebung effect (Flenley, 1995). The Altitude of the Taita hills varies between 481 - 2200 meters above sea level with three major topographical zones; the upper zone, lower zone and volcanic foothills. The topography of the region ranges from 700 - 2208 meters above sea level with the Taita Taveta district comprising of two distinct topographical areas i.e. Tsavo Plains at 400 m to the east and 1000 m to the west and the Taita Hills at 1200 - 2200 m.

Several inselbergs characterize the lowlands, the highest being Kasigau mountain reaching 1600 meters. The highest peak in the Taita Hills is Vuria (2208 m), but several peaks range between 1600 and 2200 m.

2.1.3 Plant Species Composition and Diversity

The diversity of plant species within a plant community reflects the complexity in the physical, chemical and human environment (Chege and Bytebier, 2005) The area consists of mist/cloud forests which have been fragmented over a period of time with remnants of the original afro-montane forest vegetation restricted to isolated mountain peaks (Aerts *et al.*, 2011).

Vegetation types in these forest patches vary from indigenous to exotic with over 2000 plant species in 800 genera in the Taita hills and surrounding forests. About 800 of these species are believed to be endemic to this ecoregion. The forests are the centers of global endemism for the African violet (*Saintpaulia*) and Busy Lizzies (*Impatiens*), Usambara violet (*Saintpaulia ionantha*), Msambo tree (*Allanblackia stuhlmanni*) and Wild nutmeg (*Cephalosphaera usambarensis*). (www.wwf.panda.org, accessed on 26/07/2012).

Table 2.1: Size, vegetation types and geographical locality of the Study Sites (Taita Hills stakeholders workshop report 2005)

FOREST	**TYPE**	**LOCALITY**	**SIZE (HA)**
1.Ngangao	Indigenous	Maghimbinyi	92
2.Chawia	Indigenous &some exotic	Chawia	50
3.Fururu	indigenous	Ngerenyi	12
4.Mwachora	Indigenous+ eucalypts	Wundanyi	4
5.Macha	cypress+black wattle, Eucalypts	Wundanyi	3
6.Ndiwenyi	Indigenous	Ngerenyi	3
7.Iyale	Mixed	Werugha	2
8.Vuria	Exotic+some indigenous	Mgange Dawida	1
9.Kichuchenyi	indigenous	Ngerenyi	< 1

Table 2.1 illustrates the vegetation types range from Eucalyptus forest, Grevilia forest, Pine forest, and Cypress forest in descending order of fragment size; Erica heath and Agriculture matrices (Omoro *et al*, 2010).

Also endemic is the wild coffee, *Coffea fadenii*. About 40% of species, 2% of genera and 13% of taxa are endemic to the area. Additional twenty two (22) plant species here are found only in Kenya and Tanzania. Thus the Taita Hills have been named as one of the 34 biological diversity hotspots of the world (Omoro *et al.,* 2010). Among other species present, the forest consists of *Phoenix reclinata, Tabernaemontana stapfiana, Acacia mearnsii, Maesa lanceolata, Ocotea usambarensis, Eucalyptus saligna and Cupressus lusitanica.* The forests are listed under the International Union for Conservation of Nature (IUCN) red list because 236 of its plant species are either vulnerable or endangered.

The Taita hills forests fragments are home to endemic animals including birds and insects. The biodiversity richness and endemism of the Taita Hills have been influenced by more than 100 years of isolation Due to the heavy fragmentation and habitat disturbance. Thus some species are found only in this habitat. Being the most fragmented part of the EAM forests, it is an area of concern for conservationists worldwide, because threats posed to it are a threat to biodiversity as well.

Various studies indicate that: 13-plant and 9-animal taxa endemic; 22-plant and 3-animal species are characteristic of the East Arc Mountains, 37-plant species rare both nationally and globally; Birds: 3 endemic birds (see Plate 2.2 and 2.3) list in various threat categories; the Taita Thrush (*Turdus helleri*), the Taita White-eye (*Zosterops Silvanus*) and the Taita Apalis (*Apalis fuscigularis*). Endemic plants include: *Saintpaulia teitensis* (African violet) and *Zimmermania ovata; Coffea fadenii.* There is also high endemism in invertebrates (both specific and related to Eastern Arc Mountain forests) at genus and species levels. On reptiles and amphibians Taita Hills have the nationally endemic gecko and the Taita reed frog.

(Beentje and Ndiang'ui, 1988) conducted inventories and surveyed the protection status of the forest`s biodiversity while the Taita Hills Biodiversity Programme (THBP, 2001) investigated the general occurrence presence or absence of some species and taxonomy. Despite over 25 years of conservation and research, the Taita Hills cover and biodiversity continued to decline due to human encroachment. A lot of research has been conducted with little having been used in conservation and management of the habitat in the past. Various forums for stakeholders have been held in a bid to discuss threats, challenges and to identify options for restoration and enhancing connectivity of the fragments. Interventions pointed out e.g. in the Critical Ecosystem Partnership Fund (CEPF) Workshop 7-10 February 2005 included:

- Gazettment and survey mapping of the fragments: Out of the 52 forest patches only 24 are gazetted and only 3 out of the 24 gazetted are surveyed. The surveyed ones are Mbololo Juu, Mwambirwa, and Ngangao Forests. Gazzeted forests are managed by the Forest Department, I observed that forests under the Forest department were better managed and conserved than those under the county (formerly Taita Taveta municipal council). Surveying establishes clear boundaries and this enables better management especially in relation to the edge effect.

- Developments of alternative livelihoods for the residents that will enable them not overexploit the forest resources. This being for individuals who depend on e.g. timber harvesting as a source of living, an alternative livelihood will result in fewer trees harvested for timber in these forests.

- Inventory of the Biodiversity of the Taita Hills e.g. The East African Wildlife Society (EAWLS) partnered with the National Museums of Kenya in 1984 to conduct a biodiversity inventory of the Taita Hills Forests.
- Participatory Approach: The need to include people living in the matrix in finding workable solutions regarding how to conserve the forests is obvious and this calls for education and awareness creation; also enlightening them on the importance of biodiversity.
- In situ conservation of resources and biodiversity in the Taita Hills forests should be enhanced with fair and equitable sharing with conservation and sustainable resource use to enable for conservation of the forests for the future to reap their benefits and services as well.

Locals should be included in restoration efforts of the Taita hills forests; they should be educated more on the benefits of the intrinsic and extrinsic values of the forests` biodiversity and continued existence. The Plates 2.1(a), (b) and (c) illustrate some endemic species of the Taita Hills forests.

(a) (b) (c)

Plate 2.1 (a) Bush baby (*Galago senegalensis)*, (b) The Taita White-eye (*Zosterops Silvanus*) and (c) Taita Trush (*Turdus helleri*)

2.1.4 Study Sites

The study sites were chosen on the basis of fragments that consisted of the original afromontane cloud/mist forest originally found in the Taita hills. Chawia, Fururu, Macha, Ngangao, Iyale, Mwachora, Ndiwenyi, Kichuchenyi and Vuria, were considered to be under this category.

Chawia forest: The second largest and southernmost forest fragment in Dabida, comprising 50ha. The highest point is at 1587m. It has heavily disturbed and plantations of exotic trees inside the forest. It is surrounded by agricultural land. It is located in Chawia location Mwatate division and is managed by the Taita Taveta County govt. The fragment is a main habitat for the Taita thrush (*Turdus helleri)*, a critically endangered bird species.

Fururu forest is a partly disturbed small fragment (5ha) with patches of plantation forest. It is surrounded by agricultural land. It consists of mostly indigenous forest and is located in Ngerenyi location, Mwatate division and has been gazetted by the Government of Kenya.

Macha forest: A small forest fragment of approx. 2ha. The Highest point is 1653m. It is disturbed and surrounded by plantation and agricultural land. It consists of mostly cypress, black wattle and eucalyptus, is located in Wundanyi location and division and is gazetted by the government.

Vuria forest: Its highest peak is (2208m) and is the western most forest of the Taita Hills. It’s a small fragment of closed canopy forest remaining on western slope; the rest is heavily disturbed and has a lot of low secondary vegetation. It consists of exotic and some indigenous trees and is located in Mgange Dawida location, Wundanyi division and is managed by the Taita Taveta County Government. An important water catchment forest with natural vegetation covering a smaller area and the exotic covering a larger portion of the forest.

Iyale forest: Found few kilometres from Vuria, it is sheltered by a massive rock (Iyale rock) which also forms part of the forest with trees growing on it. The forest consists of patches with both indigenous and planted forests.

Mwachora forest: Located in an area also known as `Chome` opposite the Macha fragment with the road to Wundanyi from Mwatate running between them. The fragment has cultural significance since the name Mwachora was coined from the English word "mortuary". A steep rock located at the fragment was the point of execution for convicts and people who went against the Taita laws in the past, whereby they were pushed down the rock. This fragment is dominated by *Phoenix reclinata* trees and is surrounded by homesteads with farmlands.

Kichuchenyi forest: A small fragmented forest patch of the Taita Hills that is excluded and surrounded by farmlands. It also sheltered by a huge rock that serves as a shelter for other biodiversity like the small mammals.

Ndiwenyi forest: Located next to a permanent stream and surrounded by farmlands and homesteads on one side. The forest is also very disturbed with evident tree poaching.

Ngangao forest: The second largest fragment after Mbololo, it is gazette and is managed by the Kenya forest Service with a forest warden stationed. The forest is intact and has numerous species present. It is also the location of the mother tree the biggest tree in the Taita hills forests.

Figure 2.1: Taita Hills Area and location on the Kenyan Map.

(Source: www.ilri.org/gis)

c

Figure 2.2: Taita Hills as part of the Eastern Arc Mountains forests: An important global biodiversity hotspot

(Source www.google.co.ke)

2.2 Materials and Methods

2.2.1 Species Studied

A total of 18 species were studied, 17 of these were derived from previous studies done in the Taita Hills forests, e.g. Thijs K. PhD research (ongoing), which established plots in the area and found the 17 to be the most dominant species based on basal area and stem density. (See appendix 5.4 for list of species studied).

2.2.2 Sampling

Prior knowledge of the area, maps and a field guide who was familiar with the area were used to help access the fragments and familiarize with the locals neighboring the forest.

Sampling was done using the simple random sampling method, where possible four plots (400x400 m) were established in the fragments of study representatively and species of interest were randomly sampled within the plot. Species of interest were identified using photos of plant leaves from previous studies in the area e.g. (Nickmans and Muys, 2011) and a taxonomic key that was found suitable for this work, i.e. (Nickmans *et al.,* 2011). Initially, it was intended that 21 species were to be studied but due to the following reasons this was impossible:-

- Absence of *Ocotea usambarensis* between (1.0-3.5) m heights in the forest fragments visited, with only mature trees observed in the fragments like Ngangao forest. This may be attributed to over exploitation of the species due to its good quality of wood. In all fragments of study, there were numerous saw pits in the forests which as per the field guides had been used to saw timber from fallen *Ocotea usambarensis* trees.

- It is also possible that a bottle neck may have developed with no seeds from mature trees being dispersed to enable for growth of saplings. There are numerous *Ocotea usambarensis* in Mbololo forest (the largest) and it can be said that the seed dispersers e.g. frugivores like hornbills may not be sufficient in dispersing the seeds from here to the distant fragments like the ones studied.

Plate 2.2: A saw pit observed in Ngangao forest (left)

- *Oxyanthus speciousus* was excluded from the study because of possible mis-identification during its study since the cues on the leaves used it had similarity to other species.

Despite one sample being collected in Ngangao, *Podocarpous latifolius* was excluded since it had no other saplings spotted in the other fragments as well.

