ASSESSMENT OF THE FLORAL DIVERSITY ALONG DISTURBANCE GRADIENT IN KAYA MUHAKA FOREST, MSAMBWENI DISTRICT

BY

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ABSTRACT

Kaya Muhaka Forest in the Kenyan Coast is one of the remianng lowland forest patches belonging to Zanzibar-Inhambane vegetation mosaic of Eastern Africa, which are rich in endemic and threatened flora and fauna. Although gazetted and protected as a national monument, the forest biodiversity is still endangered. This research attempted to establish the flora diversity along disturbance gradient ranging from the forest core to the agro-ecosytems of the forest. The belt transect method was used where quadrants of 20m x 20m placed at intervals of every 250m were systematically selected along two parallel transects of 3km long each and all the plant species recorded. An additional nine plots of similar size and placement were surveyed on three parallel transects of 1km each established from the edge of the forest to the forest core. The flora diversity was calculated by use of the Shannon-Wiener Index of diversity. The Importance Value Index, forest strcture, the species area curve and dominance were determined. Other ecological attributes established included species composition, and canopy cover. The distribution and conservation status of endangered species was studied by means of random walks and georeferencing the target species using Global Positioning System Forest disturbance was also recorded by use of indictaors such as presence of paths, tree stamps and evidence of firewood collection. *Scorodophloeus fisheri* (Taub) J. Lion was the most important species in the forest and *Cocos nucifera* L. was the most important in the farmland. A total of 492 species in 92 families were recorded. The forest was found to be heavily disturbed with numerous paths crossing it. The threatened speices are not protected and they risk being logged. There was a high diversity of plant species in the Kaya Muhaka forest and agro-ecosystems. The forest is homogenous with most of the species being indigenous and endemic. The protection of the forest should be improved. Further research should be done on the conservation, presence and mapping of the endangered species in Kaya Muhaka forest.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The coastal forests of East Africa, covering an area of approximately 3,170 km^2 from southern Somalia to northern Mozambique including small amounts of forest in south eastern Malawi and eastern Zimbabwe, are one of the top ten priority ecosystems for biodiversity conservation on the African continent (Burgess and Clarke, 2000). In Kenya, these fragmented, sometimes in relatively miniature forest relicts conserved as 'Kayas', have been earmarked as one of the 25 world's hotspots of biodiversity. To qualify as a biodiversity hotspot on Myers *et al.,* (2000) edition of the hotspot-map, a region must meet two strict criteria: it must contain at least 0.5% or 1,500 species of vascular plants as endemics, and it has to have lost at least 70% of its primary vegetation. The kayas are small relict patches of forests in Kwale and Kilifi districts which once sheltered the fortified villages of the Mijikenda. They were managed and conserved by elders (The Ngambi), but the power and respect for the elders ended during the colonial and later the post colonial times. Kaya Muhaka is located about 32 km south of Mombasa and 5.5 km inland from the Indian Ocean. With about 150 ha, it is one of the largest Kayas in Kwale (Myers *et al.*, 2000). However, despite Kaya Muhaka being of high biodiversity value both at the national and international level, it is facing great threats which are driven by human population pressure. The prevailing threats to the forest include agricultural encroachment, charcoal burning, firewood collection, cutting of building material, over exploitation of ornamental and medicinal plants and invasion of exotic species. Unsustainable logging especially of old threatened tree species such as *Julbernardia magnistipulata* (Harms) Troupin, *Cynometra suaheliensis* (Taub.)

Baker f. and *Synsepalum subverticillatum* E.A.Bruce has highly contributed to forest degradation in the recent past. However, the Kaya is still used by a group of elders for social-cultural activities. There is paucity of information on the diversity, disturbance and status of threatened species within Kaya Muhaka. For decades, conservation of biodiversity within Kaya Muhaka has been compromised by continued anthropogenic effects exacerbated by gradual decline of traditional values coupled with rising poverty among the rural communities. This is despite the important role the Kaya has provided through a multiplicity of ecosystem services at landscape level. These dwindling landscape services need to be understood and management strategies developed to improve the livelihoods of the local communities in line with Kenya's Vision 2030 section 4.6 on environment management.

1.2 Problem Statement

The most significant current threat to the coastal forests of the Eastern Africa biodiversity hotspot is the expansion of agriculture (UNESCO, 2009). The soils are poor and can only support subsistence agriculture with most agricultural development involving short term shifting cultivation concentrating on food crops such as cassava, maize, coconut and banana. The human population is increasing at 2.5–3.5 percent annually and the demand for additional farmland increases every year (UNESCO, 2009). Commercial agricultural development in the form of coconut, sisal, cardamom and cashew nut plantations has led to the loss of lowland coastal forests and other natural habitats (UNESCO, 2009). Recently, commercial growing of *Casuarina equisetifolia* L. and *Jatropha curcas* L. species has been common in landscapes further threatening the indigenous forest species.

The communities living around Kaya Muhaka practice subsistence agriculture for their livelihoods and often turn to overexploitation of forest resources for their livelihoods and social-economic needs. The fallows maintained by the farmers may also harbor unique flora which is never studied. In spite of great international interest in biodiversity and its conservation, only few detailed floral checklists exist for much of Eastern Africa. Futhermore, those that do exist have been made by biologists who have spent varying periods in a particular locality. The collecting effort varies considerably between them making it extremely difficult to compare the flora of one geographical area with another (Coe *et al.*, 1999).

1.3 Objectives

The main objective of this research was to assess the diversity of plant species along disturbance gradient in Kaya Muhaka forest, Msambweni District.

The specific objectives were;

a) To determine the diversity of flora in agro-ecosystems, forest edge and forest core in Kaya Muhaka.
b) To determine forest structure, species richness and composition in Kaya Muhaka.
c) To determine the disturbance, distribution and conservation status of threatened plant species in Kaya Muhaka.

1.4 Hypotheses.

a) The flora diversity of Kaya Muhaka forest is low due to human induced degradation.

b) There is high disturbance in Kaya Muhaka forest.

c) The threatened species in Kaya Muhaka are poorly conserved due to high disturbance.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conservation Status of East African Coastal Forests

In this thesis, the term forest will be applied according to the FAO (2006) as a stand of trees in a minimum area of land of 0.05 to 1 Ha with a canopy cover (or equivalent stocking level) of more than 10% to 30% with trees with the potential to reach a minimum height of 2m to 5m at maturity in situ. The term 'coastal forest' will be defined as all forest on the land over the sedimentary (and intrusive volcanic) rocks on the coastal plains and plateau, to the east of the exposed basement coastal land (Lehmann and Kioko, 2005). A biodiversity hotspot is a region with high species diversity and concentration of many narrowly endemic plant and animal species (Robertson and Luke, 1993; Myers *et al.*, 2000). Tropical forests are facing annihilation worldwide. This is due to unsustainable harvesting of their timber and non-timber products for economic gains and also due to burning for various reasons including clearing for agricultural use. Over the past decade, more than 13 million hectares of tropical forest was cleared every year, and the largest population of this is the tropical dry forest type (Bawa *et al.,* 2009). There are about 4,050 vascular plant species in the coastal forests of Eastern Africa biodiversity hotspot and approximately 1,750 (43%) of the plant species are endemic. About 70% of endemic species and 90% of endemic genera are found in forest habitats. Furthermore, about 40% of the endemic plant species are found in only one single forest. For example, the Rondo Forest in southern Tanzania has about 60 endemic species and two endemic plant genera.

The high species endemism in these forests is also exhibited in faunal diversity. With more than 633 species of birds recorded, 11 of them endemic and 11 species of the 200 species of mammals, are endemic with some threatened species like the black rhino (*Dicens bicornis*) and savannah elephants (*Loxodonta africana*). Of the close to 250 known reptile species more than 50 of these are endemic. The hotspot also has over 85 amphibian species 6 of which are found nowhere else like the Shimba Hills banana frog (*Afrixalus sylvaticus*). There are 220 fish species living in the fresh water ways of the coastal forests of eastern Africa and more than 30 of these are endemic. The levels of endemism within some invertebrate groups are significantly higher than among vertebrates. About 80% of millipedes and 68% of molluscs are endemic. Burgess and Clarke (2000) found that 33% of the coastal forest flora is endemic or near endemic while 49.3% is widespread with only 3% occurring in both the Swahilian and Guineo-Congolian regions. Although tropical forest conservation is a top priority for human and environmental health, deforestation persists, mainly because of food and economic needs. No community will totally give up economic activities for the sake of ecological integrity unless it is given alternative economic activities from which to draw its livelihood (Coe *et al.*, 1999). Indigenous forest cover has reduced by more than 60% over the last 50 years, largely due to agricultural intensification.

The once vast natural habitats have been reduced into 'islands' of vegetation relics (Bussman, 2002). Today such habitats are undoubtedly few and extremely vulnerable due to human pressure through over exploitation of forest resources like timber and firewood in the potentially agriculturural zones of Kenya. However, in spite of their environmental and ecological vulnerability the natural remnants are under protected. It is necessary that they be protected as they are our heritage (Myers *et al.,* 2000). Kaya Muhaka forest is one such remnant of the indigenous forests. The Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya hotspot (figure1) is one of the smallest of the 25 global biodiversity hotspots. It qualifies by virtue of its high endemicity and a severe degree of threat. Although the hotspot ranks low compared to other hotspots in total numbers of endemic species, it ranks first among the 25 hotspots in the number of endemic plant and vertebrate species per unit area (Myers *et al.,* 2000).

The Convention on Biological Diversity (CBD) makes it clear that use of biodiversity must be on a sustainable basis and that current use must not lead to long term decline. Several articles of the CBD are particularly relevant to efforts that focus on conservation and sustainable use of biodiversity (Coe *et al*., 1999). The use value of biodiversity relates to its being a key resource base for many subsistence and economic purposes. It provides many ecosystem services such as providing food, medicine, genetic resources, industrial materials and recreational exploitation. Importantly, biodiversity regulates the level of toxic gases in the soil and atmosphere thus mitigating climate change effects and supportive services such as control of soil erosion and combating desertification. The passive use of biodiversity concerns the ecological 'services' that it provides such as atmospheric, hydrological and climatic regulation, nutrient cycling, soil formation and maintenance, pest control and pollination . Fundamentally, therefore, the maintenance of biodiversity is essential for the normal functioning of ecosystems and the continued provision of goods and services upon which increasing human populations depend (Coe *et al*., 1999). Current economic valuation of biodiversity focuses only on use values and tends to promote short term consumptive exploitation, which generally has a negative impact on species and ecosystems threatening the long term productivity. Efforts to promote sustainable use must acknowledge that current patterns of use are on the whole destructive. Exploited ecosystems are at increasing risk of being destabilized through increased rates of use due to human population growth, environmental change and unpredictable ecological processes. Efforts to conserve biodiversity must therefore seek to limit rates of consumptive use as well as ensure that local communities obtain economic benefit from biodiversity conservation (Coe *et al*., 1999). An obvious approach to conserve plant biodiversity is to map distributional patterns and look for concentrations of diversity and endemism (Gentry 1992). Further, management of forest requires understanding of its composition in relation to other forests, the effects of past impacts on the present status and the present relationship of the forest with surrounding land uses (Geldenhuys and Murray 1993)

Plants are recognized as a vital part of the world's biodiversity and an essential resource for the planet. They play a key role in maintaining the planet's basic environmental balance and ecosystem stability and provide an important component of the habitats for the world's animal life (Mligo *et al.,* 2009). In order to effect efficient plant conservation, the first step is to understand and document what diversity exists, their distribution and threats. Botanical inventories therefore are of crucial importance to effective conservation planning.

2.2 Uniqueness of the Forests

Coastal forests are an important and highly threatened centre of endemism for plants (*c* 550 endemic species), mammals (6 species), birds (9 species), reptiles (26 species), frogs (2 species), butterflies (79 species), snails (>86 species) and millipedes (>20 species) (Burgess *et al.*,1998b). Endemic species are concentrated in the forests of the Tana River, between Malindi in Kenya to Tanga in northern Tanzania, and in southern Tanzania. Forests with highest numbers of endemics are: lower Tana River, Arabuko-Sokoke, Shimba Hills (Kenya); lowland East Usambara, Pugu Hills, Matumbi Hills, Rondo and Litipo and other plateaus near Lindi (Tanzania); the Tanzanian offshore island of Pemba; Bazaruto archipelago (Mozambique), and tiny forest remnants of southern Malawi, eastern Zimbabwe and Mozambique (Burgess *et al.*,1998a). Most coastal forest endemics have a narrow distributional range, often exhibiting single-site endemism or with scattered distributional patterns. They are best interpreted as relicts and not the result of recent evolution. Relictualization probably started with the separation of the ancient Pan African rainforest into two parts during the Miocene (Burgess *et al.*,1998a).The pattern of endemism in the Coastal Forest Mosaic is complex, reflecting the wide range of habitats and heterogeneous forest types, a high degree of turnover of local species between adjacent forest patches and many disjunct distributions ((Burgess and Clarke, 2000).The ecoregion, which includes the islands of Zanzibar and Pemba, is a mosaic of forest patches, savanna woodlands, bush lands, thickets and farmland. The highest biodiversity is found in the various kinds of closed canopy forest vegetation: dry forest, scrub forest, *Brachystegia* (*miombo*) forest, riverine forest, groundwater forest, swamp forest and coastal/afromontane transition forest (Burgess and Clarke, 2000).Closed canopy forests, however, makes up only 1 percent of the total area of the Coastal Forest Mosaic (Burgess and Clarke, 2000).

Overall, there are more than 4,500 plant species and 1,050 plant genera with around 3,000 species and 750 genera occurring in East African coastal forest. At least 400 plant species are endemic to the forest patches and about another 500 are endemic to the intervening habitats that make up 99 percent of the ecoregion area. The majority of these species are woody but there are also endemic climbers, shrubs, herbs, grasses and sedges (Burgess and Clarke, 2000). A substantial proportion of the endemic plants are confined to a single forest (for example, Rondo Forest, Tanzania, has 60 strict endemics and Shimba Hills, Kenya, has 12 (Burgess and Clarke, 2000).

