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RESEARCH ARTICLE

FOREST STRUCTURE OF A PROTECTED EAST AFRICAN COASTAL FOREST: A CASE STUDY OF KAYA MUHAKA FOREST, KENYA

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ABSTRACT

Agricultural expansion continues to be the biggest threat facing the Coastal Forests of East Africa. Due to poor soil quality and an increasing population trend, subsistence agriculture as well as commercial farming continue to consume more and more of the region's natural habitat. The study assessed the forest structure of the Kaya Muhaka forest and the adjacent agro-ecosystems at the Kenyan Coast. Two 3 km parallel transects running through the agroecosystem and Kaya Muhaka forest from East to west and three 1 km parallel transects running from north to south of the forest were set up. 20 m x 20 m quadrats were laid out every 250 m along transects. The vegetation structure of the forest was assessed by identifying and recording all trees with a Diameter at Breast Height (DBH) of 5 and above within each quadrat. The DBH was measured using a diameter tape measure in the following class intervals; 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. Most forest species occupied the lowest DBH class of 5-9cm, with the overall DBH class distribution exhibiting an inverse letter J indicating regeneration. The canopy cover and height within the three life form layers (herb shrub and tree) were estimated in each plot by ocular estimates. 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. In all the sampled transects, the upper stratum was the least represented while the lower stratum dominated the forest canopy. These results were interpreted to mean that the forest has experienced significant disturbance from the surrounding smallholder farmers and is under a regeneration process.

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INTRODUCTION

The East African Coastal forests ecoregion supports a large number of endemic species, at a density among the highest in the world (Myers *et al*. 2000). These endemics are concentrated in the forest areas, but are also found in drier bushland and grassland habitats. Biologically, the drier forest types within this ecoregion are the most distinctive, with monospecific genera and numerous endemic species, especially within the plants (Burgess and Clarke 2000). Species richness is low in the strict forest taxa, but is greatly boosted by savanna, woodland and wetland species that also occur in the ecoregion. 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

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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). Kaya Muhaka agroecosystems have been heavily settled for many years and only a few blocks of lingering forest remain widely distributed and isolated throughout the ecoregion. Looking for wood to fuel their fires and space to grow their crops, local people have cleared much of the region's forests. Agricultural expansion continues to be the biggest threat facing the Coastal Forests of East Africa. Due to poor soil quality and an increasing population trend, subsistence agriculture as well as commercial farming continue to consume more and more of the region's natural habitat. However, there is paucity of information on the forest structure of Kaya Muhaka. The overall objective of this research was to assess the forest structure of Kaya Muhaka forest and its agro-ecosystems.

MATERIALS AND METHODS

Study Area

Kaya Muhaka is located 0419°S 3931°E, at an altitude of 45m above sea level (Robertson and Luke, 1993), about 32 km south of Mombasa City and 5.5 km inland from the Indian Ocean and 15 km South East of the Shimba Hills, close to Muhaka village (Figure, 1). With 150 ha, it is one of the largest Kayas in Kwale (Myers *et al*., 2000; Lehmann and Kioko, 2005). The rainfall average is 1129 mm annually and is received in two seasons. The long rain (mean of 568 mm) is received from April to June, and the short rains (mean of 257 mm) received from September to November (Jaetzold & Schmidt, 1983). Kaya Muhaka is situated on lagoonal deposits and sub recent marine deposits (Kilindini sands). The soils are complex and very deep (>130m), 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).

Vegetation sampling methods

The vegetation sampling method was adopted from Wilder *et al*. (1998) and Bullock (1996). Two main 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 Northern part exhibits characteristics of a dry forest while the southern part is more moist (Lehman and Kioko, 2005). Three parallel transects of 1 km each from the western edge of the forest to the forest core were laid namely; transect C1 along the forest edge, transect C1.1 parallel to C1 and transect C1.2 parallel to C1.1. This was done so as to capture species diversity and composition from the forest edge to the forest core so as to monitor disturbance. Quadrats measuring 20m by 20m were laid out at regular intervals of 250m apart along each transect to ensure sample independence. 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.

Forest Structure

The forest structure of the forest was assessed by identifying and recording all trees with a Diameter at Breast Height (DBH) of 5 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.The canopy cover and height within the three life form layers (herb shrub and tree) were estimated in each plot by ocular estimates (Avsar, 2010). However, ocular estimates are always subjective, and the results can vary even with changing weather (Jennings *et al*., 1999). 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.

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:

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

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

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).