2.2.2a Field sampling

Leaf traits: Areas in the forest fragments studied with favorable terrain and forest cover were allocated 4x400m square quadrats. Tree species 1 - 3.5m were randomly sampled. (Height was selected in line in the preliminary study done in Ngangao and Mbololo by Nickmans and Muys, 2011). It was seen to be the most appropriate height range from which to capture interactions of the leaf and wood traits of a tree with its environment.

Plate 2.3: Taking light measurements using improvised densitometer at Chawia forest

A total of ten (10) leaves were collected from each plant studied for farther analysis that involved measuring the petiole length, leaf thickness, leaf dry mass and fresh mass during the laboratory work. The position and elevation of each sample was determined using a GPS to obtain the coordinates and the altitude of a tree species sampled. Light condition/canopy cover was determined using an improvised spherical densitometer (Plate 2.5) that was made from a table spoon that had 24 squares drawn on its concave side**.** A percentage light class was obtained by counting the number of squares out of the

24 with 50% canopy coverage then dividing this number by 24 and calculating its percentage. This was done at the four cardinal points of a plant for replication. An average was found for each of the four points to give the light class in %.

Farther analysis had leaf thickness obtained by measuring the thickness of leaves using a micrometer screw gauge. Leaf fresh mass was obtained by submerging the leaf samples in water for 24 hours then weighing them on a weighing balance. On the other hand leaf dry mass was obtained after drying the collected leaf samples on a plant press, then an oven (for 24 Hours). Afterwards the leaves were weighed on a weighing balance. Leaf dry mass content was obtained by obtaining a percentage of the leaf dry mass and the fresh mass. Leaf variables for each individual tree specimen were obtained by averaging each variable to obtain the value for variables of each plant.

Tree species like *Macaranga capensis, Phoenix reclinata, Craibia zimmermannii, Polyscias fulva, Newtonia buchananii and Albizia gummifera* had compound leaves (pinnate and bipinnate). The leaflets (for pinnate) and sub leaflets (for bi pinnate) were counted with an average leaflet being selected to act as a representative. From this the numbers of pinnae were counted and one was chosen and subjected to the measurements similar to those of single leaves. To determine the fresh mass of the leaves, the leaves were submerged in water overnight immediately after being sampled from the field. When fully saturated, the fresh mass was determined by weighing each leaf on a weighing balance; for *Albizia gummifera* ten (10) leaflets were weighed, five (5) for *Craibia zimmermannii* and fifty (50) for *Newtonia buchananii.*

The variables for these leaves were then obtained by calculating the total values for all leaves using the weighed ones as a representative.

E.g *Newtonia buchananii*: Total number of sub leaflets = 500

Fresh mass for 50 sub leaflets = 0.5g

Total Fresh Mass = 0.5*500/50 = 5g

Thus fresh mass for that leaf = 5g

Leaves were then dried between news papers and when completely dry, their mass was determined using a weighing scale as in the procedure for single leaves. The procedures above were adapted from Nickmans and Muys, 2011.Variables measured and their units were as follows: - Foliar Nitrogen and Phosphorus content (mg/l), leaf petiole length and thickness (mm), wood density (g/cm^3).

Leaf Traits are dependent on biotic/abiotic conditions of tree stands that create specific conditions dictating a tree`s survival. When these conditions e.g. light, altitude, salinity e.t.c. exceed the tolerance of a tree species, negative aspects precede and occur like poor growth or no germination (Turreson 1930; Grime 2001).

Wood Traits: From the quadrat developed for sampling, at least three wood samples per species per fragment (where possible) were sampled randomly, Care was taken since some of these saplings were few in the fragments and this sampling was destructive in that it involved cutting down a tree species. Collected samples were dried at 55^0C then weighed after 24, 48 and 72 hours until a constant mass was achieved. The density was then determined using the Volume Displacement Method (Chave 2005). The Volume Displacement Method involved submerging a wood sample in a known volume of water, determining the amount of water displaced after submerging then dividing this by the mass of the wood sample to determine the density, (Nickmans and Muys, 2011).

2.2.3 N and P Content: This was determined from collected leaf samples after all other variables had been determined. Specimens selected were according to number of samples per species collected in fragments. Species occurring in the median and extreme light classes were selected for this analysis. In cases where more than five species were sampled have three specimens was used for analysis according to occurrence in the respective light classes. In cases where there were three (3) or less samples per species, all were used for the analysis. Ten leaves from each specimen selected were ground to create a sample for analysis then N and P content was determined using wet Kjedahl digestion of plant tissues followed by spectral analysis (National Museums of Kenya, 2010 and Persson *et al.,* 2008).

CHAPTER THREE

DATA ANALYSIS AND RESULTS

3.1 Prevalence and distribution of species studied

3.1.1 Abundance and presence of selected species

Table 3.1 illustrates a breakdown of the presence or absence of saplings for the tree species species studied in the nine fragments of the Taita hills during the random field sampling in section 2.2.2a:-

Milletia oblata was present in all fragments while *Albizia gummifera* and *Maesa lanceolata* were absent in Kichuchenyi. *Strombosia scheffleri* was present only in Vuria and Iyale while *Chrysophyllum gorungosanum, Craibia zimmermannii and Cola greenwayi* were only present in Vuria and Chawia. *Leptonychia usambarensis* was present in Ngangao, Chawia and Mwachora while *Macaranga capensis* was present in Ngangao, Chawia, Iyale and Vuria. *Phoenix reclinata* was absent in Ngangao with mature trees observed while *Newtonia buchananni* was present in Ngangao, Chawia and Macha. *Polyscias fulva* was present in Vuria, Chawia and Ndiwenyi while *Prunus africana* was absent in Ndiwenyi, Fururu and Iyale. *Syzigium guineense* was absent in Kichuchenyi, Iyale and Vuria while *Rapanea melanophloeos* was present in Ngangao, Vuria, Iyale and Fururu. *Strombosia scheffleri* was present in Ngangao, Chawia and Ndiwenyi while *Tabernaemontana stapfiana* was absent in Ndiwenyi, Kichuchenyi and Mwachora. *Xymalos monospora* was also absent in Ndiwenyi, Kichuchenyi and Mwachora.

3.1.2. Altitude and Canopy cover in relation to selected species

Figure 3.2 shows that the species found under the highest canopy cover are *C.gorungosanum*, *Cola greenwayi*, *R. melanophloes*, *S. scheffleri*, and *T. Stapfiana* (22) while *P.africana* was found to occur under the least canopy cover of 17. *M. lanceolata*, *M. oblata*, *A. gummifera* had a canopy cover of 19 (light species); *P. fulva* (18), *P. Africana* (17), *P. reclinata and syzigium guineense* (20). Figure 3.2 shows that *S. schlerrophyllum* had the highest average altitude of 2036 (thus its presence in Iyale and Vuria only); while *C. greenwayi* had the least at 1588. Notably all species averages were above 1580m above sea level.

Table 3.1: Species presence in forest fragments in order of the most prevalent

FOREST SP. PRESENT	KICH	MWA	MAC	FUR	NDI	CHA	NGA	IYA	VUR
MOB	×	×	×	×	×	×	×	×	×
PRE	×	×	×	×	×	×		×	×
AGU		×	×	×	×	×	×	×	×
MLA		×	×	×	×	×	×	×	×
TST			×	×		×	×	×	×
XMO			×	×		×	×	×	×
PAF	×	×	×			×	×		×
SGU		×	×	×	×	×	×		
RME				×			×	×	×
MCA						×	×	×	×
SSH								×	×
LUS		×				×	×		
NBU			×			×	×		
PFU					×	×			×
CGO						×			×
CGR						×			×

CZI		×			×
SSC	×	×	×		

NB: × species presence in a fragment

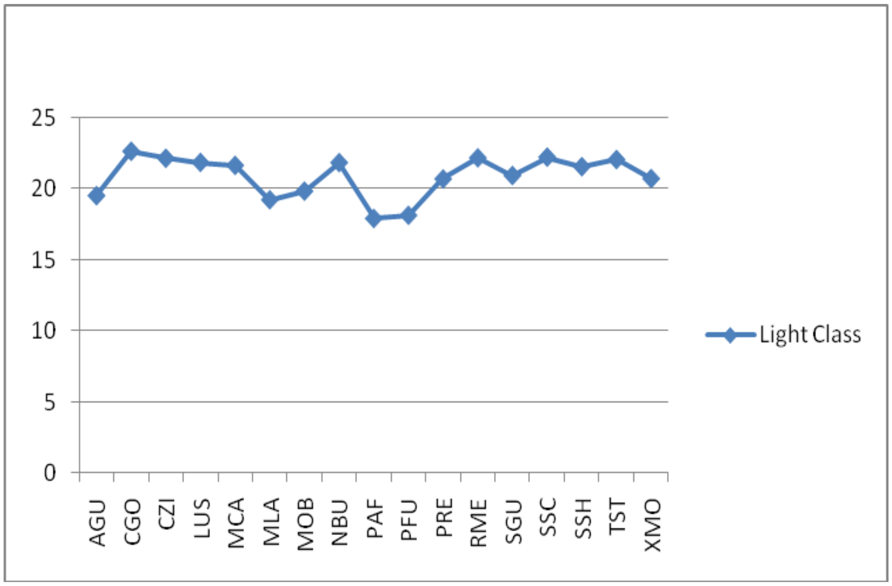

Figure 3.1: Canopy cover (solar radiation) for species studied in the Taita Hills Forests

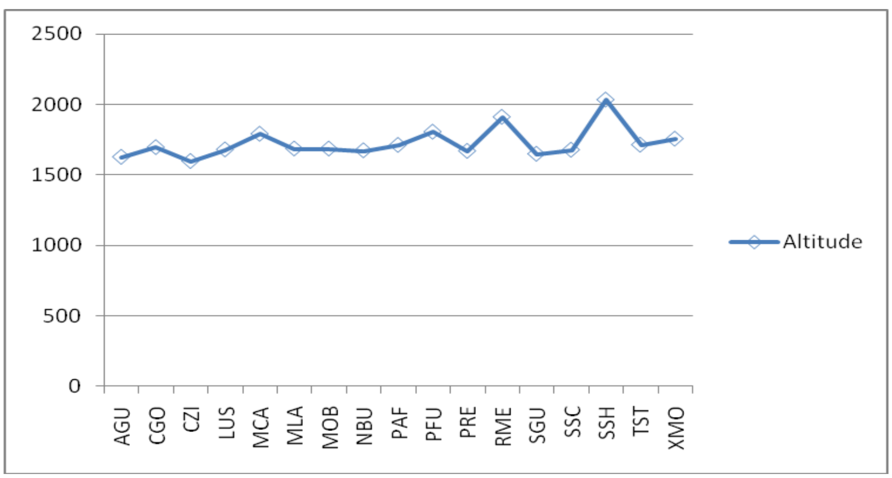

Figure 3.2: Altitude for species averages in the Taita Hills Forests

Vuria and Iyale were observed to have the highest average altitude for the fragments studied, with Kichuchenyi having the lowest. It is notable that majority of the fragments were at an average altitude of just over 1500m above sea level.