The flora as a whole has affinities with that of West Africa, suggesting an ancient connection with the Guineo-Congolian lowland forests (Lovett, 1993). Endemism is primarily relictual rather than recently evolved (Burgess and Clarke, 2000; Burgess *et al.* 1998). Among the best known plants in the hotspot are the species of the African violet (*Saintpaulia* sp). The 40,000 cultivated varieties of the African violet, which forms the basis of a US$100 million per year house plant trade globally, are all derived from just three species found in coastal Tanzanian and Kenyan forests. The biodiversity hotspot also contains 11 species of wild coffee, 8 of which are endemic; none of them has been exploited commercially (McGinley and Duffy, 2010). A few such as *Coffea zanguebariae* Lour are under going breeding research trials at the Coffee Research Foundation of Kenya.

Faunal endemism rates have been estimated for forest species in the Swahelian Regional Centre of Endemism (including the transition zone in Mozambique). These are highest in the invertebrate groups such as millipedes (80 percent of all the forest species), molluscs (68 percent) and forest butterflies (19 percent) (Burgess, 2000). Amongst the vertebrates, 7 percent of forest mammals, 10 percent of forest birds, 57 percent of forest reptiles and 36 percent of 13 forest amphibians are endemic (Burgess, 2000). If Mozambique is excluded, endemics include 14 species of birds (including four on Pemba Island), eight mammals, 36 reptiles and five amphibians. (WWF, 2002).In terms of species richness, there are at least 158 species of mammals (17 percent of all Afrotropical species), 94 reptiles and 1200 molluscs As with the plants, endemism is primarily relictual (Burgess *et al.,* 1998) and single site endemism and disjunct distributions are common. This makes it extremely difficult to prioritize the forests in terms of their biodiversity. Burgess *et al.,* 2000) made a preliminary analysis on the basis of species richness and endemism, using vascular plants, birds, mammals, reptiles and amphibians. This showed that different forests are important for different groups. For example, while Arabuko-Sokoke is top for endemic birds and for mammal species richness, it barely makes it into the top ten for plants. Overall, the five most important forests are Rondo (plants and birds), lowland East Usambaras and Arabuko-Sokoke (birds, mammals and reptiles), Shimba (plants and birds) and Pugu Hills (birds and mammals). Pemba Island, with an area of only 101400 ha, is extraordinarily important for birds with four endemic species (Baker and Baker, 2002) while Zanzibar has six endemic mammals and three endemic birds (Burgess, 2000).

2.3 Levels of Protection

Eastern African coastal forests are located within the Swahili regional centre of endemism and Swahili-Maputaland regional transition zone in eastern Africa between 1°North and 25° South, and 34° to 41° East (Burgess *et al.,* 1998). Approximately 3167 km^2 coastal forest remains: 2 km^2 in Somalia, 660 km^2 in Kenya, 697 km^2 in Tanzania, 16 km^2 in Malawi, 3 km^2 in Zimbabwe and perhaps 1790 km^2 in Mozambique. Most forests are small (≤ 20 km^2), and all but 19 are under 30 km^2 in area (Burgess *et al.,* 1998). Over 80% of coastal forest is located on government land, principally Forest Reserves; only 8.3 km^2 is found in National Parks, 6.2 km^2 in Kenya (Arabuko-Sokoke), 2 km^2 in Tanzania (Mafia Island) and tiny patches in Zimbabwe (Burgess *et al.,* 1998). Forests in this biodiversity hotspot are located in two countries and fall under multiple management regimes. Figure 1 shows the major protected areas in and around the hotspot.In Kenya, the protected area network at national level consists of national parks, national reserves, forest reserves, nature reserves and national monuments (Bennun and Njoroge, 1999).

Many of the national monuments on the coast are sacred forests called *Kaya* Forests. At a lower level, many forests are located on trust lands and fall under the control of County and Municipal councils. In some cases the local inhabitants oversee the activities in thw forests. In Tanzania, the protected area network at national level consists of national parks, game reserves, government catchment forests, game controlled areas, forest reserves and nature reserves (Baker and Baker, 2002). Below the national level a large number of forests, particularly in the coastal forest belt, fall under local authorities, owned and managed by the Mijikenda community. In both countries, no exploitation is allowed in national parks and protection levels are generally high. In both countries, confusing and overlapping legislation on the environment and natural resources is being rationalized through the enactment of new polices.

Within the Kenyan area of the hotspot, there are four national reserves; Shimba, Tana River, Boni and Dodori which fall under the jurisdiction of the Kenya Wildlife Service (KWS), (WWF, 2002). The Shimba Hills were gazetted as National Forest in 1903 and then double gazetted (with the exception of two small areas that remained as forest reserves under the control of the Forest Department) in 1968 as the Shimba Hills National Reserve (Bennun and Njoroge, 1999). Protection levels are higher in the area controlled by KWS, as they have armed rangers and a clearer institutional mandate for conservation. The largest of the Kenyan forest reserves is Arabuko Sokoke (417 km2). For the last 10 years this forest has been under multi-institutional management; KWS, the Forest Department, Kenya Forestry Research Institute (KEFRI) and the National Museums of Kenya, (NMK) (Arabuko-Sokoke Forest Management Team, 2002). This arrangement has been taken as a model for other indigenous forests in Kenya but has been rarely implemented. Protection levels suffer from the proximity of the tourist resorts of Malindi and Watamu and the resultant demand for carving wood and timber. The effectiveness of management has been variable over time, being subject to the commitment of the personnel on the ground, the working relationships between KWS and the Forest Department and the level of resources available. Generally, however, management has been more effective than in the other 17 forest reserves (WWF, 2002) within the Kenyan coastal forest belt. In the fragmented forests of the Kenyan portion of the Eastern Arc Mountains (Taita Hills), some patches, including plantation, have been gazetted as forest reserve. Others are on trust land administered by the local county council, some of which have been recommended for gazettement as forest reserves (Bennun and Njoroge, 1999).

The major threats to the natural ecosystems of the world are the increase in human population density and its expectations especially in the developing countries where agriculture is the main basic economic source. In the last 50 years, about 60% of the East African natural habitats have been converted to urban and rural settlements, plantations and croplands (Malombe and Mutangah, 2005). The Convention on Biological Diversity adopted at the 1992 Earth Summit in Rio de Janeiro, acknowledged the need to protect and encourage customary use of biological resources in accordance with tradition cultural practices that are compatible with conservation or sustainable use requirements (Article 10). A number of international gatherings have since been held in relation to this issue, such as the 1998 UNESCO symposium on "Sacred sites, Cultural Diversity and Biological Diversity". They reflect a growing realization of the importance of sacred sites as a component of protected area networks.

The sacred Kaya Forests are situated on the coastal plains and hills of Kenya, East Africa. They are residual patches (from ten to two hundred hectares) of once-extensive diverse lowland forest of Eastern Africa occurring within the Zanzibar-Inhambane Regional Mosaic (UNESCO classification) as shown in figure 1. The Kaya forests are botanically diverse and have a high conservation value, more than half of Kenya's rare plants are found in the coastal region, many in the Kayas (Githitho, 1998). The cutting of trees and other activities that could potentially cause damage to the forest around the Kaya and sacred spots was strictly forbidden by the Kaya Elders (Githitho, 1998). This included collecting or removing dead logs or twigs or any other forest material. Uncommon animals, particularly large snakes, were to be left alone if encountered. Any structures built for ritual purposes used materials from the Kaya forest. In addition to these restrictions on physical interactions at the site, there were behavioral controls as well; designed to maintain the tranquility of the Kaya.They emphasized decorum and respect as well as control of physical and emotional passions (Githitho, 1998).

The coastal forests of Kenya represent rare and threatened forest types rich in biodiversity. There is a high possibility of collecting more unique species, some even new to science as the forest sites are generally understudied. However, increased demand for forest resources is undermining the conservation efforts to save these rare species from extinction. The existing forest patches including the sacred Kaya forests are increasingly under great threats. This is due to pressure on land resources, urbanization and social transformations. Also the traditions and cultural practices associated to the Kaya settlements are fast diminishing, posing great danger to the social fabric and cohesiveness of the Mijikenda communities who venerate and celebrate them as their identity and symbol of continuity.The coastal forests need greater recognition of their global values; they also need adequate protection, appropriate use and effective management (Burgess and Clarke, 2000). However nearly 40% of Kenyan coastal forests are either poorly protected or otherwise wholly unprotected (Conservation International and McGinley, 2008).

Three hundred and thirty one plant species (331) in 77 families were recorded in Kaya Muhaka (Lehmann and Kioko, 2005).This represents 7.4% of all species estimated for the Zanzibar – Inhambane regional mosaic or 4.7% of all species known for Kenya (Lehmann and Kioko, 2005). Kaya Muhaka forest has a high species diversity and endemism and it is therefore imperative that it is conserved for future generations. The forest has been described as "wetter mixed semi-deciduous forest by Lehmann and Kioko (2005) and is locally dominated by caesalpiniaceous trees such as *Cynometra* and *Scorodophloeus*. These species are also found in the wet forests of west and central Africa indicating some homogeneity with these forests (Lehmann and Kioko, 2005). Kaya Muhaka forest also contains rare species like *Gigasiphon macrosiphon* and *Keetia lukei* which are restricted to less than five localities and only located to the Kenyan coast (Lehmann and Kioko, 2005).

2.4 Forest Destruction

Over the past three or four decades there has been a decline in knowledge about traditional values that protected these forests in these areas due to economic, social, cultural, and other changes in society(Githitho,1998). This has been combined with a rising demand for forest products and land for agriculture, mining, and other activities due to the increased population. One result has been the destruction and loss of the small Kaya forests and groves. By the time an active conservation programme began to be implemented for the Kayas in the early 1990s, the sacred forests had suffered considerably. As an extreme example, local agricultural encroachment has reduced forest cover in Kaya Chonyi, the sacred forest of the Chonyi Mijikenda group, to a fifth of its original area (Githitho, 1998).

Encroachment has also diminished other Kayas in size to varying degrees, particularly along Kenya's north coast (such as Kaya Jibana, Kaya Rabai, and Kaya Kambe). These sites are in fairly fertile areas with relatively dense populations. They have also been logged for valuable hardwood timber, and some species of these trees have disappeared altogether. Along the south coast, the Digo Kayas, which occur along beach areas, have fallen prey to intensive hotel development and planned settlement schemes (Githitho, 1998). In addition to important biological resources, the countries of eastern Africa are also endowed with a wealth of mineral resources, in coastal areas; these include gas, gemstones, iron, titanium, limestone and kaolin (Conservation International and McGinley, 2008). Destructive mining practices can destroy large areas of natural habitat. The coastal sands contain titanium and the mining of this ore destroys the natural vegetation. The Kenyan Government has recently given approval to a Canadian based multinational mining company, Tiomin inc. to start mining titanium in the Kwale area. High grade silica sands for glass manufacture are also mined from deposits in Msambweni while Iron and Manganese are mined on small scale in the Kwale Kaya forests of Coastal Kenya. There are also extensive areas of limestone along the coast and rubies and other precious stones in some of the coastal forests in Tanzania (Conservation International and Ginley, 2008).

A research by Roberson and Luke (1993) entitled noted that the forest patches also protected many small but important species of the coastal foothills, particularly on the narrow rivers cutting through the Jurassic limestone and ameliorating the effect of the erratic rainfall of the coast by ensuring constantly flowing streams. Destruction of the forests on coral rag for the cultivation of the fragile calcium rich soils, observed at Waa lead to barren rocky platforms, useful only for coral block diggings and then very difficult to rehabilitate. But the greatest destruction was observed in the beach crest zone of coral rag forest and thicket targeted for development of tourist and residential buildings and associated structures. Developers often burnt and slashed all the indigenous vegetation and were then faced with landscaping, having to import at vast expense, extra soil in which to plant. Such threats are also eminent in Kaya Kinondo, which is currently well established and marketed as an excellent ecotourism destination. Lehmann and Kioko (2005) noted that the area near Muhaka village was being eroded by seasonal fires, and many timber trees like *C. suaheliensis* were being poached, suggesting that the elders were no longer able to protect the Kaya. Pole cutting increased since 2001 and collecting firewood was common (Lehmann and Kioko, 2005). The land tenure around Kaya Muhaka consists of small scale subsistence farmers with individual owner operator systems. In most cases the land is ancestral coupled with scattered areas of land bought from the locals.Burning of woody plants for charcoal production causes major habitat loss near coastal towns and alongside main roads in Tanzania, while collection of firewood poses a threat in areas away from towns and roads. Uncontrolled burning to clear farmland to drive animals away, to collect honey and to reduce tsetse flies also threatens lowland coastal forests and thicket patches. This replaces rare, endemic coastal forest species, with more common, wide ranging fire adapted (resistant) species (Robertson and Luke, 1993). Since their abandonment as preferred places of settlement Kayas have been transferred from the domestic aspect of the Mijikenda landscape to its spiritual sphere. The Kayas are under threat both externally (economic activities) and from within Mijikenda society through the decline of traditional knowledge and respect of practices (UNESCO, 2009). Logging reduces the basal area and stem density. In a study conducted by Lehmann and Kioko, (2005) Kaya Muhaka was found to be moderately logged. The total number of dead standing stems however increased from 6 to 8 per hectare after 1996 indicating that firewood collection could have reduced.

2.5 Current Status of Forest Conservation and potential benefits.

The Critical Ecosystems Patnership Fund (CEPF) noted that international interest in the Eastern Arc Mountains and Coastal forests hotspot has increased over the last three decades as the realization of its biodiversity importance and of the global crisis affecting tropical forests has deepened (The Critical Ecosystems Patnership Fund, 2005). Although descriptions of the wealth of biodiversity in the forests of the Eastern Arc Mountains date back to 1860 and there has been outstanding scientific work in the hotspot during the last 100 years, concerns for its conservation are relatively recent. Until about 30 years ago, nearly all the investment in the forests of the area had been in plantations, many of which were established after clearing indigenous forest (The Critical Ecosystems Patnership Fund, 2005). Most of the important plant species that are potential sources of bee nectar and pollen are frequently burnt out during the dry season. Habitat restoration will increase the habitat scientific values ensuring survival of the endemic or threatened, maintenance of the unique flora as gene pools of plant germplasm and units of socio-economic development by providing herbal medicinal materials and ecotourism potential among other important resources (UNESCO, 2009). The latest UNESCO list of Intangible Culture includes several sacred sites and sacred traditions. The UNESCO (2009) Committee on Intangible Culture considered these cultural elements as endangered despite the efforts of the communities or groups concerned. Following the inscription, countries concerned will implement specific safeguarding plans, as indicated in their nomination files. Intangible cultural elements in need of urgent safeguarding will be eligible for financial assistance from the fund established to this end (UNESCO, 2009). The Kayas demonstrate authenticity but aspects associated with traditional practices are highly vulnerable. Over the past few years increasing emphasis has been placed on promoting fast growing species that serve a variety of uses such as fuel wood, timber, and fodder in order to relieve pressure on existing forests.