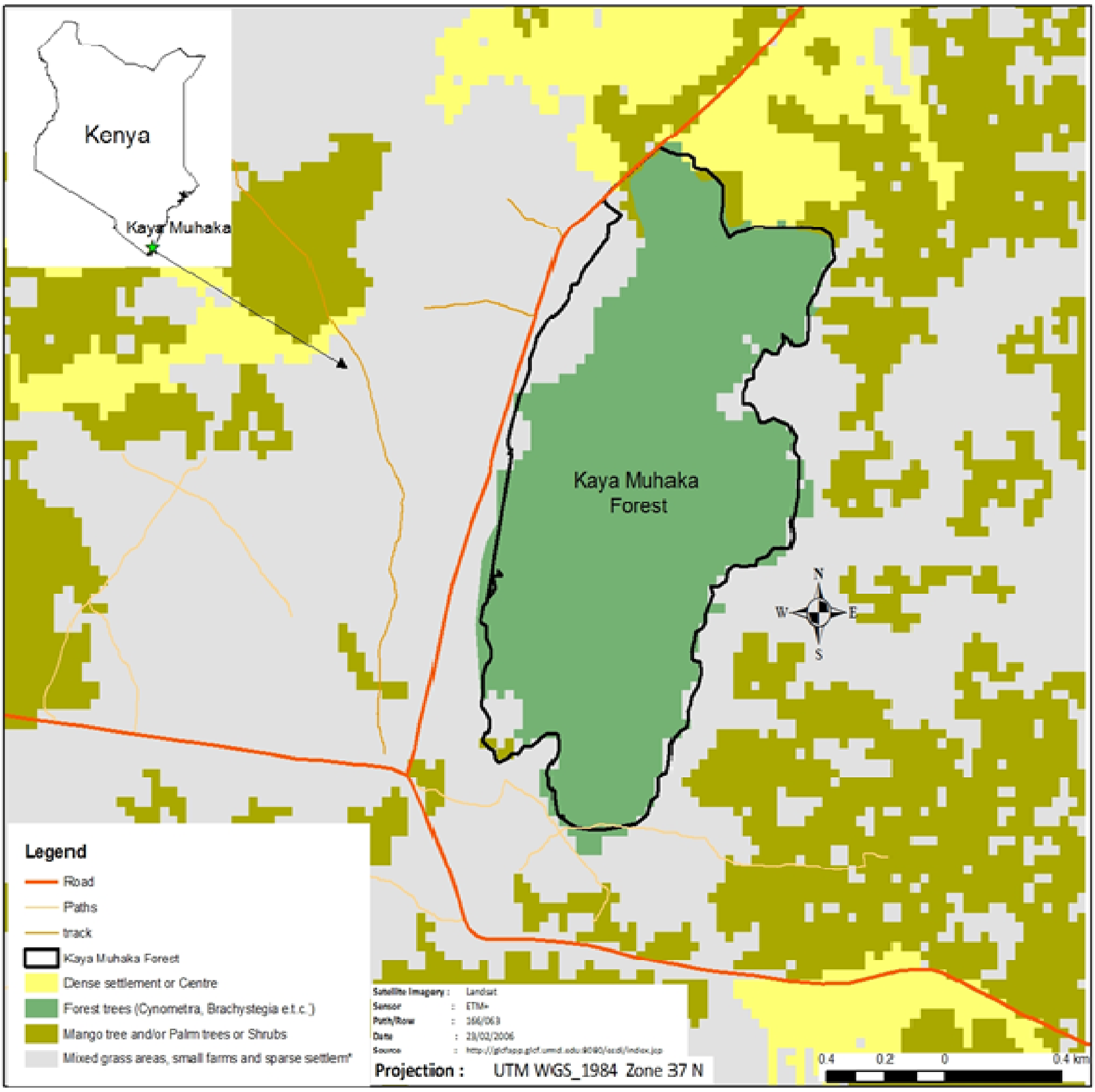

Figure 1. Map showing the position of Kaya Muhaka Forest

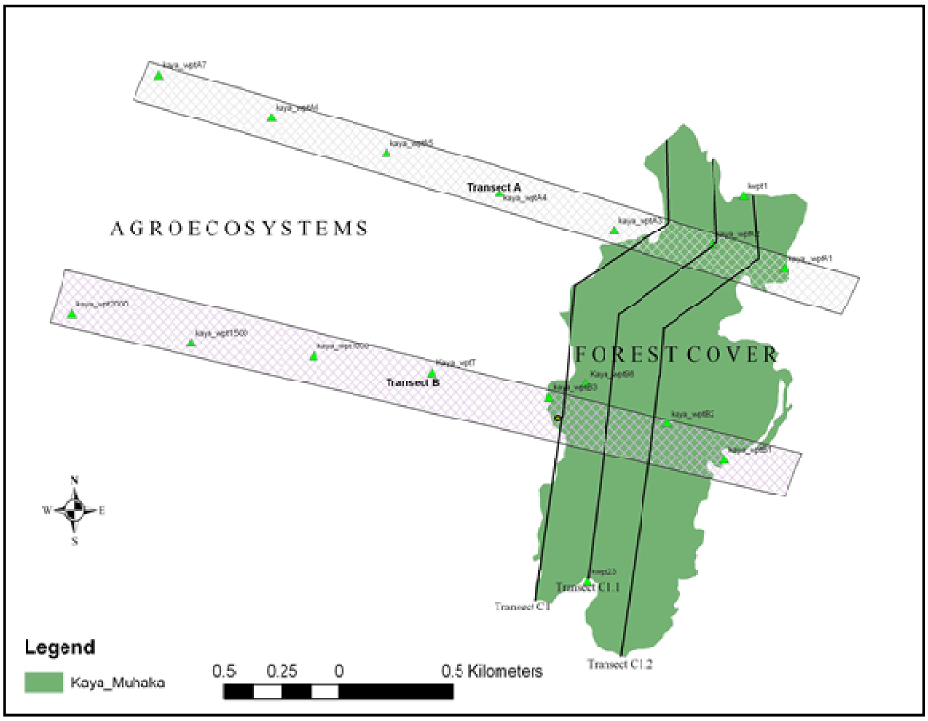

Figure 2. Sampling sites in the Kaya Muhaka Forest and its Agroecosystems

Data Analysis

The Chi squared test for homogeneity at 5% probability was used to test the significance of the DBH class distributions.

RESULTS

Forest structure and species composition

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) (Figure 3). The shape of the curve in each transect was an inverse J- shaped.

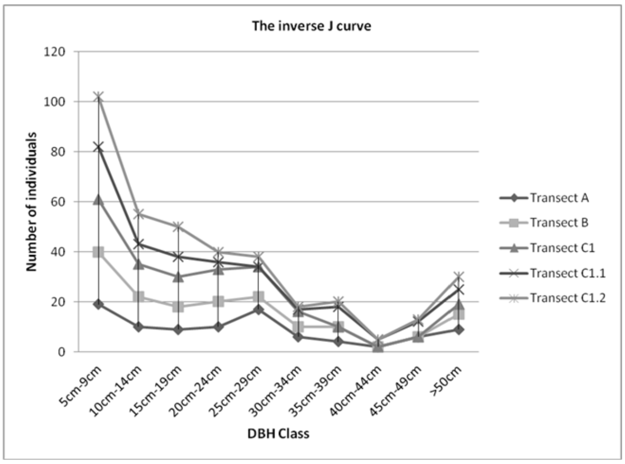

Figure 3. The inverse J curve of DBH Class Distributions in Kaya Muhaka Forest

All the transects had the highest number of individuals in the DBH class of 5-9 cm interval. In all transects there was a slight reduction in number of individuals in the DBH classes 10-14 cm, 15-19 cm and then it started rising from the 20-24 cm DBH class up to 25-29 cm DBH class. Another noticeable reduction occurred in the classes between 30-34 cm and 40-44 cm followed by an increase from the 45-49 cm to the >50cm DBH class. The Chi Square test for homogeneity for the DBH Class Distribution in all transects was highly significant (Table 1). In addition the Chi Square test for homogeneity for species richness in the forest core, forest edge and agro-ecosystems was 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.

Importance Value Index (IVI)

Table 2 below shows the ten most important species as per the Importance Value Index (IVI). *S. fischeri*. had the highest Importance Value Index in the forest and *Cocos nucifera* L. in the agroecosystems. The family Leguminosae dominated the forest while Anacardiaceae dominated the farmlands Other notable species being *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. Ssp. *Senegalensis.*

Table 1. The Chi Squared test for homogeneity for the DBH Class Distribution in all transects and for species richness in the forest core, forest edge and agro-ecosystems

Chi Square Test	d.f	0.05 p value	Chi value	Significance at 5% p
DBH Class distribution	9	16.91898	184.12329	p<5% highly significant.