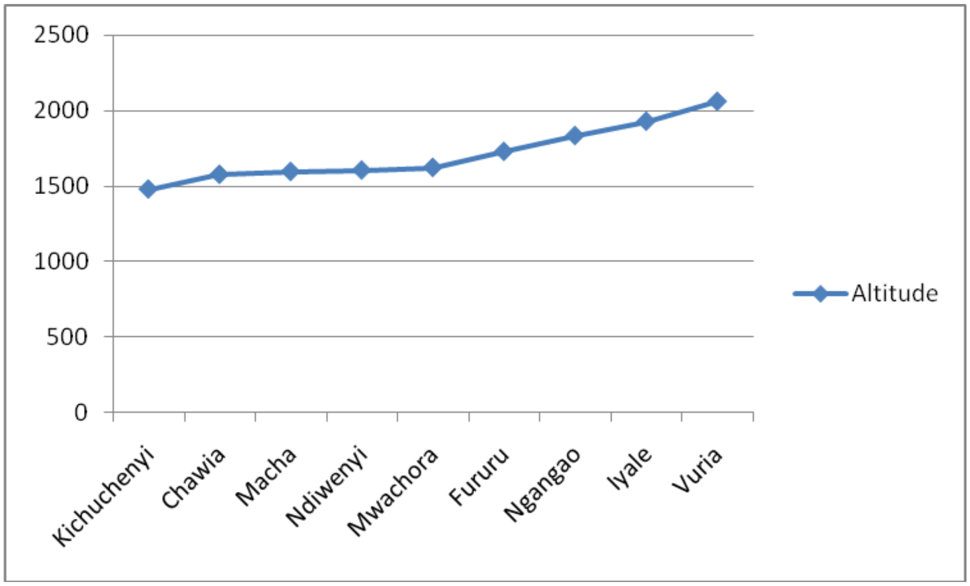

Figure 3.3: Altitude for fragment averages in the Taita Hills Forests

Figure 3.4 illustrates canopy cover in the fragments studied with Kichuchenyi fragment having the least canopy cover, while it was also observed that majority of the fragments had a cover of more than 20%.

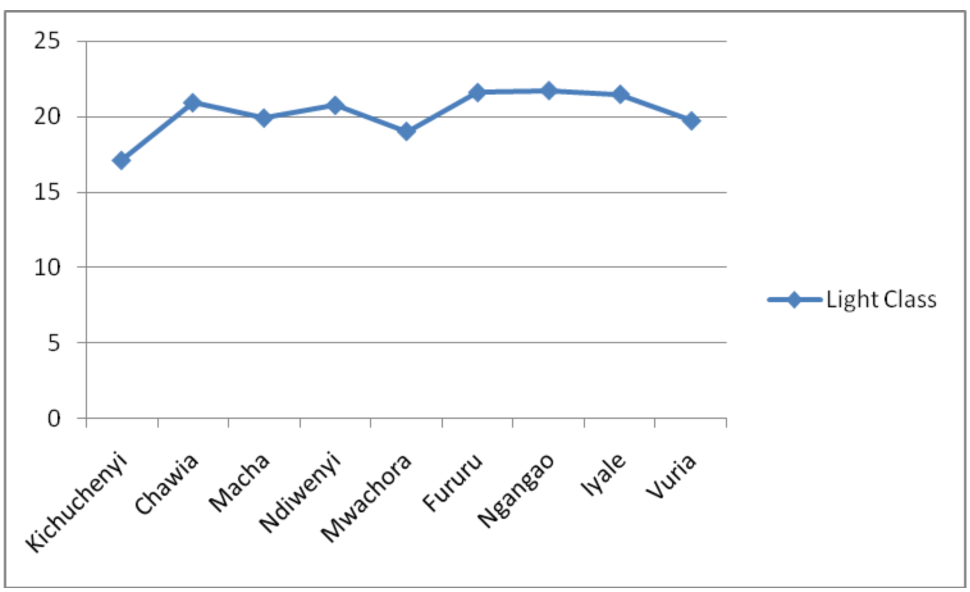

Figure 3.4: Canopy cover for fragment averages in the Taita Hills Forests

3.2 Correlation analysis

Raw data obtained included the following: - Leaf thickness, petiole length, leaf dry mass content, fresh and dry mass, foliar Nitrogen and Phosphorus. This data was averaged to have e.g. a single Figure for individual species within and between fragments, so as to enable for analysis of individual species and fragments.

The one sample Kolmogrov-Smirnov test was used to test for the normality of the data set because most samples here had ($n \leq 25$), making this the most suitable method to determine normality here. Logarithmic transformations were used to normalize the data. Normality of data gave direction as to which correlation method to apply (Pearson-product-moment correlation for normal data and Spearman rank correlation for non normal data). Data for individual species and fragments were analyzed using multiple correlations to determine their association with each other. The strength (strong, moderate or weak) was determined from the coefficient of determination (r^2). The covariance/association (negative or positive) was ascertained from correlation coefficient (r) while a decision on the hypothesis was arrived at from the *p* value for the hypothesis test.

This research had a multivariate analysis of variables carried out and this sometimes results in the family wise error rate. These results from rejecting a null hypothesis because the *p* value is less than the critical value when actually one shouldn`t have rejected it. To determine which correlations are more significant than others, a Bonferroni correction was used after the correlation; where by the significance level for correlation used (0.05) was divided by the number of variables tested. The value obtained will be used as the new significance level (Dytham, 2003), e.g. if 20 variables:-

Bonferonni correction:-

Significance level/No. of Variables tested; (0.05/20) = (0.025)

i.e. New significance level = 0.025

3.2.1 Correlation of leaf and wood traits between selected tree species

Studies by (Ninemeets *et al.*, 2006; Bongers and Popma, 1990) indicate that tree species relationships on functional variables and foliage trends in relation to their environment (in this case light) are not universal. Tree species may adapt to both shade and light showing characteristics for both depending on where they grow. This research had all variables listed (see section 3.2) correlated, but only those that showed direct significance towards data interpretation for the correlation in relation to identifying the functional groups were tabulated and discussed for the fragments. In most cases this were LDMC (being a function of Leaf fresh and dry mass), leaf thickness, foliar N and P.

The correlations coefficients for individual species were tabulated with only correlations of interest that were significant being mentioned in the results, this is despite interest only in some of the variables that were of most importance.

3.2.1a *Albizia gummifera*

There were positive correlations between LDMC – L.C. (weak, P=0.710, ns) and P.L. - L.T (moderate, P=0.894, ns). Negative correlations were observed for N - L.T. (moderate, P=0.207, ns) and N – P.L. (weak, P=0.923, ns). P – P.L. (weak, P=0.333, ns) and P-L.T. (weak, P=0.578, ns).

Significant correlations were observed for correlations of N - W.D. (*P*=0.05,), P - L.C (*P*=0.05), W.D. – L.C. (*P*=0.01), D.M. – Alt. (*P*=0.05), Alt. – W.D. (*P*=0.05), L.C. – P (*P*=0.05), L.C. – W.D. (*P*=0.01) and L.C. – Alt (*P*=0.05). Altitude and Light class both had strong correlations for cases where the correlations were significant (0.77, 0.87, 0.83, 0.84, 0.88 and 0.86). This implies that over 70% of correlations were correlated in cases all where the correlations were significant. Altitude and light class were correlated significantly with more than one variable showing its importance in the groth of *Albizia gummifera* as a tree species.

Table 3.2: Correlation Coefficient r for *Albizia gummifera* in the Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**P**	**W. D.**	**N**	**Alt.**	**L.C.**
L.T.	0.63	-0.52	-0.35	-0.74	-0.26	-0.65	0.54	0.75	0.59
P.L.	1	0.32	0.53	-0.16	-0.43	-0.35	0.05	0.08	0.45
D.M.		1	0.96**	0.27	0.46	0.73*	-0.818*	-0.77*	-0.54
F. M.			1	0.09	0.34	0.55	-0.68	-0.66	-0.38
LDMC				1	-0.21	0.48	-0.49	-0.29	-0.17
		n = 35							

NB: **Significant at 0.01 (2 tailed) *Significant at 0.05 (2 tailed)

3.2.1b *Chrysophyllum gorungosanum*

The correlations of this species suggest that it is a shade tolerant species. LDMC was negatively correlated with petiole length and nitrogen while it was positively correlated with leaf thickness, light class and phosphorus. Thickness – petiole length and petiole length – light class had negative correlations while thickness – light class had a positive correlation. Notably all correlations had significance at *P*=0.01(2 tail), n = 7.

3.2.1c *Craibia zimmermannii*

All correlations were perfect with all variables either negatively correlated at *P*=0.01(2 tail). L.D.M.C. – P.L. and L.D.M.C. – N had a positive correlation while L.T. – L.D.M.C. and L.T. – N had negative correlations that suggest that this is an adaptive species that can exist in shaded and lit environments, n = 10.

3.2.1d *Leptonychia usambarensis*

All variables were perfectly correlated for P.L. – T, L.D.M.C. – T, P.L. – D.M., D.M. – T, D.M. – P.L., L.D.M.C. – D.M., P – W.D. and F.M. – N and were significant at *P*=0.01. It was evident that this is a shade species as evidenced from the mixed correlations the leaf traits had. N – T (strong, *P*=0.667ns), T – P.L. (Perfect, *P*=0.01s), L.D.M.C – T, (Perfect, *P*=0.01s), L.D.M.C. - N (strong, *P*=0.667ns), and L.C. – L.D.M.C. (Weak, *P*=0.333ns) had negative correlations while L.D.M.C. – P.L. had a positive correlation (Perfect, *P*=0.01s).

Table 3.3: Spearman Rank Correlation Coefficients (rho) for *Leptonychia usambarensis* in Taita Hills Forests

	P. L	D .M.	F.M.	LDMC	W. D.	N	P	Alt.	L.C.
L.T.	-1	-1**	1	0.5	-0.5	-0.5	0.5	-0.866	0.866
P.L.		1	-1**	-0.5	0.5	0.5	-0.5	-0.866	0.866
D.M.			1	0.5	-0.5	-0.5	0.5	-0.866	0.866
F.M.				1	-1**	0.5	-0.5	-0.866	0.00
LDMC					0.5	0.5	-0.5	0.866	-0.866
				n = 20					

NB **Significant at 0.01 level (2 tail)

3.2.1e *Macaranga capensis*

Macaranga capensis had correlations characteristic of pioneer species where by L.D.M.C.–P.L.(weak,*P=0.628ns)*,L.D.M.C–T(strong,*P=0.014ns)*,L.D.M.C–N(weak, *P=0.052ns)*,T – N(weak, *P*=0.622ns), T – P (moderate, *P*=0.489ns) and L.D.M.C–L.C.(weak, *P*=0.71) were positively correlated. The correlations are characteristic of a pioneer species. Significant correlations were observed between L.D.M.C.-T (Strong, *P*=0.05) and L.D.M.C-F.M. (strong, *P*=0.01).

Table 3.4: Correlation Coefficients (r) for *Macaranga capensis* in Taita Hills Forests

	P. L	D .M.	F.M.	LDMC	W. D.	N	P	Alt.	L.C.
L.T.	0.511	0.907	-0.974	0.986	0.378	-0.622	-0.446	0.720	0.128
P. L	1	0.799	-0.310	0.372	-0.094	0.165	-0.310	0.752	-0.738
D.M.		1	-0.807	0.844	0.346	-0.429	-0.580	0.745	-0.197
F.M.			1	-0.998	-0.491	0.761	0.466	-0.572	-0.348
L.D.M.C.				1	0.477	-0.734	-0.480	0.608	0.290
				n = 24					

NB **Significant at 0.01 level (2 tail) *Significant at 0.05 level (2 tail)

3.2.1f *Maesa lanceolata*

L.D.M.C.-P.L. (weak, *P*=0.429ns), L.D.M.C-L.C. (weak, *P*=0.691ns), L.D.M.C-N (strong, *P* =0.018, ns), N-T (moderate, *P*=0.064ns) and T-P (moderate, *P*=0.069ns) had negative correlations.