Communities must gain clear benefits if they are going to be involved in some level of community use or benefit sharing will be necessary. Efforts should concentrate on establishing what constitutes wise use (Robertson, 1984). A classic strategy in forest conservation is the promotion of alternatives to potentially damaging utilization of the natural resources of the forest (Coe *et al*., 1999). In the case of the Kayas, the Coastal Forests Conservation Unit (CFCU), in conjunction with donors, has supported such an initiative for some years. Local farmers' groups have been provided with potting materials, seeds and seedlings to assist them in setting up of woodlots. The species most favored by farmers are exotic fast-growing trees like *Casuarina equisetifolia* L. rather than local species, perceived to be slow growers. Certain tree and shrub species of the Kaya sites, however, are more popular with local people, and proposals are being developed for a domestication project to target the most promising of these. Such a project would establish the ecological, sociological, cultural, and economic feasibility of local farmers growing these forest species on their farms. Bee keeping in the forest buffer zone and agro-ecosysterms instead of traditional destructive honey harvesting from forest trees is an example of a way in which the forest resources can be used sustainability. Some plants in the forest could provide wax, and pollen for the bees as the bees help in pollinating them. 127 species of butterflies were recorded in a previous research by Lehman and Kioko (2005), over a period of 10 years (1994 – 2003). This is 14% of the currently known Kenyan butterfly fauna. 93 species were recorded in 0.625 Ha. This shows that Kaya Muhaka has relatively high butterfly species riches and diversity (Lehmann and Kioko, 2005). Such is a valuable resource and can be channeled to provide commercial products of high value such as silk.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

Kaya Muhaka is located about 32 km south of Mombasa and 5.5 km inland from the Indian Ocean (figure 1). With 150 ha, it is one of the largest Kayas in Kwale (Myers *et al.*, 2000; Lehmann and Kioko, 2005). It is located in Msambweni District, 15 km south east of the Shimba Hills, close to Muhaka village (figure 1). It is also called Kaya Kambe or Mwadabara and was gazetted as a national monument in 1992. It is found near Mwabungu, Digo; 0419°S 3931°E, 45m altitude, (Robertson and Luke, 1993). Kaya Muhaka has an average annual rainfall of 1129 mm (23 years record) with 132 mm during December to March (February is the driest month), 568 mm during the long rains, April – June, 172mm in July and August and 257 mm during the short rains from September to November (Jaetzold and Schmidt, 1983). Kaya Muhaka is situated on lagoonal deposits and sub recent marine deposits (Kilindini sands). The soils are complex and very deep (>1.3m), of varying drainage condition and colour, texture and salinity.They are classified as; albic and ferralic arenosols, orthic ferralsols, gleyic luvisols to acrisols and sodic planosols; vertigleyic luvisols and pellic vertisols, sodic phase (Michieka *et al.*, 1978). The community around comprises mainly of subsistence farmers with high poverty levels.

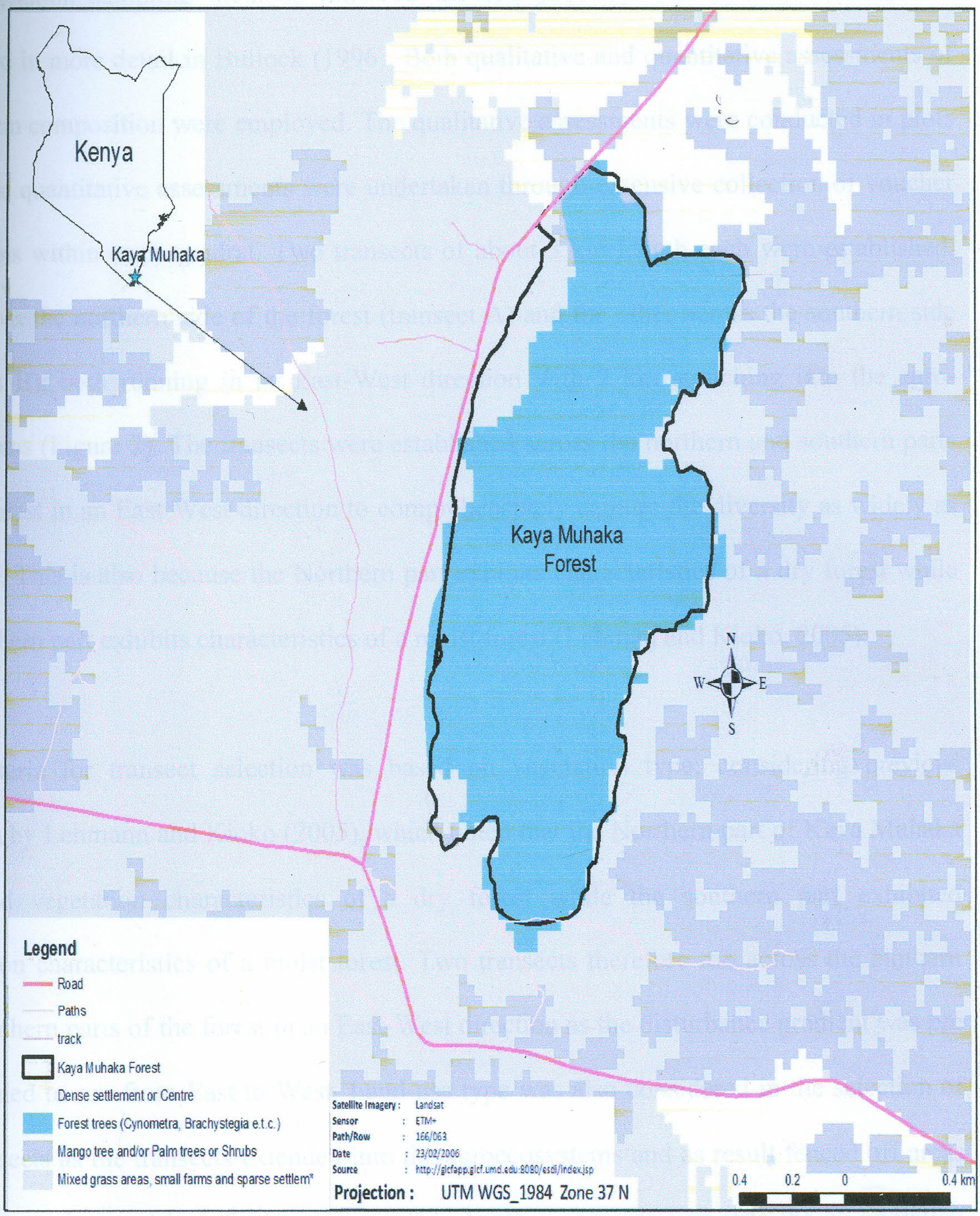

Figure1: The position of Kaya Muhaka forest and associated agroecosystems as generated by ARC GIS 9.3 software using Google earth digitization.

3.2.1 Vegetation Sampling Methods

The vegetation sampling methods followed the one used by Wilder *et al.* (1998) and described in more detail in Bullock (1996). Both qualitative and quantitative assessments of vegetation composition were employed. The qualitative assessments were conducted in plots while the quantitative assessments were undertaken through extensive collection of voucher specimens within each quadrat. Two transects of about 3 km length each were established, one across the northern side of the forest (transect A) and the other across the southern side (transect B), both running in an East-West direction with 2 km stretching into the agro-ecosystems (Figure 2). The transects were established across the northern and southern parts of the forest in an East West direction to comprehensively capture the diversity as widely as possible. This is also because the Northern part exhibits characteristics of a dry forest while the southern part exhibits characteristics of a moist forest (Lehman and Kioko, 2005).

The criteria for transect selection was based on vegetation type; considering previous research by Lehmann and Kioko (2005), which noted that the Northern part of Kaya Muhaka exhibited vegetation characteristics of a dry forest while the southern part exhibited vegetation characteristics of a moist forest. Two transects therefore ran across the Nothern and Southern parts of the forest in an East-West direction as the disturbance gradient was pre determined to run from East to West. Land use type was also considered in the selection of the transects as the transects extended into the agroecosystems and as result fenced off areas and areas under seed beds had to be avoided. Another consideration was the co-operation from locals so as to allow us to traverse their lands. In each area, sample sites were established along a transect by belt transect method and mapped using a GPS. The quadrats were layed by use of a callibrated measuring string using a tape measure. Each quadrat of 20m by 20m was sampled and they were located 250m apart to ensure sample independence. The sample plots were geo-referenced and can be used for future monitoring of biodiversity changes. An additional nine plots were surveyed on three parallel transects of 1 km each from the western edge of the forest to the forest core.Transect C1 ran along the forest edge, transect C1.1 ran parallel to C1 and transect C1.2 ran parallel to C1.1 and was in the forest core. These transects were also 250 m apart with quadrats of 20 m by 20 m placed at regular interval of 250 m.This was done so as to capture species diversity and composition from the forest edge to the forest core. The quadrats were perpendicularly divided midway by the transect line. Each quadrat was further divided into four sub-quadrats of 10 m by 10 m for systematic collection of specimen. Overall 32 plots were sampled totaling to 1.28 Ha of the area sampled.

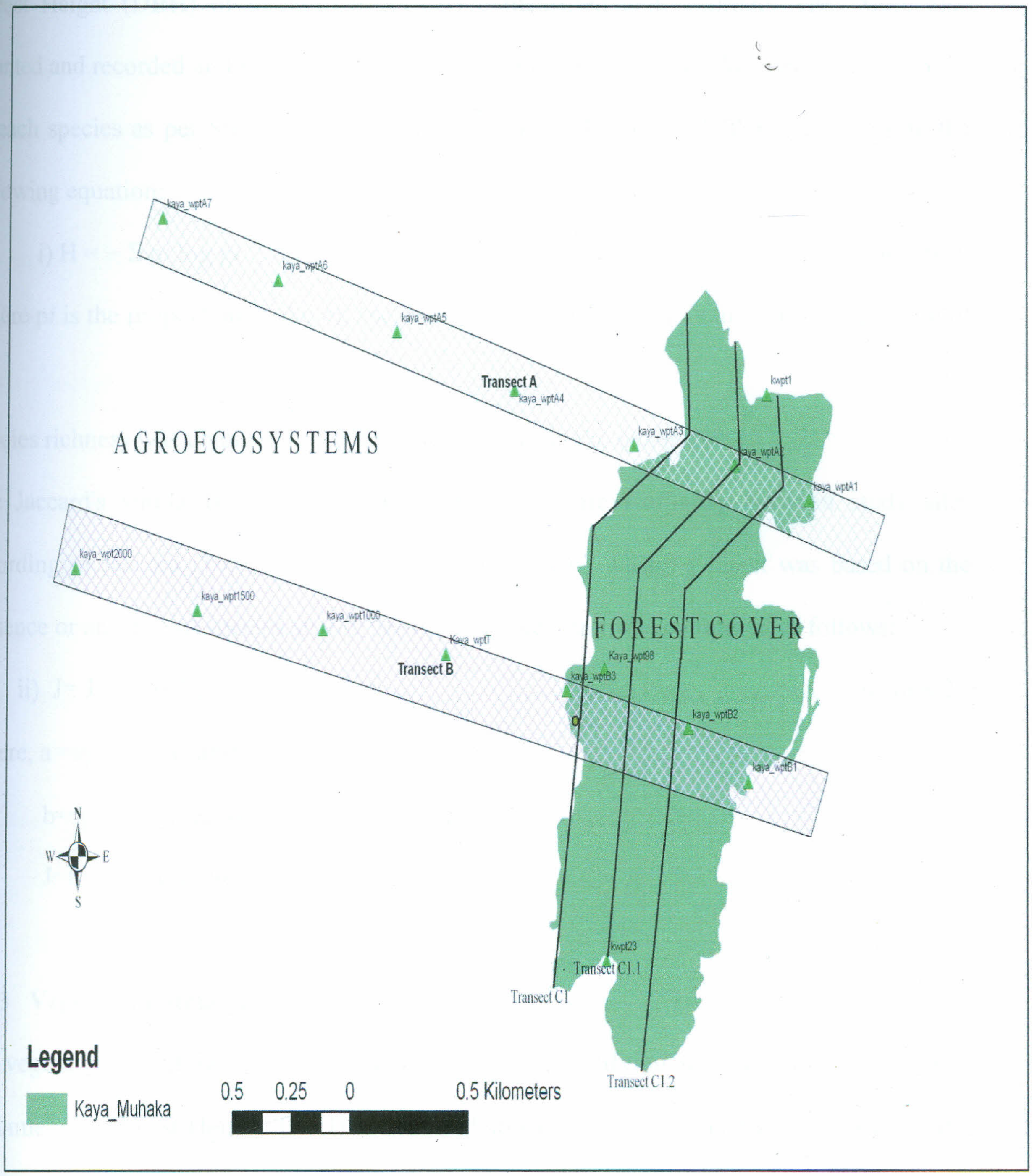

Figure 2: The sampling transects in Kaya Muhaka forest core, forest edge and agro-ecosystems as generated by ARC GIS 9.3 software using Google earth digitization.

3.2.2 Species Diversity

In each plot the presence or absence of species was recorded. The species with a Diameter at Breast Height (DBH) of more than 5cm were measured and recorded. They were also counted and recorded and this data was used to calculate the Shannon-Wiener diversity index of each species as per Shannon and Wiener (1963) and Kumar and Bhatt (2006) using the following equation:

i) $H = -\Sigma p_i \log p_i$ ………………………………………………………….equation 1

Where p_i is the proportion of the ith species in the sample and log is the natural logarithm of p_i.