Table 2. Importance Value Index as per Mueller-Dombois and Ellenberg (1974) for species in Kaya Muhaka showing the 10 most dominant species and the dominant and co-dominant species in the forest and the agroecosystems

Botanic name	family	IVI
Cocos nucifera L.	Palmae	666.5
Scorodophloeus fischeri (Taub.) J.L,on	Leguminosae	618.3
Mangifera indica L.	Anacardiaceae	480.9
Anacardium occidentale L.	Anacardiaceae	302.4
Cynometra suaheliensis (Taub.) Baker f.	Leguminosae	260.1
Julbernardia magnistipulata (Harms) Troupin	Leguminosae	256.3
Hyphaene compressa H.Wendl.	Palmae	240.3
Craibia brevicaudata (Vatke) Dunn ssp. *brevicaudata*	Leguminosae	176.7
Antidesma venosum Tul.	Euphorbiaceae	175.7
Grewia plagiophylla K.Schum.	Tiliaceae	170.4

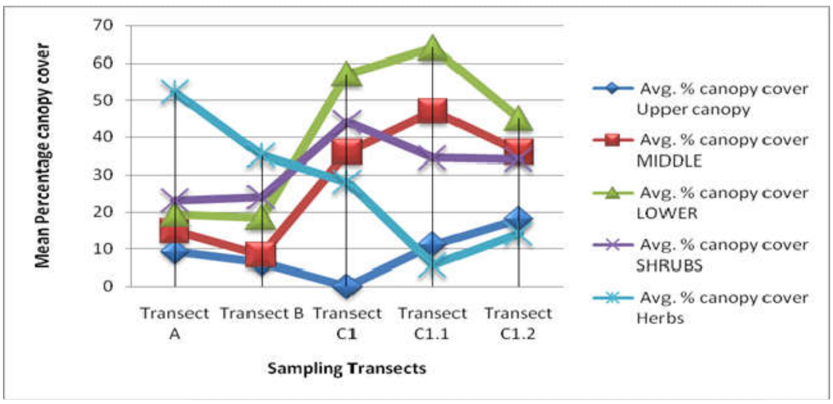

Figure 4. Average percentage canopy cover in the transects in the forest core, forest edge and agro-ecosystems in the canopy layers

Canopy cover

Figure 4 below shows the average percentage canopy cover of the various strata and life forms. Transect A was dominated by the herb, *Agathisanthemumbojeri* Klotzsch. 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 4 shows that in Transect C1, the lower stratum dominated the canopy cover comprising mainly *J. Magnistipulata* and *Polysphaeriaparvifolia* Hiern. Transect C1.2 which is in the forest core also had the lower stratum dominating, comprising mainly *S.fischeri*. The upper canopy was generally low. Transect C1.2 had the highest percentage of the upper canopy cover, mainly *S.fischeri* and *C. Suahiliensis.* The lower canopy cover was highest in transect C1.1 mainly composed of *J. Magnistipulata*. The herb and shrub layer were highest in Transect C1 and they comprised *P. parvifolia* and*A. bojeri.* The general comparison between the forest and the agroecosystems is that the forest was dominated by the lower canopy while the agroecosystems are dominated by the herb canopy. In all the sampled transects, the upper canopy was the least represented while herbs was most dominant in transects A and B. The Lower canopy occupied highest percentages in the C transects where herbs are notably lower.

DISCUSSION

Forest structure and Importance Value Index

Supriya et al., (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 *et al.,* (2006); therefore showing that the forest has been disturbed. Richards (1996), suggested that a natural rainforest displays a roughly negative exponential, or 'inverse J' curve when the relative abundance of stems are plotted against DBH classes. In this research, the size class distributions of stems at the forest sites exhibited the roughly negative exponential, or 'inverse J', curves typical of natural rain forests showing a regeneration rate reminiscent of a natural rain 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 research established that *S. fischeri* was the most dominant and *C. suaheliensis* was the co-dominant species in the forest. The IVI in the agroecosystems showed *C. nucifera* as being the most dominant and *M. indica* being the co-dominant species.

This research showed that the forest edge had an open canopy owing to 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 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. 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.

Conclusion

Most of the trees in the Kaya Muhaka forest are dominated by the lower DBH class of 5-9 cm, indicating that the forest is regenerating. Conservation measures should be put in place to save the forest from extinction since it is a refuge for rare species, refugium for pollinators, acts as mitigation for carbon sequestration and an ecotourism attraction. It is recommended that conservation and mapping of the endangered species be carried out in order to enhance their conservation and protection.

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