Table 3.5: Correlation Coefficients (r) for *Maesa lanceolata* in The Taita Hills Forests

	P. L	D .M.	F.M.	LDMC	W. D.	N	P	Alt.	L.C.
L.T.	-0.058	0.123	-0.834**	0.95**	-0.679	-0.671	0.341	0.9**	-0.147
P.L.	1	-0.322	0.443	-0.327	0.675	0.475	-0.380	0.144	-0.251
D.M.		1	0.024	0.337	-0.023	0.202	0.242	-0.211	-0.395

F.M.			1	-0.88**	0.942	0.9**	-0.386	-0.684	0.059
LDMC				1	-0.8**	-0.721	0.485	0.753*	-0.168
			n = 42						

Significant correlations for *Maesa lanceolata* were observed between F.M.-T (*P*=0.01), L.D.M.C-T (*P*=0.01), Alt.-T (*P*=0.01), L.D.M.C.-F.M. (*P*=0.01) and N-F.M. Those significant at *P*=0.05 2 tail were observed between L.D.M.C-N and L.D.M.C.-P. It was notable that L.D.M.C. was an important variable for these correlations occurring in most incidences of correlation with other variables.

3.2.1g *Milletia oblata*

L.D.M.C-N (weak, *P*=0.869ns), L.D.M.C.-P.L. (strong, *P*=0.01s) and L.D.M.C.-L.C. (weak, *P*=0.552ns) had negative correlations while N-T (weak, *P*=0.591ns) and T-P (weak, *P*=0.207ns) had positive correlations. Correlations significant at *P*=0.01s, 2 tailed were T-Alt, P.L.-L.D.M.C. and F.M.-Alt. while N-P had significant correlations at *P*=0.05 2 tailed.

Table 3.6: Correlation Coefficients (r) for *Milletia oblata* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**
L.T.	-0.460	0.223	-0.416	0.438	0.226	0.473	0.106	-0.778	0.143
P. L.	1	-0.602	0.190	-0.747	-0.161	-0.433	0.406	0.559	0.031
D.M.		1	0.351	0.602	-0.320	-0.167	-0.601	0.022	0.162
F.M.			1	-0.438	0.031	-0.294	-0.258	0.743	0.049
LDMC				1	-0.070	0.226	-0.348	-0.425	-0.249
			n = 33						

3.2.1h Newtonia buchananii

Negative correlations were observed between L.D.M.C.-N (moderate, *P*=0.654ns), T-P (weak, *P*=0.951ns) and L.D.M.C.-N. (moderate, *P*=0.62ns). There were positive correlations between L.D.M.C.-P.L. (moderate, *P*=0.654ns) and N-T (weak, *P*=0.765ns), n = 14.

3.2.1i *Prunus africana*

Significant correlations at P=0.05, 2 tail were observed between T-D.M., T-F.M., T-P and W.D.-P. Those significant at *P*=0.01, 2 tail were T-L.D.M.C. and T-N with all variables strongly correlated. Positive correlations were observed between P.L.-T (weak, *P*=0.810ns), N-P (moderate, *P*=0.133ns) while N-T had a negative correlation (strong, *P*=0.075ns). All these were characteristic of light species.

Table 3.7: Correlation Coefficients r for *Newtonia buchananii* in the Taita Hills Forests

	P. L	D .M.	F.M.	LDMC	W. D.	N	P	Alt.	L.C.
L.T.	0.995	0.953	0.822	0.604	0.361	-0.076	0.014	-0.319	0.319
P.L.	1	0.979	0.877	0.518	0.457	-0.180	0.119	-0.416	0.416
D.M.		1	0.956	0.334	0.627	-0.375	0.317	-0.592	0.592
F.M.			1	0.043	0.828	-0.631	0.582	-0.802	0.802
LDMC				1	-0.525	0.748	-0.788	0.562	-0.562
			n = 14						

3.2.1j *Polyscias fulva*

Negative correlations for this species` variables were observed between P.L.-T, N-P and L.D.M.C.-T, all (moderate, *P*=0.6ns), Positive correlations were observed between T-N (weak, *P*=0.8ns), n=8.

This species had no significant correlations with all variables correlated (perfect correlations) observed between W.D.-T, P-D.M. and L.C.-L.D.M.C.

Table 3.8: Correlation Coefficients (r) for *Prunus africana* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**	**P. L**
L.T.	1	0.128	0.885*	-0.918*	.994**	-.92**	-0.825*	-0.744	0.934	0.272
P.L.		1	0.406	0.132	0.078	-0.174	0.023	-0.233	-0.061	-0.039
D.M.			1	-0.696	0.862	-0.818	-0.536	-0.599	0.714	-0.127
F.M.				1	-0.944	0.896	0.849	0.753	-0.855	-0.385
LDMC					1	-.956*	-0.808	-0.712	0.933	0.279

n = 33

Table 3.9: Spearman Rank Correlation Coefficients (rho) for *Polyscias fulva* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**
L.T.	-0.400	-0.200	-0.400	-0.400	-0.800	-0.200	1.000	0.200	-0.400
P.L.		0.800	1.000	0.400	-0.200	0.800	-0.400	0.000	0.400
D.M.			0.8000	0.800	-0.400	1.000	-0.200	0.600	0.800
F.M..				0.400	-0.200	0.800	-0.400	0.000	0.400

n = 8

NB **Significant at 0.01 level (2 tail) *Significant at 0.05 level (2 tail)

3.2.1k *Phoenix reclinata*

All variables were perfectly correlated for L.C. - Alt. these being significant at *P*=0.05, 2 tail. N-P had a negative correlation (moderate, *P*=0.113ns). Positive correlations were observed between P.L.-T (weak, *P*=0.337ns), L.D.M.C.-T (weak, *P*=0.525ns) and T-N (weak, *P*=0.866ns).

3.2.1l *Rapanea melanophloeos*

There were no perfect or significant correlations for this species. Negative correlations were observed between N-P (moderate, *P*=0.182ns), T-N (weak, *P*=0.954ns) and P.L.-T (moderate, P=0.407ns). On the other hand, positive correlations were observed between L.D.M.C.-T (strong, *P*=0.225ns), n = 20. This species had correlations similar to those of light loving species and it was observed to occur in fragments that were at a higher altitude and a lower temperature e.g. Vuria, Iyale and Fururu. Moreover, (Nickmans and Muys 2011) found that it is an adaptive species that can survive in every light condition.

Table 3.10: Correlation Coefficients (r) for *Phoenix reclinata* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**
L.T.	0.392	0.138	0.053	0.266	0.072	0.265	-0.267	0.022	0.023
P.L.	1	-0.669	-0.761	0.414	0.457	0.155	-0.525	-0.657	-0.654
D.M.		1	0.972	-0.071	-0.122	-0.128	0.426	0.419	0.416
F.M.			1	-0.287	-0.194	-0.088	0.469	0.496	0.493
LDMC				1	0.009	-0.012	-0.097	-0.464	-0.464
				n = 22					

Table 3.11: Correlation Coefficients (r) for *Rapanea melanophloeos* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**
L.T.	-0.593	0.766	0.700	0.978	-0.046	-0.534	-0.312	0.233	0.841
P.L.	1	-0.034	-0.332	-0.629	0.170	0.238	-0.062	0.623	-0.111
D.M.		1	0.856	0.643	0.428	-0.776	-0.060	0.585	0.988
F.M.			1	0.539	0.681	-0.977	0.386	0.099	0.814
LDMC				1	-0.250	-0.351	-0.464	0.216	0.744
			n = 20						

3.2.1m *Syzigium guinensee*

Table 3.12: Correlation Coefficients (r) for *Syzigium guinensee* in Taita Hills Forests

	P. L	D .M.	F.M.	LDMC	W. D.	N	P	Alt.	L.C.
L.T.	0.502	0.865	0.432	-0.786	-0.703	0.569	0.121	0.533	-0.045
P.L.	1	0.481	0.140	-0.220	-0.693	0.467	0.138	0.903	0.296
D.M.		1	0.758	-0.651	-0.596	0.749	-0.163	0.635	-0.074
F.M.			1	-0.550	-0.419	0.794	-0.409	0.449	-0.096
LDMC				1	0.586	-0.449	-0.319	-0.259	0.343
			n = 35						

This species had mixed correlations for the variables which indicate that it is an adaptive species and can survive in every light condition. Positive correlations were observed between P.L.-T (moderate, *P*=0.310ns) while negative correlations were observed between N-P (strong, *P*=0.495ns), L.D.M.C.-T (strong, *P*=0.64ns) and T-N (strong, *P*=0.119ns), see table 3.12.

3.2.1n *Syzigium schlerophyllum*

All correlations were perfect with negative correlations between N-P and T-N while positive correlations were observed between P.L.-T and L.D.M.C. – T. All correlations were significant at *P*=0.05, 2tail.

3.2.1o *Strombosia scheffleri*

Negative correlations were observed between P.L-T (medium, *P*=0.592ns), N-P (strong, *P*=0.095ns), L.D.M.C.-T (weak, *P*=0.291ns) and T-N (weak, *P*=0.771ns). Alt-N had correlations significant at *P*=0.01, 2 tail while P.L.-F.M. had significant correlations at *P*=0.05, 2 tail.

Table 3.13: Correlation Coefficients (r) for *Syzigium Schlerophyllum* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**
L.T.	1	-1	1	-1	-1	-1	1	1	1
P.L.		-1	-1	1	-1	-1	1	1	1
D.M.			1	-1	1	1	-1	-1	-1
F.M.				-1	1	1	-1	-1	-1
LDMC			-		-1	-1	-1	1	1
				n = 17					

Table 3.14: Correlation Coefficients (r) for S*trombosia scheffleri* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**
L.T.	-0.598	-0.285	-0.651	-0.897	-0.351	0.486	-0.817	0.351	-0.031
P.L.		-0.598	0.998	0.182	-0.540	0.410	0.950	0.541	-0.783
D.M.			-0.543	0.679	0.998	-0.976	-0.319	-.998	0.967
F.M.				0.249	-0.482	0.347	0.969	0.483	-0.739
LDMC					0.729	-0.822	0.479	-0.728	0.469
				n= 16					

This is an adaptive - shade species and it spends its entire life in the shaded understory and this was evident in Ngangao and Chawia. An observation is that it had longer petiole lengths; this is as opposed to what was found in literature earlier; suggesting it is not that lit species that have longer petiole lengths only.

3.2.1p *Tabernaemontana stapfiana*

Correlations were positive for P.L.-T (weak, *P*=0.704ns), N-P (strong, *P*=0.05s), L.D.M.C.-T (strong, *P*=0.98ns) and T-N (weak, *P*=0.509ns). Significant correlations were observed between D.M.-F.M., L.C.-P and N-P, all significant at *P*=0.01, 2 tail.

Correlations suggest that is a light species while Nickmans and Muys 2011 found that this was an edge species. It has a faster growing rate as opposed to other edge species and this is another probable explanation as to why it was abundant in most fragments of the Taita hills forests.

Table 3.15: Correlation Coefficients (r) for *Tabernaemontana stapfiana* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**
L.T.	0.200	0.222	0.332	0.013	-0.341	0.285	-0.642	-0.055	0.372
P.L.		0.414	0.742	-0.437	0.571	-0.438	0.402	-0.709	-0.249
D.M.			0.911*	0.623	0.622	-0.708	-0.060	-0.131	-0.323
F.M.				0.249	0.633	-0.659	0.057	-0.365	-0.274
LDMC					0.220	-0.390	-0.350	0.351	-0.242

n = 30

3.2.1q *Xymalos monospora*

Positive correlations were observed between P.L.-T (weak, *P*=0.967ns) while negative correlations were observed between N-P (strong, *P*=0.03ns), T-N (weak, *P*=0.675ns) and L.D.M.C.-T (weak, *P*=0.358ns).