Species richness was obtained by counting the species in the quadrats.

The Jaccard's similarity index, J, was used to compare similarity between study sites according to Jaccard (1908) and Real and Vargas (1996). Jacard's index was based on the presence or absence of species shared between samples, and was computed as follows:

ii) $J = J/(a+b)-J$…………………………………………………………..equation 2

Where, a =species in sample point a and not in b

b=species in sample point b and not in a

J=total species in points a and b

3.2.3 Vegetation Structure

The vegetation structure of the forest was assessed by identifying and recording all trees with a Diameter at Breast Height (DBH) of 5cm and above within each quadrat (Richards, 1996). The DBH was measured using a diameter tape measure.The Diameter at Breast Height

(DBH) class intervals were as follows; 5-9 cm, 10-14 cm, 15-19 cm, 20-24 cm, 25-29 cm,30-34 cm, 35-39 cm, 40-44 cm, 45-49 cm and >50cm.

3.2.4 Canopy cover

The canopy cover and height within the three life form layers (herb shrub and tree) were estimated in each plot by ocular estimates (Avsar and Ayyildiz, 2010). Objectivity was increased in the process by dividing the plot into smaller sections and counting the average of estimates made for each section (Sarvas, 1953, Bunnell and Vales 1990). The tree layer cover was estimated in three sub canopy layers namely; upper stratum (>20m height), middle stratum (5-10m height), lower stratum (5-10m height).The canopy cover estimation involved the imaginary projection of the aerial shadow of each vegetation layer on the ground and estimation of its percentage area. The total percentage cover of each area was assumed to be 100%. Tree height measurement was done by use of a suunto clinometer and the tree height was calculated trigonometrically.

3.2.5 Species Composition

The species composition was assessed by recording all the species in the sampling sites by use of the data collection sheet in Appendix III. Each species in a quadrat was collected and identified using approved literature; Flora of Tropical East Africa volumes, Beentje (1994) and Agnew and Agnew (1994). These were recorded in the data collection sheet.

3.2.6 Importance Value Index

Vegetation analysis was quantitatively analysed for abundance, density and frequency following Curtis and McIntosh (1950) and the relative values were summed up to represent Importance Value Index (IVI) as per Curtis (1959).The importance value index (IVI) was used to describe the species composition of the forest. The IVI of a species was defined as the sum of its relative dominance (Rdom), its relative density (Rden) and its relative frequency (Rfre), which in turn was calculated as:

(i) Rdom = (total basal area for a species/total basal area for all species) x 100

(ii) Rden = (number of individuals of a species/total number of individuals) x 100

(iii) Rfre = (frequency of a species/ sum frequencies of all species) x 100

The frequency of a species was defined as the number of plots in which the species was present. To calculate IVI, individuals with dbh > 5 cm were considered, as basal area was not computed for individuals with dbh < 5 cm (Mueller-Dombois and Ellenberg 1974).

3.2.7 Regeneration Potential

Regeneration potential of key plant species was determined by recording the number of seedlings on each sample area. These were recorded in the data collection sheet shown in Appendix III. To obtain the best regenerating species in the forest, the seedling and sapling populations of each species samples were identified and recorded.Their frequencies were then converted into percentages so as to compare their levels of regeneration. The species with the highest percentage of seedlings was considered to be of a higher regeneration potential.

3.2.8 Distribution and Conservation Status of Endangered Species

Particular focus was placed on plant species diversity and unique species of high conservation value as elucidated in the IUCN Red List of threatened species (IUCN, 2010). The IUCN categorizes threatened species into the following groups (IUCN 2010)

a) Extinct (EX)

A taxon is extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), and throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

b) Extinct in the wild (EW)

A taxon is extinct in the wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the pastrange. A taxon is presumed Extinct in the wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), and throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

c) Critically endangered (CR)

A taxon is critically endangered when the best available evidence indicates that it meets any of the criteria A to E for critically endangered and it is therefore considered to be facing an extremely high risk of extinction in the wild.

d) Endangered (EN)

A taxon is endangered when the best available evidence indicates that it meets any of the criteria A to E for endangered and it is therefore considered to be facing a very high risk of extinction in the wild.

e) Vulnerable (VU)

A taxon is vulnerable when the best available evidence indicates that it meets any of the criteria A to E for vulnerable and it is therefore considered to be facing a high risk of extinction in the wild.

f) Near threatened (NT)

A taxon is near threatened when it has been evaluated against the criteria but does not qualify for critically endangered, endangered or vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

Mapping of threatened species was done by means of random walks and georeferencing using a GPS. The entire forest was also mapped. The maps were created using GPS coverage through walking around the forest edge and along the transects. The GPS readings were complemented and translated to ARC GIS 9.3 software using Google earth digitization.

The key in figure 3shows codes of the following species; Ak- *Artabotrys modestus* Diels ssp. *macranthus* Verdc.; Cp- *Cola octoloboides* Brenan; Dh- *Dialium holtzii* Harms; Gf- *Gigasiphon macrosiphon* (Harms) Brenan; Mf- *Mkilua fragrans* Verdc.; Mfd- *Mkilua fragrans* Verdc. stumps; Rm- *Rothmania macrosiphon* (Engl.) Bridson; Ss-*Synsepalum subverticillatum* (E.A.Bruce) T.D.Penn

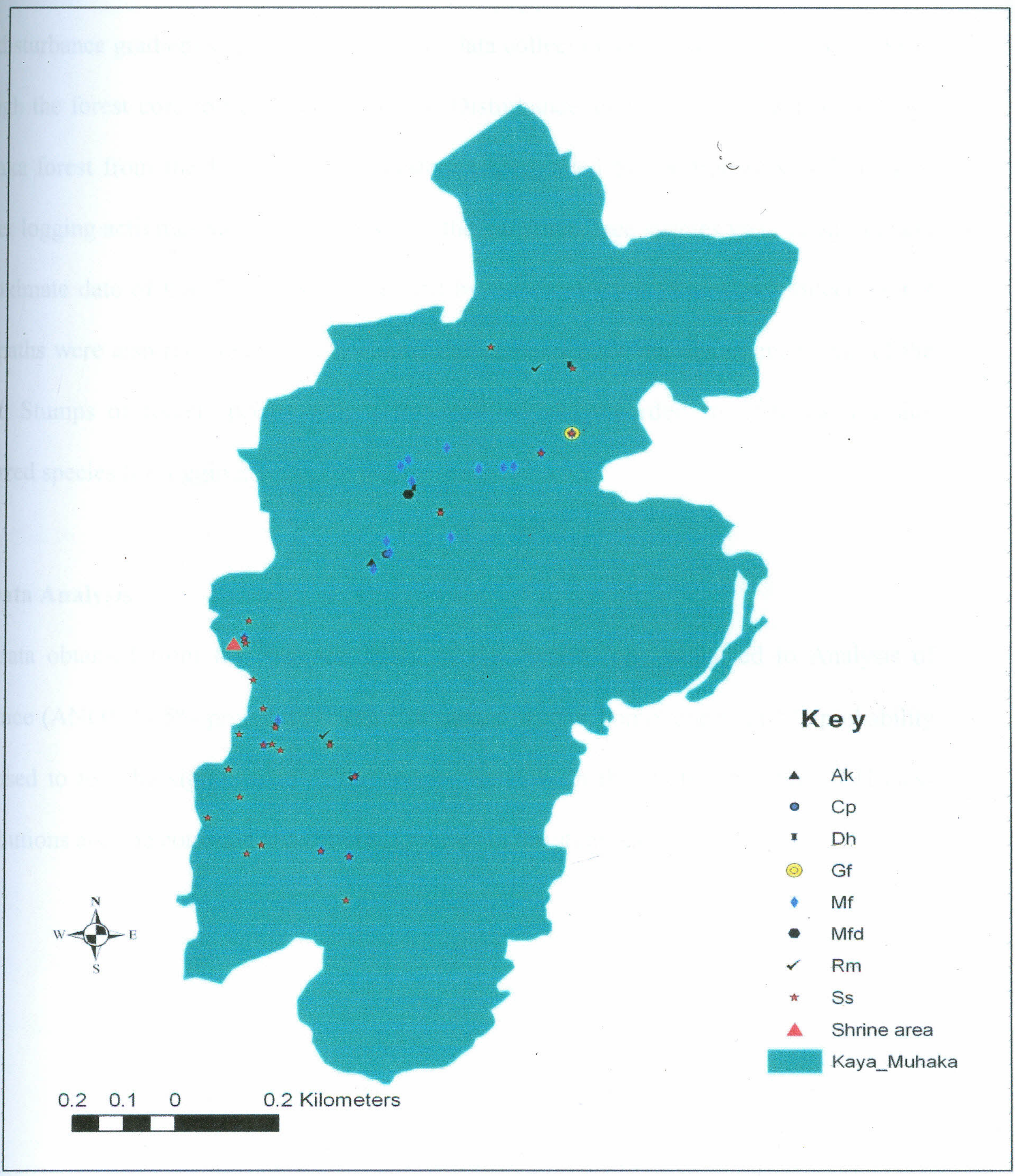

Figure 3: Random sampling points as generated by ARC GIS 9.3 software using Google earth digitization in Kaya Muhaka forest for threatened species as per The IUCN Red List of globally threatened species (2010).

3.2.9 Disturbance

The disturbance gradient was identified prior to data collection and it was from East to West, through the forest core to the agroecosystems. Disturbance analysis only targeted the Kaya Muhaka forest from the Eastern to the Western edge guided by the transects. All signs of former logging activities were recorded within the quadrats. Tree species were identified and approximate date of tree felling was estimated by the local guide. Firewood collection and foot paths were also recorded so as to enable the assessment of the disturbance level of the forest. Stumps of forest species were also identified and recorded so as to capture any preferred species for logging.

3.3 Data Analysis

The data obtained from the Shannon index of biodiversity was subjected to Analysis of Variance (ANOVA) 5% probability. The Chi square test for homogeneity at 5% probability was used to test the significance of the species richness in the study sites, the DBH class distributions and the common and different species in the study sites.

CHAPTER FOUR

RESULTS

4.1 Diversity of flora in agro-ecosystems, forest edge and forest core.

There was no significant difference in the species diversity between the forest core, forest edge and agroecosystems (Appendix IV, Table 6). The Shannon Wiener Diversity Index increased with an increase in number of species. Table 1 below shows the forest edge (Transect C1) contained a higher Shannon wiener diversity index of 5.25 as compared to the forest core (Transect C1.2) which has a Shannon wiener diversity index of 4.71 (Table 1). Transect A had the highest Shannon wiener diversity index at 5.67 closely followed by transect B at 5.62. Transect C1.2 (the forest core) had the lowest Shannon wiener diversity index hence the lowest species diversity. The forest edge (Transect C1) had the highest diversity among the forest transects. The general trend therefore showed that the diversity reduced from the forest edge to the forest core.

4.1.2 Species Richness (S)

A total of 492 plant species were recorded with 210 (42%) new to Kaya Muhaka and one, *Zamioculcas sp.*, possibly new to science, as the specific epithet was not established. They belonged to 324 genera in 92 families as shown in Appendix 1. Transect A had 365 species making it the highest in species richness. It was followed by Transects B with 228 species, C1 with 152, C1.1 and C1.2 with 124 species which was lowest number of species (Table 1).

Table 1: Species Richness, Diversity and Similarity of the transects in the forest core, forest edge and agro-ecosystems.

Parameter	Forest to agroecosystems (Transect A)	Forest to agroecosystems (Transect B)	Forest edge (Transect C1)	250m from forest edge (Transect C1.1)	Forest core (Transect C1.2)
Species Richness (S)	365	228	152	124	124
Species Diversity (H')	5.67	5.62	5.25	4.87	4.70
Species Similarity (J)	0.96	1.03	1.04	1.01	0.97

Table 2 shows that the Chi Square test for homogeneity for species richness in the forest core, forest edge and agro-ecosystems was very highly significant.

Table 2: The Chi Square tests for homogeneity at 5% probability, 9 and 4 degrees of freedom for the different species in the forest core, forest edge and agro-ecosystems, the common species in the forest core, forest edge and agro-ecosystems, the DBH Class Distribution in the forest core, forest edge and agro-ecosystems and the species richness in the forest core, forest edge and agro-ecosystems. All the tests showed that there were significant differences between the forest core, forest edge and agro-ecosystems.

Chi Square Test	d.f	0.05 p value	Chi value	Significance at 5% p
Different species	9	16.91	149.23	p<5% highly significant.
Common species	9	16.91	225.80	p<5% highly significant.
DBH Class distribution	9	16.91	184.12	p<5% highly significant.
Species richness	4	9.48	210.75	p<5% highly significant.

The highest number of species was recorded in the kaya forest (352, 72%) with 186 (38%) of the species not found in agroecosystems. The secondary vegetation at forest edges was the most species rich.

4.1.3 Similarity indices between transects.

Table 3 below summarises the common species, different species and the jaccards similarity index as compared between all transects. Transects C1.1 and C1.2 had the highest Jaccards similarity index of 60.46. Transect A and B also had a high Jaccards similarity index of

54.72. The least similarity was between transects C1 and C1.2 with a Jaccards similarity index of 23.50. The forest edge therefore was very dissimilar from the forest core.

Table 3: The Jaccard's Similarity Index between transects in the forest core, forest edge and agro-ecosystems showing the common and different species in the forest core, forest edge and agro-ecosystems.

Transects	Common	Different	Jaccards
AVs B	249	206	54.72
AVs C1	194	205	48.62
A Vs C1.1	119	278	29.97
A Vs C1.2	104	281	27.01
BVs C1	181	206	46.77
B Vs C1.1	127	238	34.79
B Vs C1.2	103	258	28.53
C1 Vs C1.1	76	228	25
C1 Vs C1.2	67	218	23.50
C1.1 Vs C1.2	104	68	60.46

Table 2 shows that the Chi Square test for homogeneity for the common and different species in the transects was very highly significant.

4.2 Forest structure and species composition in various sites of the forest.

4.2.1 Vegetation structure

Figure 4 below shows the DBH class distribution in all transects.The highest number of individuals (stems) occupied the lowest DBH class (5- 9 cm), and the least was towards the highest class (between 35- 39cm and 45- 49cm). A closer look at each transect shows that there was an inverse J- shaped curve in all the transects.

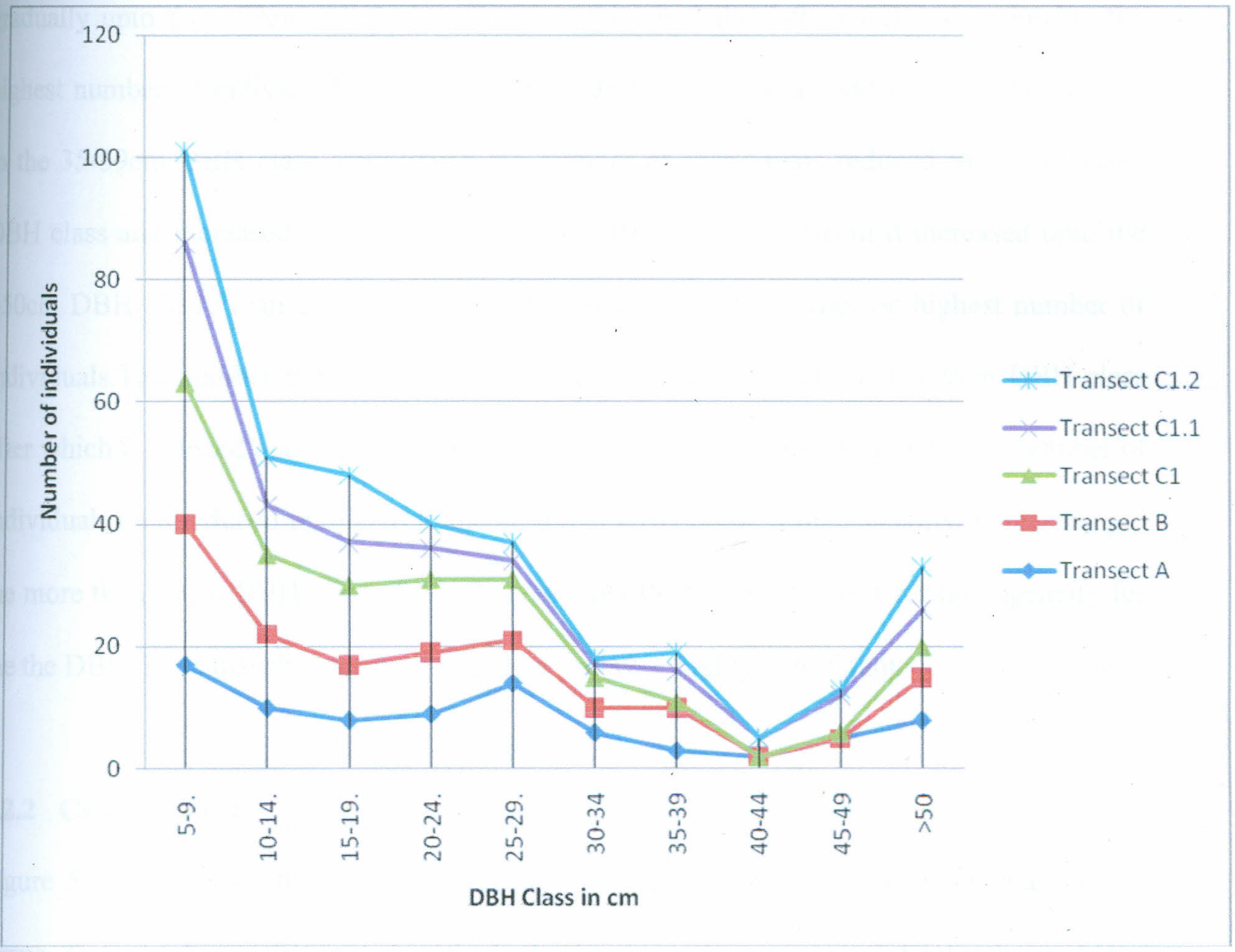

Figure 4: The Number of individual stems plotted against DBH Class distribution in the transects in the forest core, forest edge and agro-ecosystems, showing an inverse J-shape curve typical of a natural rainforest.

Transect A had the 5-9cm DBH class having the highest number of individuals.This number reduced upto 25-29cm DBH class. It further reduced and increased again in the >50cm DBH class.Transect B had the 5-9cm DBH class having the highest number of individuals.The number reduced upto the 35-39cm DBH classes.The number of individuals then approached zero in the 40-44cm from where it increased constantly upto the >50cm DBH class.Transect C1 had the 5-9cm DBH class having the highest number of individuals.The number reduced steadily until its lowest point which was zero in the 40-44cm DBH class.It then increased gradually upto the >50cm DBH class.Transect C1.1 had the 5-9cm DBH class having the highest number of individuals.The number then decreased steadily and has a slight increase in the 35-39cm DBH class after which the number of individuals reduced in the 40-44cm DBH class and increased again in the 45-49cm DBH class wherefrom it increased upto the >50cm DBH class. Transect C1.2 had the 5-9cm DBH class having the highest number of individuals.The number then reduced and has a slight increase in the 15-19cm DBH class after which it reduced and slightly increased again in the 35-39cm DBH class.The number of individuals then reduced upto zero in the 40-44cm DBH class. It then steadily increased upto the more than 50cm DBH class. Table 2 shows that the Chi Square test for homogeneity for the the DBH Class distribution in all transects was very highly significant.

4.2.2 Canopy cover

Figure 5 below shows the average percentage canopy cover of the various strata and life forms. Transect A was dominated by the herb, *Agathisanthemum bojeri* Klotzsch var. *bojeri* mainly because 8 out of 12 of the quadrats in this transects were in the agroecosystems. This was also the case in Transect B. Transect A had 53% herbaceous cover. Transect A had a higher percentage of herbs than Transect B.The upper canopy was the lowest in percentage in both transects. Comparatively Transect A had a higher canopy cover in all the stratifications

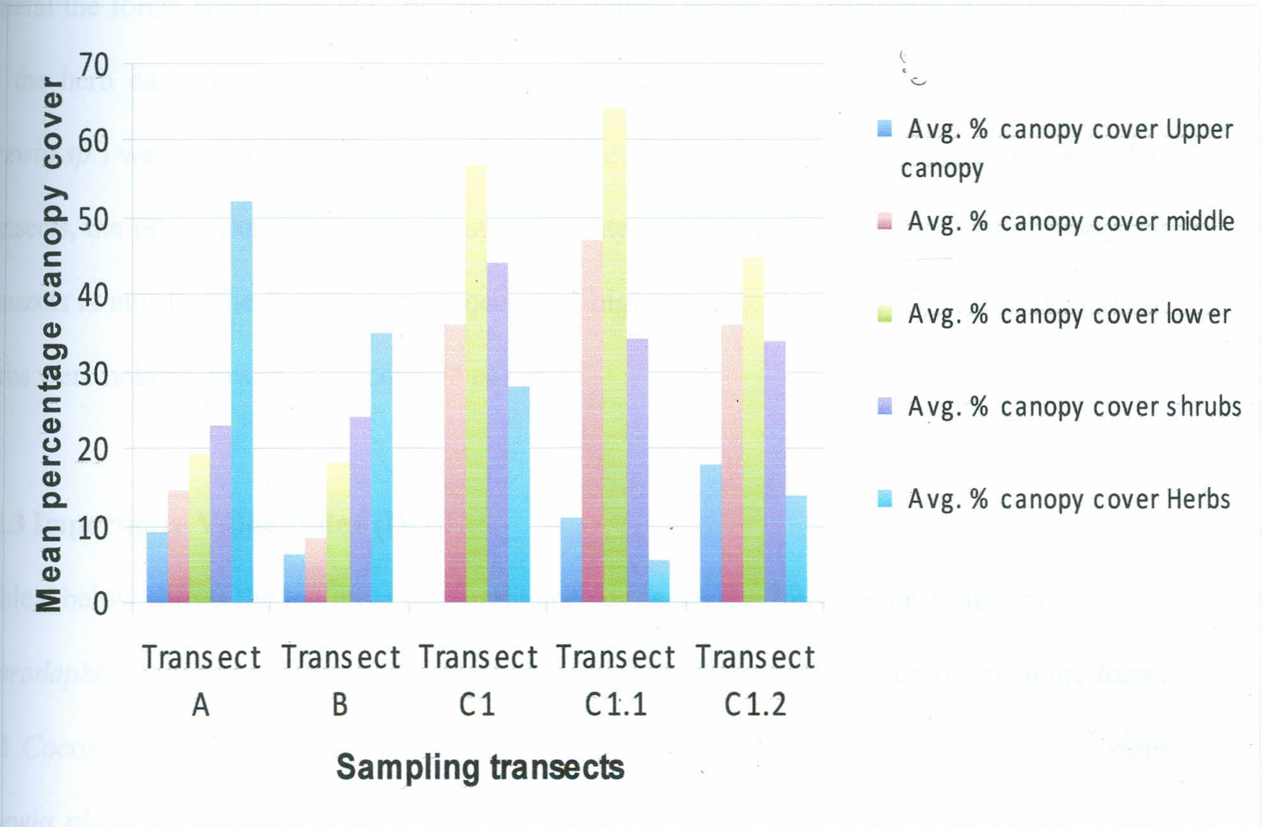

Figure 5: Average percentage canopy cover in the transects in the forest core, forest edge and agro-ecosystems in the canopy layers stratified according to height of the plant species.

Figure 5 above shows that in Transect C1, the lower stratum dominated the canopy cover comprising mainly *Julbernardia magnistipulata* (Harms) Troupin and *Polysphaeria parvifolia* Hiern. Transect C1.2 which is in the forest core also had the lower stratum dominating, comprising mainly *Scorodophloeus fischeri* (Taub.) J.Leon. Transect C1.2 had the highest percentage of the upper canopy cover, mainly *S.fischeri* and *Cynometra suahiliensis* (Taub.) Baker f.The lower canopy cover was highest in transect C1.1 mainly composed of *Julbernardia magnistipulata* .The herb and shrub layer were highest in Transect C1 and they comprised *Polysphaeria parvifolia* and *Agathisanthemum bojeri* (Plate 1). In general the forest was dominated by the lower canopy while the farmlands were dominated by the herb canopy. Generally, *Craibia brevicaudata* and climbers (*Combretum sp.* and *Grewia sp.*) were common in low and mid vegetation cover in the forest. In all the sampled transects, the upper canopy was the least represented while the herbs were most dominant in transects A and B. The Lower canopy occupied highest percentages in the C transects while herbs were notably lower in percentage cover.

4.2.3 Importance Value Index (IVI).

Table 4 below shows the ten most important species as per the Importance Value Index (IVI). *Scorodophloeus fischeri* (Taub.) J.Leon had the highest Importance Value Index in the forest and *Cocos nucifera* L. in the agroecosystems. Other notable species in the forest were *Grewia plagiophylla* K.Schum and *Craibia brevicaudata* (Vatke) Dunn Ssp. *brevicaudata.* Other notable species in the agroecosystems were *Anacardium occidentale* L. and *Annona senegalensis* Pers. spp. *Senegalensis.* The forest therefore was dominated by *Scorodophloeus fischeri* associated with *Cynometra sp.* However, the agroecosystems were characterised by *Cocos nucifera* L., *Anacardium occidentale* L., and *Annona senegalensis* Pers., with some patches of natural wooded grasslands and seasonal swamps interspersed by few forest resemblance like regenerating *Hymenaea verrucosa* Gartn. and *Julbernardia magnistipulata* (Harms) Troupin, and Cyperaceae species.The dominant families were Papilionaceae and Rubiaceae as in figure 6.

Table 4: Ten most dominant species in the forest and the agroecosystems.

Botanic name	Family	Habitat	IVI	Dominance
Cocos nucifera L.	Palmae	Agroecosystem	666.45	Dominant
Scorodophloeus fischeri (Taub.) J.Leon	Caesalpiniaceae	Forest	618.26	Dominant
Mangifera indica L.	Anacardiaceae	Agroecosystem	480.96	Co-dominant
Anacardium occidentale L.	Anacardiaceae	Agroecosystem	302.37	
Cynometra suaheliensis (Taub.) Baker f.	Caesalpiniaceae	Forest	260.05	Co-dominant
Julbernardia magnistipulata (Harms) Troupin	Caesalpiniaceae	Forest	256.28	
Hyphaene compressa H.Wendl.	Palmae	Agroecosystem and forest edge	240.31	
Craibia brevicaudata (Vatke) Dunn ssp. *brevicaudata*	Papilionaceae	Forest	176.68	
Antidesma venosum Tul.	Euphorbiaceae	Forest	175.62	
Grewia plagiophylla K.Schum.	Tiliaceae	Forest	170.37	

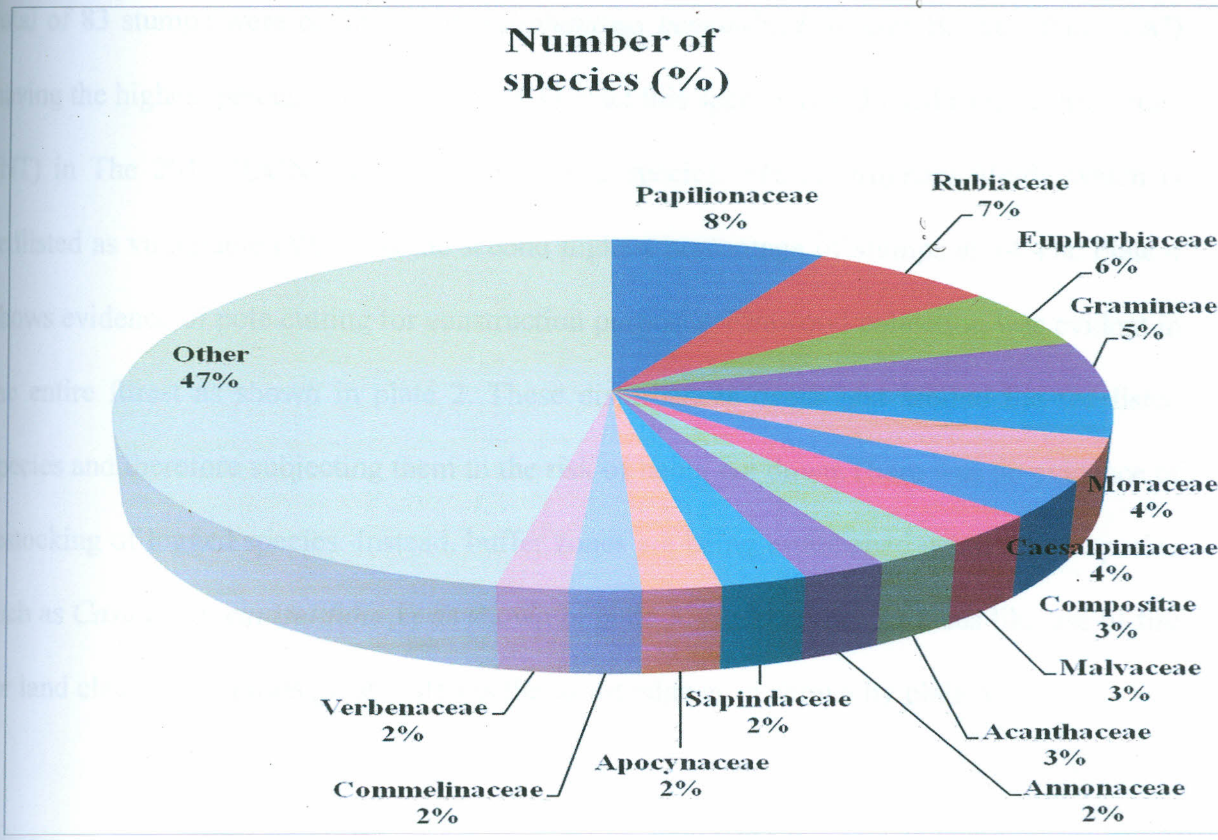

Figure 6: Relative proportions of species in plant families represented in Kaya Muhaka in terms of percentages.