Table 3.16: Correlation Coefficients (r) for *Xymalos monospora* in Taita Hills Forests

	P. L	**D .M.**	**F.M.**	**LDMC**	**W. D.**	**N**	**P**	**Alt.**	**L.C.**
L.T.	0.018	-0.311	-0.109	-0.376	-0.177	0.393	-0.331	-0.182	-0.409
P.L.		0.129	0.173	0.012	0.287	-0.184	-0.413	-0.756	0.282
D.M.			0.884	0.855	0.946	-0.819	0.615	-0.184	0.485
F.M.				0.525	0.759	-0.507	0.542	-0.023	0.231
LDMC					0.900	-0.894	0.522	-0.290	0.639

n = 39

3.3 Cluster analysis

3.3.1 Cluster analysis for individual forest fragments

The dendogram (see Figure 3.5) for forest fragments illustrates how the fragments were clustered. There were two major clusters which may be attributed to difference in altitude. Vuria and Iyale had the highest altitude and were clustered on one side with a similarity of 90.9%. These two fragments also had similar species with similar trends in variables.

Kichuchenyi had 90% similarity with the other fragments except Iyale and Vuria probably given that it was the most fragmented while the other fragments were as well fragmented, hence similar leaf traits with reducing canopy cover. Chawia and Macha had 98.8% similarity, the highest of all the clusters observed. Ndiwenyi clustered with Chawia and Macha had 97.9% similarity. Fururu, Ndiwenyi, Chawia and Macha had 97.8% similarity. Mwachora, Fururu, Ndiwenyi, Chawia and Macha had 97.6% similarity. Ngangao clustered with Mwachora, Fururu, Ndiwenyi, Chawia and Macha had 96% similarity.

3.3.2 Cluster analysis for individual species

A hierarchical cluster (Figure 3.5) was made from average values for variables of individual species from all fragments. *Syzigium guineense* and *Strombosia Scheffleri* had 98.03% similarity, *Chrysophyllum gorungosanum, Syzigium guineense* and *Strombosia scheffleri* had 97.8% similarity. *Craibia zimmermannii, Syzigium guineense, Chrysophyllum gorungosanum* and *Strombosia scheffleri* had 97.2% similarity. *Tabernaemontana stapfiana* and *Xymalos monospora* had 97.5% similarity.

Leptonychia usambarensis, Tabernaemontana stapfiana and *Xymalos monospora* had 96.7% similarity. *Rapanea melanephloes, Leptonychia usambarensis, Tabernaemontana stapfiana* and *Xymalos monospora* had 96.2 % *similarity. Albizia gummifera* and *Milletia oblata* had 96.5% similarity. *newtonia buchananii*, *Albizia gummifera* and *Milletia oblata* had 95.6% similarity. *Maesa lanceolata* and *Prunus Africana* had 95.9% similarity. *Polyscias fulva* compared with the rest of the species excluding Macaranga capensis and Phoenix reclinata had 86.6% similarity. Macaranga capensis and all other species except Phoenix reclinata had 71.7% similarity. Phoenix reclinata compared with all other species had 69.6% similarity. From the cluster it can be seen that most species studied had over 80% similarity Similarity except for Phoenix reclinata, *Polyscias fulva* and Macaranga capensis which are fast growing pioneer species which need a lot of light. As a casing point *polyscias fulva* grow fast to occupy the canopy while other species were either adaptive or shade species which occurred as edge species, shade tolerant species and shade species.

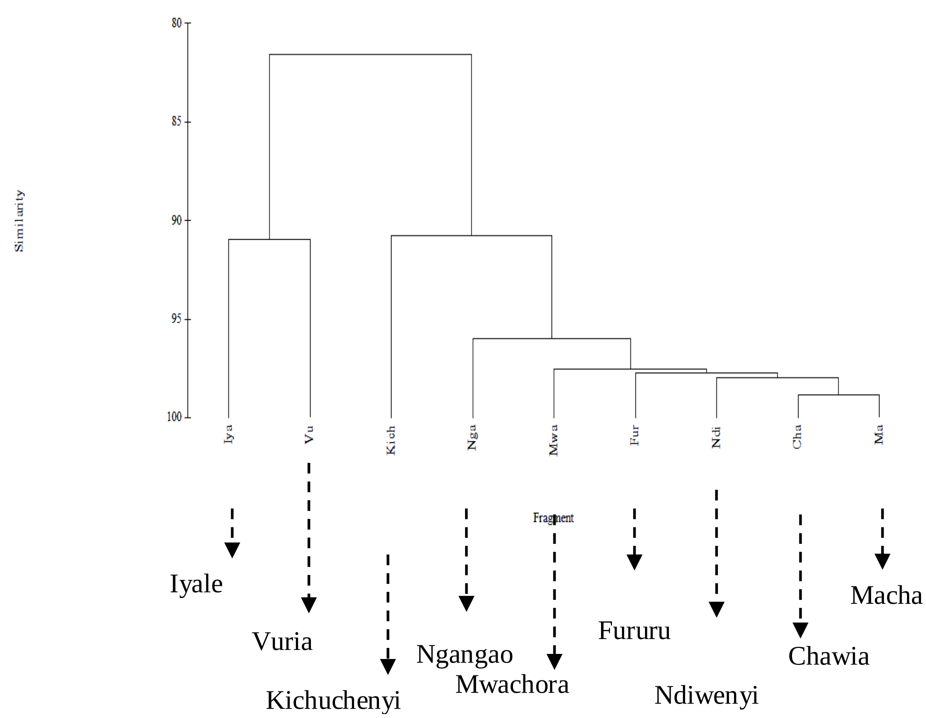

Figure 3.5: Dendogram for cluster of forest fragments of the Taita Hills

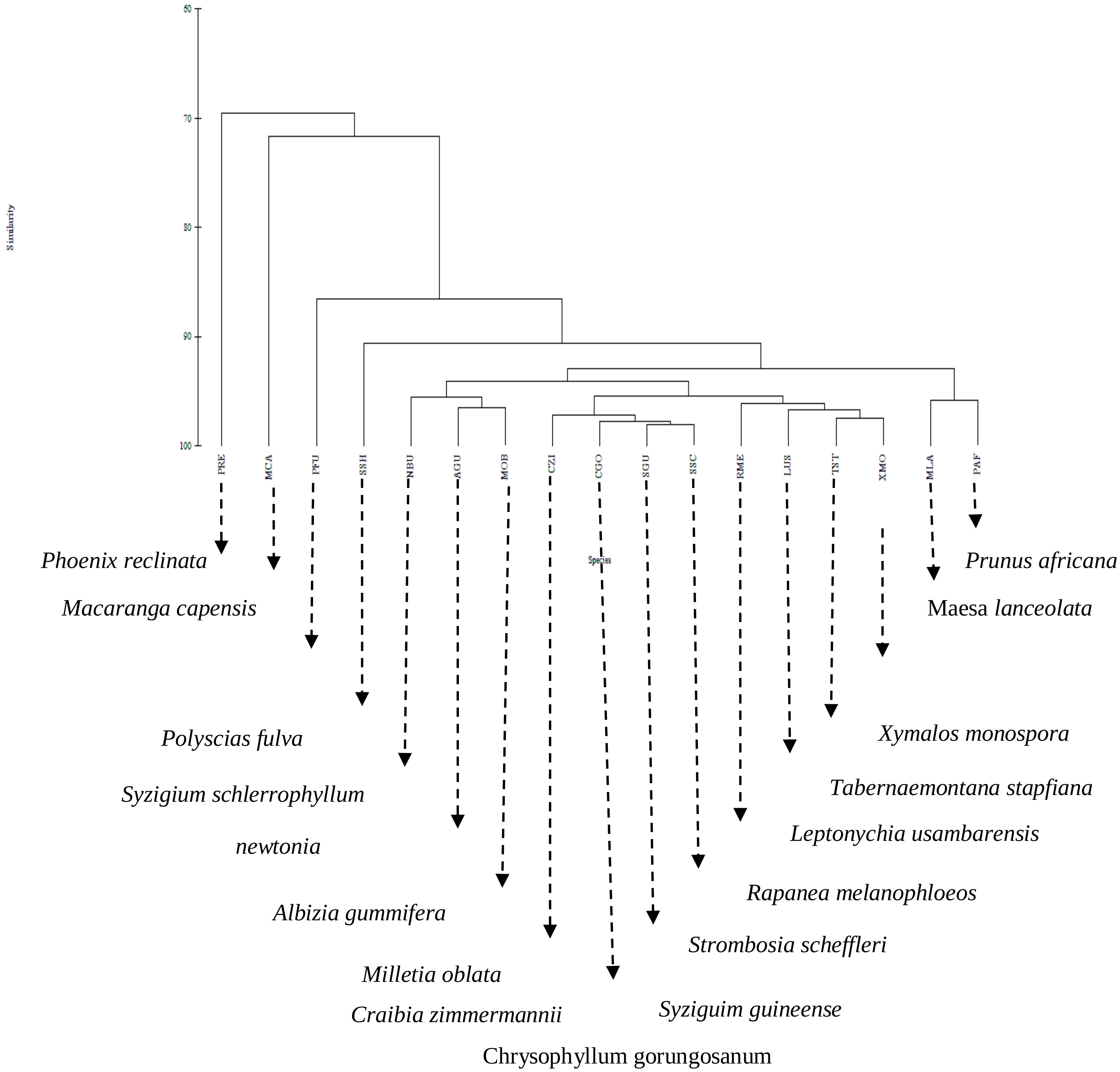

Figure 3.6: Dendogram of individual species studied in the Taita Hills Forests

3.4 Pricipal Component Analysis (PCA)

A principal Component Analysis (PCA) was done to display patterns of similarity present for the overall variables values for individual species in the Taita Hills Forests. A PCA was also done on individual species in individual fragments of the Taita Hills Forests.

As part of the PCA, a correlation was done to see how variables correlate with the axis of the ordination. The score of individual fragments and species was then compared with the axes they had most scores on, in this way it was able to see how the two related with the variables as correlated with the axis. This with the correlations for variables enabled classification of the species into different functional groups.

3.4.1 Principal Correlation Analysis for individual species

Table 3.17: Ordination for species showing explained variance by axes 1 and 2.

PC	Eigen values	%Variation	Cumulative %Variation
1	3.19	31.9	31.9
2	2.66	26.6	58.5

Axis 1 on table 3.17 shows the most variation at 31.9% while the value for axis 2 is 26.6% (both explain variance of up to 58.5%). Average leaf and wood variables for individual species were correlated with the axes to see their association.

On table 3.18, axis 1 which explains most variability is positively correlated with leaf thickness, LDMC, Altitude and light class while it was negatively correlated with leaf petiole length, dry mass, fresh mass, wood density, nitrogen and phosphorus. Axis 2 was positively correlated with leaf thickness, petiole length, LDMC, leaf fresh mass; dry mass, altitude and light class. It was also negatively correlated with wood density, Phosphorus and Nitrogen.

Table 3.18: Correlation between axes and variables for ordination

Variable	PC1	PC2
Leaf Thickness	0.215	0.371
Pet Length	-0.426	0.397
Leaf Dry Mass	-0.455	0.338
Leaf Fresh Mass	-0.457	0.334
LDMC	0.146	0.323
N	-0.321	-0.364
P	-0.330	-0.346
Wood Density.	-0.015	-0.109
Altitude	0.286	0.284
Light Class	0.203	0.170

Thus if a species has a high value on axis 1 it then will have a high leaf thickness, LDMC, Altitude and light class while on the other hand it will have a low petiole length, leaf dry mass, fresh mass, wood density, altitude and light class. A species with a high value on axis 2 has a high value in the leaf thickness, petiole length, LDMC, leaf fresh and dry mass, altitude and light class; while it had a low petiole length, leaf dry mass and fresh mass, wood density, altitude and light class.

Albizia gummifera, Chrysophyllum gorungosanum, Craibia zimmermannii, Leptonychia usambarensis, Maesa lanceolata, Milletia oblata, Newtonia buchananii, *Prunus Africana, Rapanea melanophloeos, Syzigium guineense, Strombosia scheffleri, Syzigium schlerrophyllum, Tabernaemontana stapfiana* and *Xymalos monospora* had higher scores on axis 1 while *Polyscus fulva, Macaranga capensis* and *Phoenix reclinata* had high scores on axis 2. The species with high scores on axis 1 had a high leaf thickness, LDMC, Altitude and light class.

Table 3.19: Principal component scores for species studied and axes they lie on

Sample	Score1	Score2	Axis/PC
AGU	-0.963	-1.477	1
CGO	-0.019	-0.925	1
CZI	0.880	0.010	1
LUS	0.472	-0.452	1
MCA	1.779	3.351	2
MLA	-0.578	-1.138	1
MOB	-0.818	-1.607	1
NBU	0.450	-0.163	1
PAF	-0.599	-1.512	1
PFU	-0.415	0.082	2
PRE	-5.587	3.452	2
RME	0.991	0.080	1
SGU	0.121	-0.818	1
SSC	0.684	-0.267	1
SSH	3.389	2.844	1
TST	0.235	-0.578	1
XMO	-0.020	-0.881	1

On the other hand it will have a low petiole length, leaf dry mass, fresh mass, wood density, altitude and light class. This group had both shade, light and adaptive species. The species with high scores on axis 2 have a high value in the leaf thickness, petiole length, LDMC, leaf fresh and dry mass, altitude and light class; while it had a low petiole length, leaf dry mass and fresh mass, wood density, altitude and light class. These species consisted of mostly the fast growing pioneer species and light species.

The PCA of individual species resulted in the following groups of species

- *Phoenix reclinata* lay along axis 1.
- *Macaranga Capensis* and *Syzigium schlerrophylum* were grouped together
- The rest of the tree species were clustered around the same region in the PCA, making it impossible to distinguish one from another (Figure 3.4). Explanations for this can be found in the discussion.

From the correlations and ordination done on the averages of individual species, they can be grouped into two groups as light dependent and shade species. This is important because it gives an indication of the position occupied by an individual species in the succession of the forest.

Craibia zimmermannii, *Prunus Africana,* and *Strombosia scheffleri* had higher wood densities compared to the rest of the species, an indication that these species invested more in mechanical strength and less in their growth rate (Niklas, 1992, Loehle 1988; Nickmans and Muys 2011). On the other hand species with less wood density e.g. *Polyscias fulva and macaranga capensis* invest in faster growth due to their opportunistic nature of inhabiting forest gaps in a bid to outdo other species; thus their being the fast growing pioneer species while the other species with higher densities falling within the shade tolerant to adaptive species.

Species with high foliar and soil phosphorus indicate a high above ground woody biomass growth rates (Nickmans and Muys, 2011). Plants growing in fertile soils have lower wood densities; high growth rates and tree turn over (Fyllas *et al.,* 2009), an example in this case would be *Polyscias fulva*

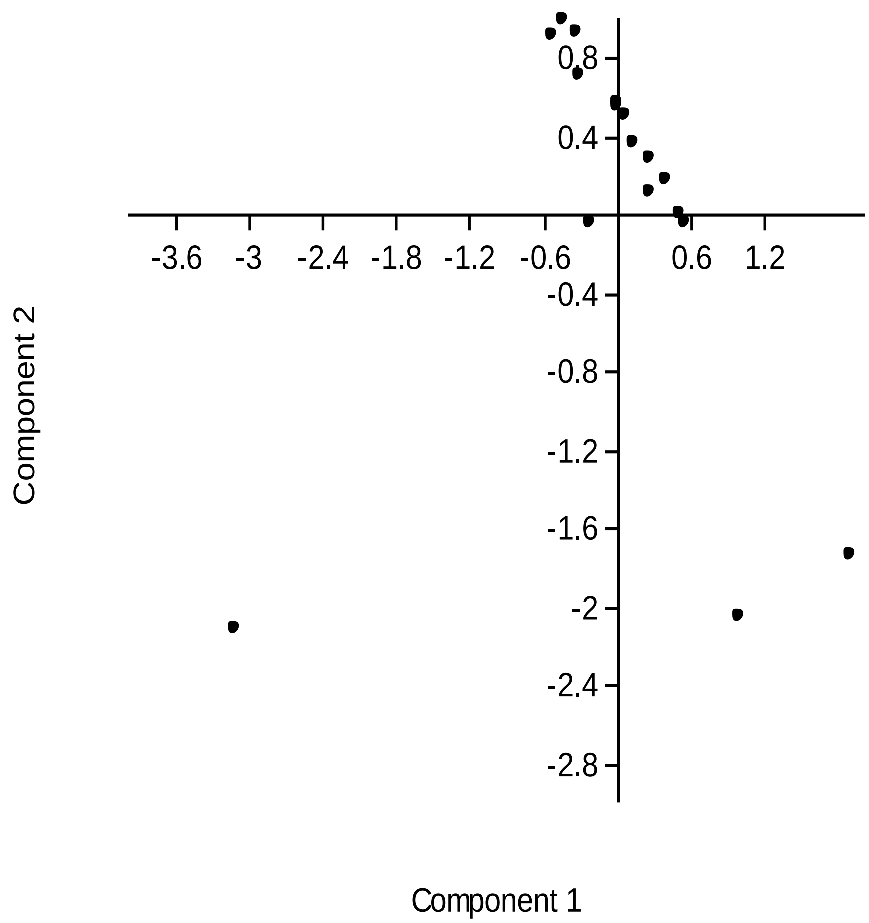

Figure 3.7 (a): Black dots illustrating Principal Component Analysis for averages of individual species

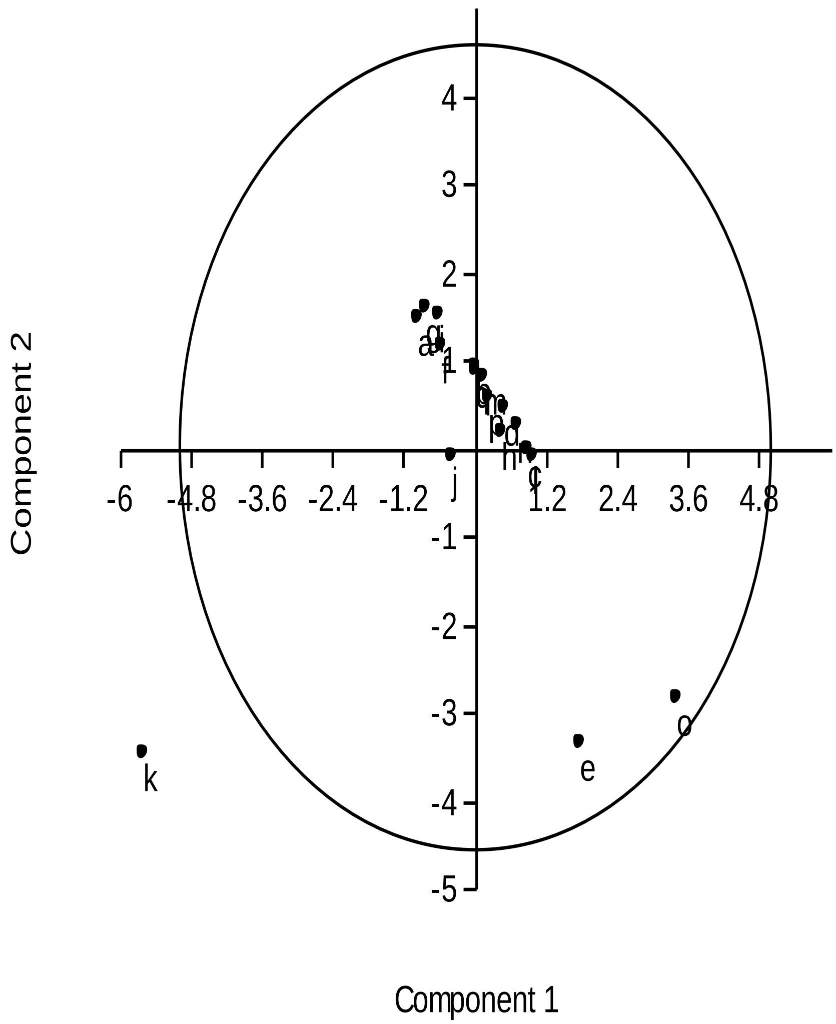

Figure 3.7 (b): Principal Component Analysis for individual species (letters representing species: K –*Phoenix reclinata,* e – *Macaranga capensis and O – Syzigium schlerophyllum.*). Other species were very close on the PCA. Circle represents a 95% ellipse which only had *Phoenix reclinata* occurring outside it.

CHAPTER 4

DISCUSSION, CONCLUSION AND RECCOMENDATION

4.1 Discussion

Generally it can be observed that individual species only occurred in preferred fragments due to the ability to adapt to the conditions that were favorable to them, in this case including amount of solar radiation, elevation, rainfall, soil nutrient content among others. In relation to canopy cover, altitude and species presence within the fragments studied, the growth and survival of a species depended on these two aspects. Notably there are species that had preference for high altitudes as exemplified by *Macaranga capensis, Rapanea melanophloes, Polyscias fulva* and *Syzigium schlerophyllum.* This means that these species would only be found in parts of the fragments that had high altitude including other favorable conditions that would promote their survival, thus the presence of *Syzigium schlerophyllum* and *Rapanea melanophloes* only in Vuria and Iyale which had high altitude.

The species presence or absence in relation to canopy cover would be determined by among other factors whether the species is a light, shaded or dark species. Light species would most probably be found in low canopy cover as exemplified by *Macaranga capensis*. Kichuchenyi fragment had the lowest altitude, canopy cover and no of species sampled. The fragment is heavily disturbed and there are fewer canopy trees in comparison to the other fragments. The species sampled here include *Phoenix reclinata*, *Milletia oblata* and *Prunus Africana* which are either light or adaptive species. Species studied in this research were afromontane, the altitude of Kichuchenyi wouldn`t allow most of these species to favorably survive since most grow at a higher altitude than Kichuchenyi`s average (1478.77m above sea level). It is also notable that the larger fragments (Chawia, Kichuchenyi and Vuria) had majority of the species studied. With a larger area, there were more chances of having mixed conditions which include different altitude ranges and species occurrence. Presence of all succession species in a forest would result in a higher abundance of the species studied in this research. Biodiversity also thrives in larger habitat than in smaller fragmented ones,

thus with this explanation, it was as observed with more species in these larger fragments. Chawia is such a fragment here with all species present except *Rapanea melanophloes*.

Kichuchenyi was the most fragmented of all and it had few species sampled. The presence of a huge rock here may have played a role in protecting the fragment from complete fragmentation with tree poachers unable to access some parts of the fragment. The extent of fragmentation can be seen in the light class (17%) which was the lowest. Chawia fragment had most species in this study sampled present with the highest altitude on its southern part where species like *Craibia zimmermannii* and *Leptonychia usambarensis* were present. Macha and Mwachora fragments are adjacent to each other separated by the Wundanyi - Mwatate road. Similar species were observed here due to the perceived similar conditions. Mwachora was at a higher altitude (1621m) while Macha was at (1594m). The fragments were also surrounded by human settlement and farms with subsistence. There was tree poaching observed and this might explain the similar light class of (19%) probably attributed to similar effect of activities that reduce canopy cover in the two adjacent forests.