4.2.4 Regeneration of forest species

Appendix II shows the best regenerating species in the forest in terms of percentage of seedlings and sapling populations of each species. A total of 4860 seedlings and saplings were recorded with *Polysphaeria parvifolia* showing the highest regeneration potential with 17.81% of the seedlings and saplings recorded.

4.2.5 Forest disturbance

Kaya Muhaka forest is a highly disturbed ecosystem with paths heavily criss-crossing the forest. Appendix III shows the percentage of stumps per species recorded within the forest. A total of 83 stumps were counted with *Elliphanthus hemandradenioides* Brenan (Pancovia?) having the highest percentage of stumps at 37.3%.; this species is redlisted as near threatened (NT) in The 2010 IUCN red list of threatened species. *Mkilua fragrans* Verdc which is redlisted as vulnerable (VU) had the second highest percentage of stumps at 14.4%. Plate 4 shows evidence of pole cutting for construction purposes. Firewood collection was evident in the entire forest as shown in plate 2. These disturbances occur just around the red listed species and therefore subjecting them to the risk of being cut down.There was no evidence of restocking of logged species. Instead, buffer zones are being established using exotic species such as *Casuarina equisetifolia* L. as shown in plate 3. Agricultural practices like use of fire for land clearing purposes greatly affects the forest edge as in shown by plate 5.

Plate 1: *Agathisanthemam bojeri* the forest most dominant bee plant in Kaya Muhaka.

Plate 2: Firewood collection on a path in the forest core.

Plate 3: Buffer of *Casuarina equisetifolia* in in the the forest edge.

Plate 4: Pole cutting on a forest path the forest core.

Plate 5: Uncontrolled burning to clear farmland affects the forest edge.

4.2.6 Unique species

Appendix 1 shows the plant checklist of Kaya Muhaka.A total of 210 new species records were recorded in Kaya Muhaka as compared to previous checklists by Lehman and Kioko, 2005 and Luke (2000). Some unique species have yet to be exploited especially for ornamental purposes like the *Zamioculcas zamiifolia* (Lodd.)Engl.(Plate 6) and *Whitfieldia elongata* (P. Beauv.)C.B. Clarke.

Plate 6: *Zamioculcus zamiifolia*

Table 5: A Checklist of threatened species found in Kaya Muhaka as per The IUCN Red List of Globally Threatened species, 2010, source: http://www.iucnredlist.org/ ; 12th September, 2010.

family	genus	species	author1	species2	author2	IUCN
Annonaceae	*Isolona*	*cauliflora*	Verdc.			EN
Annonaceae	*Lettowianthus*	*stellatus*	Diels			NT
Annonaceae	*Mkilua*	*fragrans*	Verdc.			VU
Annonaceae	*Ophrypetalum*	*odoratum*	Diels	*longipedicellatum*	Verdc.	VU
Annonaceae	*Uvariodendron*	*kirkii*	Verdc.			VU
Araceae	*Gonatopus*	*marattioides*	(Peter) Bogner			EN
Burseraceae	*Commiphora*	*obovata*	Chiov.			NT
Caesalpiniaceae	*Cynometra*	*suaheliensis*	(Taub.) Baker f.			VU
Caesalpiniaceae	*Cynometra*	*webberi*	Baker f.			VU
Caesalpiniaceae	*Dialium*	*holtzii*	Harms			VU
Caesalpiniaceae	*Gigasiphon*	*macrosiphon*	(Harms) Brenan			EN
Caesalpiniaceae	*Julbernardia*	*magnistipulata*	(Harms) Troupin			VU
Connaraceae	*Ellipanthus*	*hemandradenioides*	Brenan (Pancovia?)			NT
Ebenaceae	*Diospyros*	*greenwayi*	F.White			VU
Euphorbiaceae	*Mildbraedia*	*carpinifolia*	(Pax) Hutch.			VU
Euphorbiaceae	*Pycnocoma*	*littoralis*	Pax.			VU
Flacourtiaceae	*Bivinia*	*jalbertii*	Tul.			NT
Mimosaceae	*Newtonia*	*paucijuga*	(Harms) Brenan			VU
Moraceae	*Milicia*	*excelsa*	(Welw.) C.C.Berg			NT
Papilionaceae	*Dalbergia*	*melanoxylon*	Guill. & Perr.			NT
Papilionaceae	*Erythrina*	*sacleuxii*	Hua			VU
Rubiaceae	*Oldenlandia*	*affinis*	(Roem. Et Schult.)DC			VU
Rubiaceae	*Rothmannia*	*macrosiphon*	Waterman,P.G.;McKey, D			VU
Rutaceae	*Zanthoxylum*	*holtzianum*	(Engl.) P.G.Waterman	*holtzianum*		VU
Sapindaceae	*Chytranthus*	*obliquinervis*	Radlk. ex Engl.	*longiflorus*	(Verdc.) Halle	VU
Sapotaceae	*Synsepalum*	*subverticillatum*	E.A.Bruce			EN
Sterculiaceae	*Cola*	*octoloboides?*	Brenan			EN

This research established that 27 species are redlisted as threatened in the IUCN (2010) Redlist of Threatened Species (Table 5). Six species (22%) were Near Threatened (NT), 16 (59%) were Vulnerable (VU) and 5 (19%) were Endangered (EN). Their relative percentages are shown in figure 7 below.

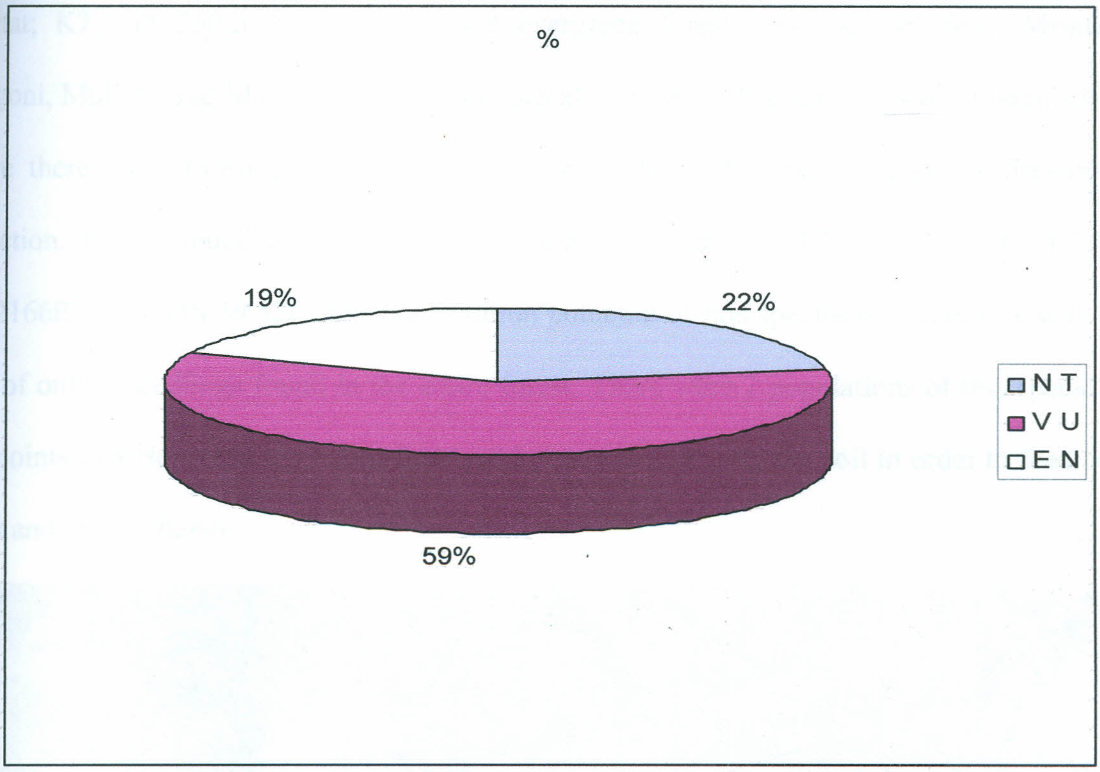

Figure 7: The relative percentage of the different IUCN categories as represented by the plant species in Kaya Muhaka.

In this research, the following 3 species were given special interest because of their rarity in the Kaya Muhaka forest.

i) *Gigasiphon macrosiphon* (Harms.) Brenan (Plate 7)

Description (Beentje, 1994);

Family: Caesalpiniaceae.

Tree 12-24m, crown rounded; bark smooth, grey. Leaves broadly ovate, base (sub-)cordate, apex acuminate, 9-20 by 7-16cm, 5-veined from base, subglabrous. Flowers whiter with one (Partly) yellow petal, petals 9-13 by 4-6cm. Fruits grey black, flattened 20-30 by 6-7.5cm. Habitat; K7; 100-250m altitude, in moist evergreen forest. Only known from Mrima, Gongoni, Muhaka and Marenje forests (and coastal Tanzania). The species was found in sites where there were forest gaps, presence of stumps, footpaths and evidence of firewood collection. It was found in the following georeferenced points; 4.33S 39.52191E, 4.33S 39.52166E and 4.33S 39.52E. The regeneration potential of this species was very low with a total of only 7 seedlings found in the entire forest. There were 2 populations of this species. The points experienced disturbance from wild pigs which dug up the soil in order to feed on seeds and create shelter.

Plate 7: *Gigasiphon macrosiphon* (Harms) Brenan tree in Kaya Muhaka forest.

ii) *Rothmannia macrosiphon* (Engl.) Bridson. (Plate 8)

Description (Beentje, 1994);

Family: Rubiaceae

Shrub or tree 2.5 to 8m, sometimes scrambling. Leaves somewhat obovate, base cuneate, apex acuminate, 5-15 by 2-7.5 cm, glabrous or nearly so, flowers white with reddish markings, pendulous, solitary; corolla tube 135-240mm long, lobes 13-32mm long.Fruit only known in young stage, round over 30mm.

Habitat; K7, 50-500m altitude in the following forests; Shimba, Buda, Marenge, Arabuko and Mangea. Economics; The fruit yields a blue black dye. It was found in the following georeferenced point 4.33S 39.51E. In Kaya Muhaka forest, it was the rarest species as it was only found at one point where there was a population of only 3 plants. The regeneration potential was zero as no seedlings were found. At the time of collection (Mid July) however it was flowering and had even produced fruits. There was evidence of firewood collection around this point which was also very close to the forest edge. The points experienced disturbance from wild pigs which dig up the soil in order to feed on seeds and create shelter.

Plate 8: *Rothmannia macrosiphon* (Engl) Bridson showing the fruits.

iii) *Cola octoloboides* Brenan. (Plate 9)

Description (Beentje, 1994);

Family: Sterculiaceae.

Shrub or tree 3-4m. Leaves elliptic or obovate, base obtuse or rounded, apex short-acuminate, 5-21 by 2.5-8.5cm, glabrous except for the base of the midrib beneath. Flowers yellow to chocolate-brown, solitary or few, sessile and axillary, perianth tube to 7mm, lobes 14-20mm long. Mature fruit unknown. Habitat; K7, 1-450m altitude in shady crevices of forest and endemic to Cha Simba, Gongoni, Muhaka and Dzombo. Beentje (1994) classifies it as endangered. It was found in the following georeferenced points; 4.33S 39.52E, 4.33S 39.52E and 4.33S 39.52E. The regeneration potential was zero as no seedlings were found. The points experienced disturbance from wild pigs which dig up the soil in order to feed on seeds and create shelter. Footpaths and firewood collection was also evidence of disturbance.