4.1.1 Functional groups

Functional groups can briefly be described as follows: - Colonization groups; they include Non-regenerating pioneers, fast growing emergent trees and forest colonizers. These plants will grow in soils with high N and P, high solar radiation, in forest gaps where they face less competition and they include light dependent and some adaptive species. Others include slow growing sub canopy trees, fast growing emergent trees, slow growing canopy trees, understory trees and fast growing sub canopy trees. These are the adaptive, shade tolerant and shaded species.

4.1.1.1 Light dependent species

Pioneer species: These are fast growing species that colonize the forest gaps or places in a forest that are full of light outgrowing other species which may compete with them e.g. for light. These species are important because depending on how they colonize and grow on the forest floor, they give way for other functional groups to colonize the forests gaps as well (Figure 4.1).

Extremely light dependent species: These are species which were found to occur in areas with least canopy cover and that were fragmented, examples being Fururu and Kichuchenyi fragments.

Correlation of variables (table 3.4 and 3.9) suggests that *Polyscias fulva, Macaranga capensis, Prunus africana* are light dependent species. All three being either pioneer species or extremely light depending species, MCA specifically was observed to grow in gaps with investment in petiole lengths as opposed to branching, as well as a low wood density. This was observed in the PCA analysis where by MCA occurred on axis 2 (table3.23) which had negative correlations with wood density (smaller wood density and hence investment in growth), positive correlation with petiole length (hence investment in petioles than branches with longer petioles), positive correlation between petiole length, light class and leaf thickness also being characteristics of a pioneer species.

Correlation for *Polyscias fulva* were most probably affected by the few samples collected owing to the few samples found (n=4), thus resulting in correlations more or less similar to *Macaranga*. From its sampling, there is no doubt it is a pioneer species as well. Its correlations were similar with the species also occurring on Axis 2 of the PCA analysis. *Prunus africana* is an endangered species that was found by (Nickmans and Muys, 2011) to be an extremely light depending species. *Prunus africana* occurred on axis 1 with correlation similar to those of light species. It also has a low wood density (negatively correlated with axis 1). Nitrogen, Phosphorus and wood density were also negatively correlated with the other variables. *Newtonia buchananii* was a species with bipinnate leaves, (Nickmans and Muys, 2011) established that this was a light species that also grew in patches. Correlations between foliar Nitrogen-leaf thickness and L.D.M.C.-petiole length suggest that this is a light species.

Edge species: These species mostly grew along the edges of forests and were observed to have high affinity for lit areas.

Light dependent species are expected to have varied correlations depending on the category. Those investing in fast growth will have low leaf thickness, high foliar N and P.

According to (Nickmans and Muys 2011), light dependent species are expected to have low N and P. High L.D.M.C., Petiole length and leaf thickness, these species are also expected to have N negatively correlated with thickness. Nickmans also observed that N and L.D.M.C. were inversely related. Lit species are expected to have low wood density and longer petiole lengths as they invest in vertical growth and less branching. These species had the ability to remain under the lower layers of the forest canopy with less maximum heights compared to the trees in the canopy e.g. *Xymalos monospora* (which was abundant on the forest edges), *Tabernaemontana stapfiana* and *Xymalos monospora.* In Iyale *X. monospora* and *M. lanceolata* saplings were observed to occur together along the forest edges.

Maesa lanceolata, *Milletia oblata*, *Albizia gummifera* and *Tabernaemontana stapfiana* were found to be edge species (Nickmans and Muys 2011). The former was observed to occur in all fragments with the exception of Kichuchenyi (see table 3.1). Its ability to inhabit the edges of the forest was remarkable and it is a bio-indicator for the edge effect and can also indicate fragmentation in case they occur on patches found inside a forest. Thus this makes *Maesa lanceolata* a very important species especially when it comes to forest conservation monitoring. In the PCA correlations all these species occurred on axis 1, implying that these species had a high leaf thickness, L.D.M.C, light class and altitude while they had lower values for petiole length wood density, N, P, dry and fresh mass.

4.1.1.2 Shade species

Adaptive/Shade tolerant species: These are species that adapt to changing light conditions and are more abundant in the understory that are shaded as compared to the adaptive species. This is the reason as to why they are separated from the other adaptive species, (abundance in the shaded understory). Adaptive species on the other hand invest in growth when in shaded conditions and can occur in every condition throughout the forest, (Nickmans and Muys, 2011) observed that *Syzigium guinensee*, *syzigium schlerrophylum* and *Rapanea melanophloes* were adaptive species. In this research it is notable that these species were prevalent in fragments that were cold and at high altitudes, suggesting that they may have been affected more by fragment altitude than light conditions. There were no significant correlations observed; Leaf thickness-foliar N, N-P and L.D.M.C-leaf thickness had negative correlations as well. In the PCA *Rapanea and Syzigium schlerophyllum* occurred on axis 1 and PC 1 and had a high leaf thickness, L.D.M.C, light class and altitude while they had lower values for petiole length wood density, N, P, dry and fresh mass. On the other hand *Syzigium guinensee* occured on PC1 with score 2 (table 3.23), the species also was prevalent in all fragments except Ndiwenyi, Mwachora and Macha. *Rapanea and Syzigium schlerophyllum* occurred in the high altitude fragments like Fururu, Vuria and Iyale only and they seemed to adapt only in these fragments.

True shade/Shaded species: are expected to have mixed correlations depending on; the conditions within which they grow and species specific plasticity. This is exemplified by the fact that long petiole lengths are not only found in lit species but also some dark species like *Strombosia scheffleri*. Shaded species are expected to have higher wood densities as opposed to observations made for the lit species. These species spend all their life in the shaded conditions from saplings to adult trees, (Nickmans and Muys, 2011) observed that *Chrysophyllum gorungosanum* and *Craibia zimmermanii* were shade tolerant species. In the PCA *Craibia* occurred on PC1 with scores 1 while *Chrysophyllum* occurred on PC1 with scores 2. In spite of this, both species were found to occur only in Chawia and Vuria fragments.

This may be as a result of these two fragments having conditions that support all the species groups from pioneer to shade tolerant species (Figure 4.1), hence forests that have undergone the full succession cycle with all canopy species present. An aspect that could be attributed to the size of these fragments, (Chawia 2nd largest and Vuria 3rd largest, see table 2.1). The larger the forest, the more the species (the larger the habita, the more the biodiversity expected) It was also observed that *Leptonychia usambarensis* and *Strombosia scheffleri* were true shade species only being found in the understory, an aspect noted by (Nickmans and Muys, 2011 as well).

It is also notable that species in the same functional groups clustered together: *Maesa lanceolata* and *Prunus Africana* (light species), *Leptonychia usamberensis*, *Tabernaemontana stapiana* and *Xymalos monospora* (adaptive species). Species occurence was affected by other factors as well, e.g. *Tabernaemontana stapfiana* and *Phoenix reclinata;* the fruits of these species are a delicacy for monkeys and frugivores who in turn help in dispersing their seeds across the fragments, hence their prevalence in majority of the fragments.

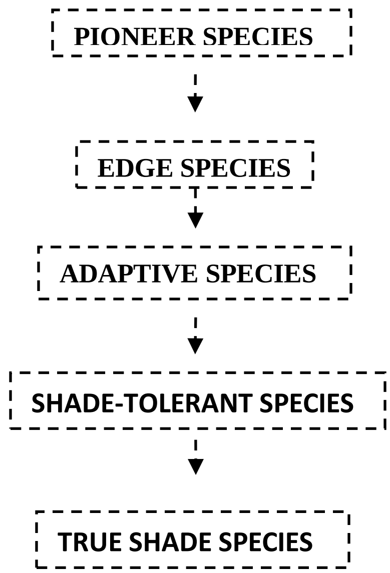

Figure 4.1: Order of succession in a forest floor

The results from this study confirm that tree traits are associated in relation to altitude and canopy cover. Most species their *P* value occur as greater than the critical value of the analysis, resulting in this decision. Despite this, the sampling size before and after averaging the data for analysis was small, and probably the study would have been more effective with a larger sample size. However, the target species were also few in the forests, this as exemplified by *Polyscias fulva and Rapanea melanophloes* which were least prevalent species in the forests, yet they were very important for this study. It is observed that tree species were associated with each other in relation to their habitat and the existing environmental conditions. Species correlations had strong significance which confirmed the hypothesis of this study. Due to the few number of tree species saplings in the forests, the most fragmented forests had fewer species sampled. This may have resulted in misleading results since the samples may not have been adequate to get proper conclusions. This is evident in cases that had non normal data for correlation analysis whose multiple correlations had majority of r values as perfect (i.e.1).

As part of the Eastern Arc mountains forests, the Taita hills forests is an important biodiversity hotspot in the world with endemic flora and fauna species. This research is a step towards conservation, management and restoration of the Taita hills forests. It gives a cue on which tree species are dominant and indigenous, thus a direction to which species to emphasize during a forestation endeavors. These being an afro montane forest, specific species thrive in this environment and this is an aspect that should be put in mind when managing these forests.

Proper management and restoration efforts in these forests will in turn help in conservation of the biodiversity in this habitat including the critically endangered birds and reptilian species found here.

4.2 Conclusion and Recommendations

Using leaf and wood variables is indeed a method that can successfully be done to study autecology and physiology of plant species e.g. in a forest. This research focused only on eighteen species (18) which were found to be dominant in a previous study by Koen Thijs who made plots in the Taita Hills and studied mature tree species while this study was done on saplings (0.5-3) meters and in my observation the forest floor can be dynamic over a short period of time. Thus this research was successful in studying these species but there is need to add other species which may be important and not captured here. An example to the argument of rapid changes on the forest floor in the Taita hills over time is the fact that earlier studies found some species present e.g. (Nickmans and

Muys, 2011) found *Podocarpous latifolius* and *Ocotea usambarensis* while during this study only two podo saplings were spotted in Ngangao while no *O. Usambarensis* was found in all fragments studied. Some species saplings were found to be abundant in the forests during these previous studies but today they are mature trees and have no representative saplings, probably a sign that the forest is undergoing succession.

Species previously studied by Nickmans and Muys would probably be mature trees or have grown beyond the 3.5m height at the time of this study. Thus a probable explanation of different observations and conclusions for the two research endeavors undertaken within a two year gap. All in all this research is a good way of monitoring forest growth processes and relating different fragmented forests like the ones studied, by understanding the results of such a venture proper measures can be put e.g. in knowing which species to plant at which locations like when doing a forestation programs; since different species responded differently in different fragments. Aerts *et al.,* (2011) found that there was high species dissimilarity of up to 69% in these fragments, with variation in species composition that changed with a biotic gradient relating to altitude; hence an explanation for some species having affinity for certain altitudinal ranges. Farther more the species had over 98% similarity for the highest and 95% for the lowest values between species. Thus these species had a high correlation in comparison of their wood and leaf variables.

Indicator species that are associated with forest margins (e.g. *Maesa lanceolata* in the Taita hills) and gaps were more frequent in smaller forest fragments. This can be an indication for future conservation on the extent of fragmentation in a forest. In regards to absence of species saplings like those of *Ocotea usambarensis* which should have been one of the species in this study but was excluded because of its absence; (Codeiro *et al.*, 2009; Lehouck *et al.*, 2009) found that in forests efficiency of seeds dispersal of different tree species between fragments decreased and as habitat quality deteroriates, species gradually become locally extinct eventually. (Lewis, 2009) found that present and future extinctions may lead to biotic homogenization and increased dominance by generalists or early succession species. My observations were that more species of interest were found in large fragments like Chawia and Ngangao, while on the other hand more species were present in Chawia which was a large and fragmented/ disturbed forest. Probably further work will be needed to see if disturbance had a positive effect on species diversity.