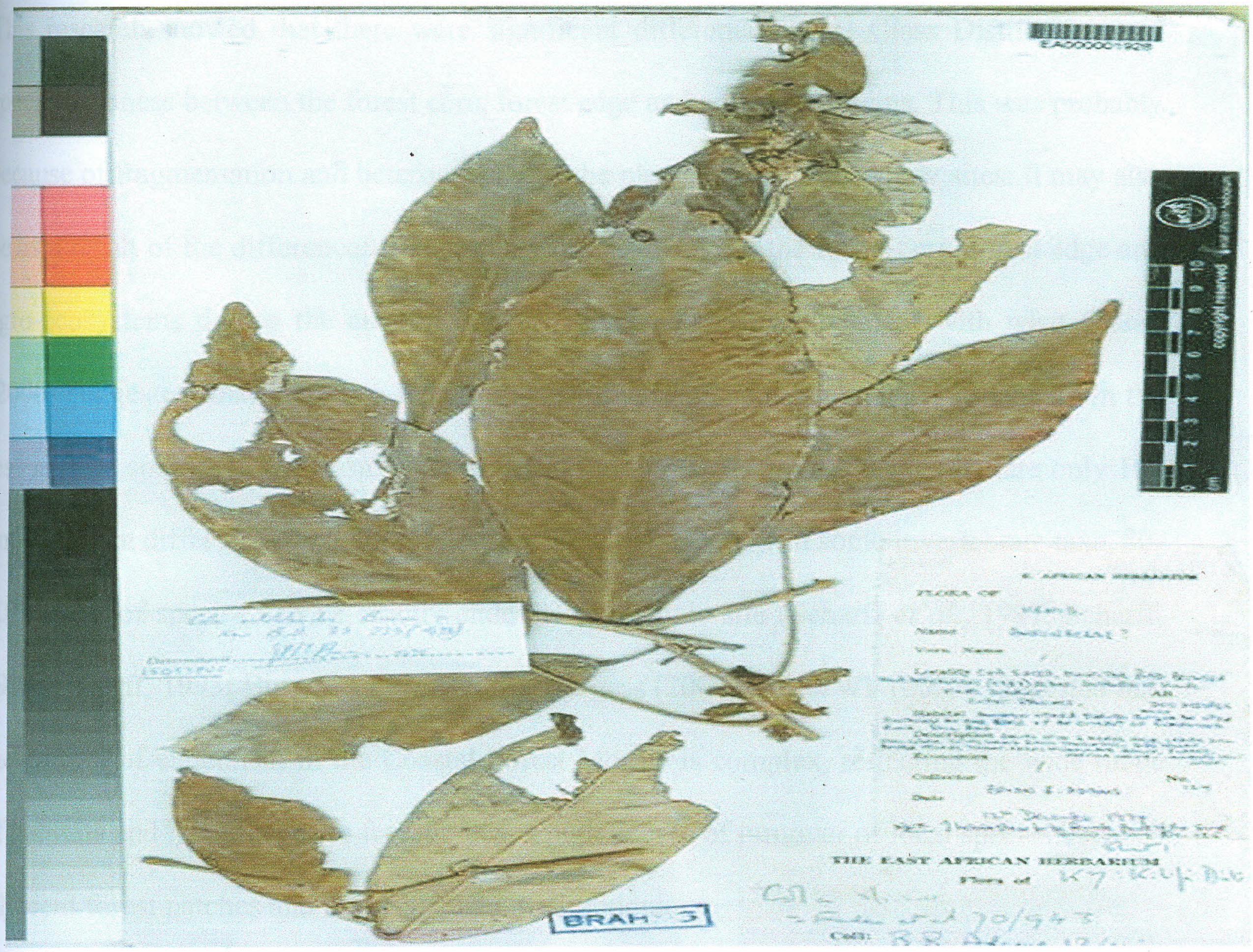

Plate 9: A collected and preserved specimen of *Cola octoloboides* Brenan at The East African Herbarium.

CHAPTER FIVE

DISCUSSION

5.1 Species Diversity in Agro-ecosystems forest edge and forest core of Kaya Muhaka

This research showed that there was no significant difference in species diversity between the forest core, forest edge and agro-ecosystems. The actual disturbances therefore had no significant effect on species diversity in the forest core, forest edge and agro-ecosystems.Moreover, the actual disturbances differ in the study sites because in the agro-ecosystems cultivation is the main form of disturbance while in the forest it is tree poaching. This research showed that there were significant differences DBH Class Distribution and species richness between the forest core, forest edge and agro-ecosystems. This was probably because of fragmentation and heterogeneity of the plant species in the study sites. It may also be as a result of the differences in the microclimates between the forest core, forest edge and agro-ecosystems due to the canopy effects. This result is in agreement with what Clarke (2000) suggested, that there is a huge turnover of species between patches, especially in the less mobile species in the Eastern African Coastal Forests Mosaic. Forests that are only 100 km apart can differ in 80 percent of their plants (Clarke, 2000). In some invertebrate taxa, 80-90 percent of species can be strictly endemic to a single site (Scharff *et al.*, 1981; Scharff, 1992, Scharff, 1993; Burgess *et al.,* 1998b). Burgess (2000) and WWF (2003) suggested that the pattern of endemism in the Coastal Forest Mosaic is complex, reflecting the wide range of habitats and heterogeneous forest types, a high degree of turnover of local species between adjacent forest patches and many disjunct distributions.

The value of diversity index in the present study ranged from 4.71 to 5.67. Knight (1975) reported that the diversity index is generally higher in tropical forests, which was reported as 5.06 and 5.40 for young and old stand respectively , whereas for Indian forests it ranged between 0.83 to 4.1 (Visalakshi, 1995) and between 1.16 to 3.40 for temperate forests (Pande *et al.*,1996). The values of diversity indices of the present study therefore lie within the range reported for tropical forests. 331 species in 77 families were recorded by Lehmann and Kioko (2005) in the Kaya Muhaka forest. 334 plant species were recorded from this small area by Luke and Verdcourt (2004). This research however revealed 492 species in 92 families. The difference may be as a result of the inclusion of farmland species in the Kaya Muhaka agroecosystem. It has been observed that diversity is lower in the absence of disturbance as well as in the presence of too much of disturbance (Pandey and Shukla, 1999). This has been shown clearly in this research where the forest edge had a higher Shannon-Wiener index than the forest core. The forest edge being an ecotone has some of the characteristics of each bordering community and often contains species not found in the overlapping communities. The influence of the two bordering communities on each other brings about the edge effect. An ecotonal area often has a higher density of organisms of one species and a greater number of species than are found in either of the communities (Encyclopædia Britannica, 2010). This research showed that the forest edge had the highest diversity among the forest transects because the rate of regeneration is high due to open canopy and the fact that it is an ecotonal area. In a study conducted by Sagar *et al.* (2008), reduced light infiltration to ground due to closed canopy was shown to reflect in lesser number of unique species and also lower species richness, evenness and alpha diversity compared to a more open canopy. On the other hand, greater irradiance on the ground was shown to increase the recruitment and diversity of herbaceous flora. Below certain thresholds, light limitation alone can prevent herbaceous species survival regardless of other resource levels (Tilman, 1982). Whittaker (1972) stated that the dominance of one stratum might affect the diversity of another stratum. In this study, the forest core had the lowest diversity due to a more closed canopy and the homogenity of the species in the core. The lower stratum dominated the canopy cover on the forest edge, where regeneration was highest, this was also the case in the forest core where the lower stratum dominated, indicating high regeneration rates therefore showing that this forest has been heavily disturbed thus the canopy was not closed enough to reduce irradiance significantly.The upper canopy was low, showing that there are few old trees thus also showing the heavy disturbance in the forest. The herb layer dominated the agroecosystems because they were often under cultivation and thus no canopy cover. The forest edge and the forest core had the lowest similarity index due to the difference in canopy cover, while the agroecosystems had a high similarity index as a result of open canopy and similar agricultural practices. The forest core had the highest similarity index due to the homogenic nature of forest core species as a result of the canopy cover.

5.2 Forest structure, Species Richness and Composition

Supriya and Yadava (2006) stated that the presence of low number of higher girth class of tree species and higher number of the saplings and seedlings indicates that the forest is young and exhibiting frequent regeneration. Lehmann and Kioko (2005) showed that Kaya Muhaka had a high density of very tall and thick trees and is less disturbed. In contrast, this research has shown that a high number of individuals (stems) occupied the lowest DBH class (5- 9 cm), and least towards the highest classes (between 35- 39cm and 45- 49cm). The prevalence of more individuals with a low DBH may be an indication that the sampled area is under a regenerating process with younger trees as per Supriya and Yadava (2006); therefore showing that the forest has been disturbed. 16 out of the 32 plots sampled were in the farmlands and therefore this may explain the trend. This is because in the farmlands most of the species regenerate in the fallow areas. Richards (1996) suggested that a natural rain forest displays a roughly negative exponential, or 'inverse J' curve when the relative abundance of stems are plotted against DBH classess. In this study, the size class distributions of stems at the forest sites exhibited the roughly negative exponential, or 'inverse J', curves typical of natural rain forests (Richards, 1996) showing a regeneration rate reminiscent of a natural rain forest. Lehman and Kioko, 2005 noted that the Northern part of Kaya Muhaka exhibited characteristics of a dry forest while the southern part exhibited characteristics of a moist forest. This research however showed that the Northern part of Kaya Muhaka exhibited characteristics of a moist forest as it had higher species richness, and the highest shrub canopy cover.

A total of 152 species were recorded in the forest edge while the forest core had a total of 124 species. It is expected that the forest edge would have more species because the rate of regeneration is high due to open canopy, as suggested by Sagar *et al.* (2008) that an open canopy will have higher species richness. The forest core transect had the least species as it ran across the forest core where there was a denser canopy with taller trees hence encouraging species homogeneity within the forest. Mueller-Dombois and Ellenberg (1974) suggested that the species having highest IVI would be identified as dominant and that having the second highest IVI would be defined as the co-dominant species. Luke and Verdcourt (2004) described Kaya Muhaka forest to be dominated by *C.suaheliensis*. Lehmann and Kioko (2005) observed that it is a "wetter mixed semi-deciduous forest" locally dominated by caesalpiniaceous trees especially *C.suaheliensis* and *S. fischeri*. The IVI for this study established that *S. fischeri* was the most dominant and *C. suaheliensis* was the co-dominant species in the forest. This may be due to the fact that *S. fischeri* has had a higher regeneration potential than *C.suaheliensis* over the years. The IVI in the agroecosystems showed *C. nucifera* as being the most dominant and *M. indica* being the co-dominant species. Supriya and Yadava (2006) reported that Poaceae (Gramineae) and Fabaceae (Leguminosae) were the most dominant families in the tropical forests of India. This study showed that the dominant families in Kaya Muhaka forest were Papilionaceae and Rubiaceae.

5.3. Forest disturbance and conservation status of endangered plant species

This research established that 27 plant species are red listed as threatened and near threatened in the IUCN (2010) Red List of Threatened Species; and the majority (85%) of these are not known in nearby Kayas of Kinondo and Mrima.The The Critical Ecosystems Patnership Fund (2005) report mentioned that 333 globally threatened (Red List) species occur in the Eastern African Coastol Forests Mosaic hotspot, with 105 species being represented in Kenya and 307 in Tanzania .The globally threatened flora and fauna in the hotspot are represented by 236 plant species, 29 mammal species, 28 bird species, 33 amphibian species and seven gastropod species. Of the 333 globally threatened species in the hotspot, 241 are Vulnerable, 68 are Endangered and 24 are Critically Endangered (The Critical Ecosystems

Patnership Fund, 2005). Two species, *C. octoloboides* and *Synsepalum subverticillatum* E.A. Bruce are globally restricted to the Kenyan coast. Three recorded orchids, *Aerangis kirkii* (Rchb.f.) Schltr., *Diaphanamthe rutila* (Rchb.f.) Summerh. and *Eulophia speciosa* R. Br. ex Lindl., are protected under The Convention on International Trade in Endangered Species (CITES). The Kaya is the first (type) locality of the Endangered (EN) *Gigasiphon macrosiphon* (Harms) Brenan, believed to be pollinated by moths in the night. Less than 10 mature individuals of the species were noted and are poorly regenerating (except a few seedlings, no single sapling was sighted). By the beginning of the twentieth century, the species was only known to exist naturally in Kaya Muhaka and Gongoni Forest Reserve, with cultivated specimens known to exist in the National Tropical Botanic Garden, Hawaii and the Botanic Garden in Nairobi (Luke and Verdcourt, 2004).

By comparison, 11.44 % of the Red Listed plant species in the Eastern African Coastol Forests Mosaic hotspot were found in Kaya Muhaka in just a sampling area of 1.28Ha.The coastal forests are interpreted as a 'vanishing refuge' with the endemic species gradually becoming more and more relict (and presumably extinct) due historically to climatic desiccation and more recently to human destruction (Burgess, 1998). A significant decrease in volume of dead wood lying on the ground over a period of 5 years (1998 – 2003) was found in Kaya Muhaka (Lehmann and Kioko, 2005). This decrease was certainly due to more firewood collection since 2001, the year when also tree poaching increased. Kaya Muhaka lost at least 5 trees of 20-30cm diameter at breast height (DBH) which were poached from the study area in 2001. Pole cutting also increased since 2001 and collecting firewood has been common (Lehmann and Kioko, 2005). Evidence from field observations in this research revealed that there is a dense presence of paths across the entire forest. Firewood collection and tree cutting was also quite evident in this forest as shown in plates 6 and 7. The clearing of the forest edge for creation of camps and the planting of exotic plant species like *C. equisetifoloa* and *J. curcas* as shown in plate 5 as a buffer also constitutes a great disturbance on the forest.The wild pigs also cause a lot of disturbance on the forest floor and this could prevent proper regeneration of threatened species. Tree poaching was also observed to be highly prevalent as shown in plate 6. Infact *M. fragrans* was found cut for poles and fresh poles (plates 6 and 7), were found abandoned on a path next to the cut *M. fragrans* which is a vulnerable species. *E. hemandradenioides* had the highest percentage of stumps and this species is redlisted as Near Threatened (NT) in The IUCN 2010 red list of threatened species. A high population density of wild pigs has led to constant burrowing of soil thus preventing seedling establishment and occasionally leading to sporadic soil erosion.

Peterson and Reich (2008) suggested that annual to biennial fire frequencies prevent shrubs and trees from competitively excluding grasses and prairie forbs, whereas spatially variable shading from overstory trees reduces grass dominance and provides a wider range of habitat conditions. Hence, high species richness in savannas is maintained by intermediate fire frequencies and variable tree canopy cover (Peterson and Reich, 2008). Pandey and Shukla (1999) suggested that moderate levels of anthropogenic disturbances are compatible with maintenance of high biodiversity of landscape. Lehmann and Kioko (2005) reported that fires were seen twice in grassland near the Western forest edge of Kaya Muhaka in February 1994 and 2003. This research established from field observations that the use of fire for land clearing purposes greatly affects the forest edge trees and encourages growth of especially

Hyparrhennia sp. Most of the bee flora in the agroecosystems is frequently burnt out during the late dry season between the months of March and April, leaving only fruit plants such as *Mangifera indica* L., *Anacardium occidentale* L.and others like *Erythrina abbysinica* DC. ssp *abbysinica* Hua. The herbaceous flora in the agroecosystems are fast growing herbs and shrubs such as *Waltheria indica* L, *A. bojeri* (Plate2) and *Eriosema glomeratum* (Guill. and Per) Hook.f. These sustain the agroecosystem after the disturbance by agricultural practices.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

The study showed that there is a high diversity of plant species in the Kaya Muhaka forest and surrounding agro-ecosystems. The forest is homogenous with species more or less evenly distributed. Most of the species are indigenous and endemic.There are also endemics that are endangered and their conservation status is very poor. The forest is heavily disturbed with numerous paths, firewood collection and tree poaching being very evident. Kaya Muhaka forest has got most of the tree species being of a lower DBH class (5-9cm) indicating that the forest is regenerating. The forest has several gaps in which there is a high diversity due to exposure to sunlight. The most dominant species in terms of the importance value index (IVI) in the forest are leguminous and those in the agro-ecosystems are fruit trees which are planted and maintained by the community for commercial and subsistence purposes. Increase in population has led to a higher demand for wood fuel and timber for construction.The forest is highly disturbed and risks extinction of some plant species if protection is not more strict and consistent. The threatened species are grossly underprotected as they are exposed to the indiscriminate logging. The continued protection of the Kayas offers survival of rare species, refugium for pollinators, mitigation of climate change (carbon sink) and as ecotourism attraction. Ecotourism involves the use of forest ecosystem for tourism purposes and could possibly increase the level of disturbance. The plant species are also used as sources of medicine, fibre, fuelwood, food, forage, building materials, ornamentals like *Whitfieldia elongata* (P. Beauv.)C.B. Clarke and cosmetics like flowers of *Mkilua fragrans*.

6.2 Recommendations

The recommendations from this research are as follows;

1. The stakeholders should invest more in biodiversity conservation of Coastal forests so as to ensure reliable income for the local communities through ecotourism.
2. The rare tree species need protection by local institutions and communities.
3. Further research should be done on the conservation and mapping of the endangered species in Kaya Muhaka forest so as to enhance their conservation and protection.
4. The new species *Zamioculcus* sp. to be taken up by scientists and studied since no work on it has been done.

REFERENCES

Agnew, A. D. Q., and Agnew S. (1994). Upland Kenya Wild Flowers Second Edition East Africa Natural History Society. Nairobi.

Arabuko-Sokoke Forest Management Team. (2002). Arabuko-Sokoke Strategic Forest Management Plan 2002–2027. BirdLife International, Cambridge.

Avsar, M.D. and Ayyildiz, V. (2010). Estimation of stand canopy cover by different methods on crown projections: Sample of Lebanon cedar stands of the Yavsan Mountain, Kahramanmaras, Turkey. *Journal of Applied Science* **10**: 1326-1330.

Bawa, K.S., Kress, W.J., Nadkani, N.M., Lele, S., Rawen, P.H., Jansen, D.H., Lugo, A.E. and 228.

Bennun, L.A. and Njoroge, P. (1999). Important Bird Areas in Kenya. Nairobi, Africa. Nature Kenya.

Beentje, H.J. (1994) Kenya Trees, Shrubs and Lianas. National Museums of Kenya, Nairobi.

Bullock, J. (1996). Plants. In: W.J.Sutherland. (ed). Ecological census techniques: A handbook. Cambridge University Press, Cambridge UK: Pp 111 – 138.

Bunnell, F.L. and Vales, D.J. (1990). Comparison of methods for estimating forest overstory cover: differences among techniques. *Canadian Journal of Forest Research* **20**: 101–107.

Burgess N.D., Negussie and Younge A. (2002): Eastern Africa Coastal Forest Programme, Regional workshop report February 4-7. Nairobi.

Burgess, N.D. and Clarke G.P. (eds) (2000). Coastal Forests of East Africa. IUCN, Gland and Cambridge.

Burgess, N.D., (2000). Global importance and patterns in the distribution of coastal forests species. In N.D. Burgess and G.P. Clarke (eds), Coastal forests of Eastern Africa. IUCN, Gland and Cambridge.

Burgess, N.D., Clarke, G.P. and Rodgers, W.A. (1998a). Coastal Forests of Eastern Africa: Status of endemism and its possible causes. *Biological Journal of the Linnean Society* **64**:337-367.

Burgess, N.D., Fjeldsa, J. and Botterweg, R. (1998b). The faunal importance of the Eastern Arc Mountains. *Journal of East African Natural History* **87**:37–58.

Bussman, R.W. (2002). Islands in the Desert – Forest vegetation of Kenya's smaller mountains and highland areas. *Journal of East African Natural History.* **91**: 27 – 29.

Clarke, G.P. (2000). Climate and climatic history. In The Coastal Forests of Eastern Africa. N.D.

Burgess and G.P. Clarke, eds. IUCN: Cambridge and Gland. Pp. 47–67.

Clarke, G.P. (1998). A new regional centre of endemism in Africa. In Aspects of the ecology, taxonomy and chorology of the floras of Africa and Madagascar. (eds. D.F. Cutler, Huxley, C.R. Lock, J.M). Kew Bulletin Additional Series.Royal Botanic Gardens, Kew.

Coe, M.J., William M.C., Stone, N.C. and Packer, G.N. (eds). (1999). MKOMAZI: The Ecology, Biodiversity and Conservation of a Tanzanian Savanna.Royal Geographical Society (With The Institute of British Geographers), London.

http://www.eoearth.org/article/Biological_diversity_in_thecoastal_forests_of_Eastern_Africa accessed on 12th September 2010.

Conservation International and Mc Ginley M., (2008). Biological diversity in the coastal forests of Eastern Africa" In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [First published in the Encyclopedia of Earth August 26, 2008; Last revised Date August 26, 2008; Retrieved January 6, 2011.

Critical Ecosystems Patnership Fund (2005): Ecosystem Profile: Eastern Arc Mountains: The Coastol Forests of Kenya and Tanzania. Conservation International and International Centre for Insect Physiology and Ecology.

Curtis, J. T. (1959). The vegetation of Wisconsin. University of Wisconsin Press. Madison, Wisconsin.

Curtis, J.T. and Mc Intosh, R. P. (1950). The Interrelation of certain analytic and synthetic phytosociological characters. *Ecology* **31**: 434-455.

Encyclopædia Britannica (2010). Encyclopædia Britannica Online Accessed on 13th Oct. 2010 <http://www.britannica.com/EBchecked/topic/178617/ecotone>.

FAO. (2006).Forests and climate change working paper 4: Choosing a forest definition for the clean development mechanism.

Geldenhuys, C.J. and B. Murray. (1993). Floristic and structural composition of Hanglip forest in the South Pansberg, Northern Transvaal. *South African Forestry Journal* **165**: 9-20.

Gentry, A.H. (1992). Tropical forests biodiversity, distributional patterns and their Conservational significance. *Oikos* **63**: 19-28.

Githitho, A. (1998). Institutional Challenges in Conservation: The Case of the Sacred Kaya Forests of the Kenya Coast. Kenya, National Museums of Kenya, Nairobi.

http://www.iucnredlist.org/ accessed on 12th September 2010.

IPGRI (1999). Diversity for Development.The New Strategy of The Internatiomal Plant GeneticResources Institute. IPGRI, Rome, Italy.

IUCN (2010). Red List of Threatened species. IUCN, Cambridge, United Kingdom.

Jaccard, R. (1908). Nouvelles recherches sur la distribution florale. *Bullutin de la Sociéetée vaudoise de Sciences Naturale* **44:** 223-270.

Jaetzold, R. and Schmidt, H., (1983). Farm Management Handbook of Kenya East Kenya (Volume II, Part C). Ministry of Agriculture, Kenya in cooperation with the German Agricultural Team (GAT) of the German Agency for Technical Cooperation (GTZ), Erhart. GmbH, Trier.

Knight, D.H. (1975). A phyto-sociological analysis of species rich tropical forest on Barro-Colorado Island: Panama. *Ecological Monograph* **45**: 259-289.

Kumar, M. and Bhatt, V. (2006). Plant Biodiversity and Conservation of Forests in Foot Hills of Garhwal Himalaya. Lyonia: *Journal of Ecology and Application* **11:** 43-59.

Lehmann, I. and Kioko, E. (2005). Lepidoptera diversity, floristic composition and structure of Three Kaya forests on the south coast of Kenya. *Journal of East African Natural History* **94**: 121 – 163.

Lovett, J.C. (1993). Climatic history and forest distribution in eastern Africa. In J.C. Lovett and S.

K. Wasser (eds), Biogeography and Ecology of the Rain Forests of Eastern Africa. Cambridge University Press, Cambridge. Pp. 23–29.

Luke, Q. and Verdcourt, B. (2004). An Early Record of *Gigasiphonmacrosiphon* (Harms) Brenan (Leguminosae-Caesalpinoidae) from Kenya and an update on its Conservation status. *Journal of East African Natural History* **93**:75-77.

Malombe,I. and Mutangah, J.(2005). Assessment of conservation value of natural habitat relics in Thika district. National Museums of Kenya, Nairobi.

Mcginley, M. and Duffy, E. (2010).Species Diversity In: Encyclopaedia of Earth.Eds. Cutler J.Cleveland (Washington D.C.: Environmental information coalition, National Council for Science and the Environment). Population sizes and distribution of primates in the lower Tana River forests, Kenya. *International Journal of Primatology* **25**:351-365.

Michieka, D.O., van der Ponw, B.J.A. and Vleeshounwer, J.J (1978). Soils of the Kwale – Mombasa – Lungalunga area. Kenya Soil survey. Reconnaissance soil survey Report No. R#, Ministry of Agricuture and National Agricultural Laboratories, Nairobi.

Mligo,C.,Lyarnu,H. and Ndagalasi, H., (2009):Vegetation CommunityStructure,Composition and Distribution Pattern in the Zaraninge Forest,Bagamoyo District,Tanzania. *Journal of East African Natural History* **98**: 223-239.

Mueller-Dombois, D. and M. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John-Wiley and Sons, New York.

Myers, N., Mittermeir R.A., Fonseca G.A and Kent J. (2000). Biodiversity hotspots for conservation priorities. *Nature* **403**: 853 – 858

Nair, P., Big Nair, D., (2009). Agroforestry as a strategy for Carbon Sequestration. *Journal of Plant Nutrition and Soil Science* **172**: 10-23.

Pande, P.K., Negi J.D.S. and Sharma S.C. (1996). Plant species diversity and vegetation analysis in moist temperate Himalayan forests. Abstracted in First Indian Ecological Congress, New Delhi. 27-31 Dec. 1996.

Pandey S.K. and Shukla, R.P. (1999). Plant diversity and community patterns along disturbance gradient in plantation forests of Sal (*Sholea robusta* Gaertn.) Department of Botany (Forest Ecology Laboratory), DDU University of Gorakhpur, India.

Peterson D.W., Reich P. B. (2008). Fire frequency and tree canopy structure influence plant species diversity in a forest-grassland ecotone. *Plant Ecology* **194**: 5-16.

Real, R.and Vargas, M. (1996). The probabilistic basis of Jaccard's index of similarity. *Systeman Biol., **45:** 380-385.*

Richards, P.W. (1996). The tropical rain forest: An ecological study.Cambridge University Press, Cambridge.

Robertson, S.A and. Luke W.R.Q. (1993). Kenya coastal forests. Report of the NMK/WWF coast forest survey. World Wide Fund for Nature, Nairobi, Kenya.

Robertson, S.A. (1984). The status of Kenya's forests. Endangered Resources for Development-Proceedings of a workshop on the status and options for management.NMK/WWF, Nairobi.

Sagar, R., Singh, A. and Singh J.S. (2008).Differential effect of woody plant canopies on species composition and diversity of ground vegetation: A case study. *Tropical Ecology* **49**: 189-197.

Sarvas, R. (1953). Measurement of the crown closure of the stand. *Communicationes Instituti Forestalis Fenniae* **41**: 13p.

Shannon, C.E. and Wiener, W. (1963). The Mathematical Theory of Communication. University of Illinois press, Urbana. 117 pp.

Scharff, N., Stoltze. M. and Jensen,D.H. (1981). The Uluguru Mountains, Tanzania: Report of a Study-Tour, 1981. Zoological Museum of The University of Copenhagen, Copenhagen.

Scharff, N. (1992). The Linyphiid fauna of eastern Africa (Araneae: Linyphiidae)—distribution patterns, diversity and endemism. *Biological Journal of the Linnean Society of London* 45: 117–154.

Scharff, N. (1993). The Linyphiid spider fauna (Araneae: Lyniphiidae) of mountain forests in the Eastern Arc Mountains. In Biogeography and Ecology of the rainforests of Eastern Africa. J.C. Lovett and S.K. Wasser, eds. Cambridge University Press, Cambridge. 115–132 pp.

Supriya, L.D., and Yadava, P.S. (2006). Floristic diversity assessment and vegetation analysis of Tropical semievergreen forest of Manipur, north east India. *Tropical Ecology* **47**: 89-98.

Tilman, D. (1982). Resource Competition and Community Structure. Princeton University Press, NJ.

UNESCO (2009). Sacred Mijikenda Kaya Forest. World Heritage Centre.13 Oct.2010, whc.unesco.org.

Visalakshi, N. (1995). Vegetation analysis of two tropical dry evergreen forests in Southern India. *Tropical Ecology* **36**: 117-127.

Whittaker, R.H. (1972). Evolution and measurements of species diversity. *Taxon* **21**: 213-251.

Wilder, C., Brooks, T. and Leus, L. (1998): Vegetation structure and composition of the Taita Hills Forests. *Journal of East African natural History* **87**: 181-187

WWF (2002). Coastal Forests of Eastern Africa: Action Plan. WWF Eastern Africa Regional Programme Office, Nairobi.

WWF (2003). Ecoregional reports: Northern Zanzibar-Inhambane coastal forest mosaic. Eastern and Southern Africa bioregions. WWF-US Conservation Science Programme.