While doing the field work I also noticed that little attention is given to the plantation forests and some researchers working in the Taita hills viewed these as a nuisance and they preferred the indigenous forests. There may be plenty of reasons for this many of which are justified; but a spot check at one the plantation patches in Iyale shows lots of positive regeneration on the species of interest in this study e.g. *Macaranga capensis* and *Syzigium* sp. Thus I believe these planted forests if given time can help in regenerating fragmented indigenous species as well. This study also brings out some aspects about the quality of the forests in regards to species composition. Thus conservation efforts should be not only conserving natural resources in terms of their quantities but also in terms of their qualitative aspects as well.

Future research should put into account studying all plant species that are present in the forests. This would add on to the biodiversity bank of knowledge on species present and probably discover new species and subspecies present. Research should be designed to be able to overcome the challenges of distance and terrain in the fragments, because there are important aspects that may be missed by excluding parts of the fragments because of the former and the latter, this being in the case of inability of my research to cover Ronge and Sagalla. There should also be consideration on how changes in the forests occur, in terms of species growth, migrations, succession and probably climate change. These changes may affect results especially for progressive projects which take a few years to implement.

Research on plant species autecology should also include a wider scope of the soil characteristics, aspects of weather like rainfall, humidity and temperature. This wide scope would also give a better explanation and interpretation of results that may be obtained. In terms of the conservation status of the species studied in relation to this research`s findings. There is a natural balance existing in the Taita hills forest fragments studied, one that is allowing for the natural succession of species across the board. There is no particular fragment visited that had a uniform stand of indigenous trees for one species (i.e. for the eighteen studied) except for the planted patches. There is a mixture of all functional groups for the saplings studied, thus an indication that the forests are naturally recovering from disturbances that may be natural or artificial/ anthropocentric. It is also difficult to determine what stage of succession the forest is in as a whole, given the matrix of fragments thus further studies including the mature trees would be required to ascertain this.

Species like *Tabernaemontana stapfiana* and *Phoenix reclinata* are abundant, while others like *Prunus Africana, Milletia oblata, Podocarpous latifolius and Ocotea usambarensis* may probably be less because of their demand for various anthropocentric uses. This as exemplified by the poaching of a mature *Prunus Africana* tree at the main entrance of Macha fragment, after I visited the Taita hills in December 2013, having seen the tree in December 2012 while on my field campaign. Just like in zoological poaching of endangered wildlife like elephants and rhinos, tree poaching is a challenge that may not have been amplified as such. It is such a problem in fragmented forests that are unprotected, not gazzeted and adjacent to heavy human presence. Mature trees are fell for timber, fire wood, cattle feed and honey harvesting. The rest except honey harvesting are species specific, and would decimate the presence of individual species greatly, e.g. absences of *Ocotea usambarensis* because of high demand for its wood.

Honey harvesting occurs with people felling trees to harvest honey from natural hives created by bees on trees, this affects all species because mostly bees settle on trees of their choice. As I observed most trees were fell in Fururu fragment and Chawia, these looked very mature trees with more than ten years old, as counted from the rings on the trunk., thus wasting many years of tree growth unsustainably to meet an anthropocentric need that will in turn lead to deforestation in the long run. This work brought out various qualitative rather than quantitative aspects of the Taita hills forest fragments and more research would be required to come up with even better conclusions to this regard.

More mass awareness needs to be impacted on the locals living in areas with biodiversity importance like the Taita Hills, in order to enable them understand the importance of these habitats both to man and nature.There is need to streamline policy issues regarding the bodies in charge of managing these resource in order to enable for better conservation and management. In this case, The National government of Kenya and The Taita Taveta County government need to work together in conserving the forests whether this responsibility has been devolved to the county government or not.

There is also need to have results from the numerous research carried out in the Taita hills put to use. In my opinion, many international organizations and students simply undertake their research and disappear with the data in a bid to meet donor expectations, complete their research, studies and publish scientific literature for fame of having done their research in Africa. The results do not get to the relevant bodies (e.g. state departments in charge of managing these forests), for proper implementation and use.It is also the initiative of such relevant bodies to seek and audit research findings from such important biodiversity hotspots so as to be able to implement the findings in policy making. Thus managing and conserving such an important resource is a duty of all.

CHAPTER FOUR

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APPENDICES

Appendix 5.1: Average values for variables of individual species in the Taita Hills forests

Sp.	Leaf T	Pet L	DM	FM	LDMC	N	P	Wood D.	Alti.	L. Class
AGU	0.23	59.44	2.87	7.35	37.39	2.24	0.13	0.53	1626.25	19.49
CGO	0.15	24	0.61	2.04	36.38	1.89	0.13	0.63	1695.4	22.61
CZI	0.17	28.912	0.78	1.98	39.86	0.98	0.053	0.79	1595.84	22.12
LUS	0.12	9.06	0.21	0.72	19.58	1.54	0.087	0.6	1679.13	21.83
MCA	4.63	210.04	2.21	3.18	1651.36	1.55	0.083	0.38	1791.45	21.62
MLA	1.01	35.34	0.69	2.52	118.41	2.25	0.13	0.50	1685.49	19.2
MOB	0.14	39.44	0.93	3.31	31.94	2.31	0.14	0.62	1685.21	19.81
NBU	0.1	29.71	4.13	8.59	58.60	1.46	0.08	0.59	1672.46	21.81
PAF	0.48	12.06	0.35	0.77	96.23	2.16	0.12	0.76	1711.41	17.89
PFU	0.12	111.27	9.02	43.13	15.74	1.68	0.1	0.26	1806.05	18.11
PRE	0.18	781.73	118.18	346.08	36.37	1.79	0.11	0.65	1668.46	20.67
RME	0.3	7.25	0.40	2.35	19.98	1.67	0.1	0.60	1912.48	22.15
SGU	0.24	11.48	0.48	1.57	35.81	1.77	0.09	0.7	1647.52	20.91
SSC	0.22	17.08	0.47	1.41	47.43	1.57	0.067	0.75	1676.79	22.20
SSH	1.6	8.30	0.61	1.49	75.00	0	0	0.65	2036.27	21.53
TST	0.19	22.76	0.55	3.79	14.65	1.77	0.11	0.55	1712.46	22.03
XMO	0.24	15.39	0.45	2.18	21.02	2.041	0.11	0.57	1756.07	20.69

Species with zero values had no samples collected for the variables

Appendix 5.2: List of the Taita Hills forest fragments consisting of both natural and planted forests (Taita Hills stakeholders' workshop report 2005)

FOREST FRAGMENT	TYPE	GAZZETEMENT
1. Chawia	Indigenous + some exotic	Taita Taveta County govt.
2. Fururu	Indigenous	Govt. Gazzeted
3. Kinyeshamvua	Eucalypts + pine	Govt. Gazzeted
4. Mwandongo	Eucalypts + pine + caltris	Govt. Gazzeted
5. Mwarunga	Pine/caltris	Taita Taveta County govt.
6. Ndiwenyi	Indigenous	Taita Taveta County govt.
7. Ngomenyi	Indigenous	Govt. Gazzeted
8. Susu	Mixed	Govt. Gazzeted
9. Vuria	Exotic + some indigenous	Taita Taveta County govt.
10. Boma	Exotic	Govt. Gazzeted
11. Ighi ikumu	Black wattle	Taita Taveta County govt.
12. Irizi	Black wattle, Eucalypts, cypress,	Taita Taveta County govt.
13. Iyale	Mixed	Govt. Gazzeted
14. Jaycee	Black wattle Mgange	Taita Taveta County govt.
15. Kalangu	Bare	Taita Taveta County govt.

16.	Kichuchenyi	Indigenous	Taita Taveta County govt.
17.	Kilulunyi	Exotic	Govt. Gazzeted
18.	Macha	Cypress+blackWattle, Eucalypts	Govt. Gazzeted
19.	Mbili	Eucalypts + black wattle	Govt. Gazzeted
20.	Mwambirwa	Exotic + some indigenous	Taita Taveta County govt.
21.	Mwanganini	Pine	Taita Taveta County govt.
22.	Mwarungu	Mixed	Taita Taveta County govt.
23.	Ngangao	Indigenous	Both
24.	Weni Mbogho	Indigenous	Govt. Gazzeted
25.	Weni mwana	Indigenous	Govt. Gazzeted
26.	Choke	Indigenous	Govt. Gazzeted
27.	Goye	Shrubs	Both
28.	Igho mkundu	Encroached	Taita Taveta County govt.
29.	Ikuminyi	Encroached	Taita Taveta County govt.
30.	Irizi		
31.	Jayce		
32.	Kitobo		Taita Taveta County govt.
33.	Lotima		Taita Taveta County govt.
34.	Mbololo	Indigenous	Govt. Gazzeted
35.	Mchungunyi	Pine	Govt. Gazzeted
36.	Modangache/Weni tole	Eucalyptus	Taita Taveta County govt.
37.	Mraru	Shrubs + eucalyptus	Taita Taveta County govt.
38.	Mtete	Bare rock	Govt. Gazzeted
39.	Mwachora	Indigenous + eucalypts	Govt. Gazzeted
40.	Mwarangu/Mwakinyambu	Encroached	Govt. Gazzeted
41.	Ronge		Taita Taveta County govt.
42.	Sagalla		Voi Municipal Council
43.	Salaita		Taita Taveta County govt.
44.	Sungululu	Eucalyptus	Taita Taveta County govt.

Appendix 5.3: List of 18 species studied with scientific and family names

Sp	Abbrev.	Family
1. *Albizia gummifera* (JF Gmel.) C.A. Sm.	AGU	*Mimosaceae*
2. *Chrysophyllum gorungosanum* Engl.	CGO	*Sapotaceae*
3. *Cola greenwayi* Brenan	CGR	*Sterculiaceae*
4. *Craibia zimmermannii* (harms.) Dunn.	CZI	*Papilionaceae*
5. *Leptonychia usambarensis* K. Schum.	LUS	*Sterculiaceae*
6. *Macaranga capensis* (Baill.) sim.	MCA	*Euphorbiaceae*
7. *Maesa lanceolata* Forssk.	MLA	*Myrsinaceae*
8. *Milletia oblata* ssp. teitensis Gillet	MOB	*Papilionaceae*
9. *Newtonia buchananii* (Bak.) Gilb. & Bout.	NBU	*Mimosaceae*
10. *Phoenix reclinata* Jacq.	PRE	*Palmae*
11. *Polyscias fulva* (Hiern.) Harms	PFU	*Araliaceae*
12. *Prunus africana* (hook f.) Kalkm.	PAF	*Rosaceae*
13. *Rapanea melanophloeos* (L.) Mez	RME	*Myrsinaceae*
14. *Strombosia scheffleri* Engl.	SSC	*Olacaceae*
15. *Syzigium guineense* (Willd.) DC.	SGU	*Myrtaceae*
16. *Syzigium schlerophyllum* Brenan	SSH	*Myrtaceae*
17. *Tabernaemontana Stapfiana* Britten	TST	*Apocynaceae*
18. *Xymalos monospora* (Harv.) Warb.	XMO	*Monimiaceae*

Abbreviations indicated in the table were used in the data matrices during data analysis to replace the long scientific names for the tree species