AFRICA ENVIRONMENTAL REVIEW Journal

ISSN: 1727-8341

AER Journal Volume 3, Issue 1, pp. 210-221, 2018

RESEARCH ARTICLE

Available Online at *http://www.aer-journal.info*

Tree Species Distribution and Diversity in Kibonge Forest Reserve, Kenya

E. Chirchir[1*], V. Sudoi[1] and J. Kimanzi[2]

[1]*Department of Biology and Health, School of Environmental Studies, P.O. Box 1125, Eldoret*

[2]*School of Natural Resources, Department of Wildlife, P.O. Box 1125, Eldoret*

**Email: elizachirchir@gmail.com*

Abstract

Many forests are under great anthropogenic force and require management interventions to protect and maintain the overall biodiversity and productivity. Understanding species diversity and distribution patterns is important for assisting managers evaluate the complexity and resources of these forests. Tree species distribution and diversity were assessed in Kibonge Forest Reserve. Data were collected between, July 2013 and July 2014 using quantitative vegetation analysis method on trees samples of DBH limit of ≥15 cm. Tree parameters; species, trees size (diameter at breast height (DBH)), total height and amount of canopy cover were determined within eighty seven (87) systematically located vegetation plots of size 20 by 10m along three transect lines. A total of 1124 trees were measured and 29 tree species were identified in the study area. Data obtained were analyzed using descriptive, Chi square tests and Cross tabulation analysis. Tree species were identified in the field while those which could not be identified had their essential parts pressed and taken to a university herbarium for identification .Chi square tests were carried out to establish variations between species and altitude. The dominant tree species in the forest were C. lustanica (39%), Dombeya goetenzii (24%), Prunus africana (11.3%), Croton macrostachyus (9.2%) and M. kilimandascharica (6.8%). The basal area estimated is 23.85m2 while the population density was 2trees/Ha. Results showed that more tree species were concentrated on altitude 2400m (χ^2=610.95, df =78, p<0.001). Having known that the population of trees is low, there was need to establish an intense programme of re afforestation and to protect further reduction the existing forest by creating buffer zones on boundaries between human habitation and the forest.

Key Words: Buffer Zone, Tree Species, Diversity and Forest Reserve

INTRODUCTION

Forests in the tropics are often referred as the most species diverse terrestrial ecosystems. Their abundant bio-diversity makes variety of natural resources used by many communities to sustain their livelihoods (Kumar *et al.*, 2002, Khan *et al.*, 1997). However many of these forests are under anthropogenic threat and require management intervention to protect and maintain overall biodiversity, sustainability and productivity (Kumar *et al.*, 2002). Understanding species diversity and distribution patterns is important for assisting managers evaluate the complexity and resources of these forests. Trees form the major structural and functional basis of tropical basis ecosystems and can serve as indicators of changes and stressors at the landscape (Misra, 1968). The present study focused on analyzing distribution and abundance pattern of tree species over a landscape covering an area of 8.7 ha in the Elgeyo escarpments of Kenya.

The high biodiversity of trees in tropical rainforests is well expressed by many ecologists and the general public (Wilson, 1998). Despite such attention, the causes of the high diversity on some altitudinal range is not known (Leigh, 1999). Over the course of decades, researchers have proposed a copious array of hypotheses to explain patterns of species richness, or the number of species per unit area (Gentry, 1988; Huston, 1994; Rosenzweig, 1995; Leigh, 1999) in other forests of the world. Some hypotheses explain high tropical diversity on the basis of biogeography, evolutionary history, or species ranges, (Rohde, 1997; Rosenzweig, 1995; Stevens, 1989). Other hypotheses, such as the pest pressure hypothesis (e.g. Janzen, 1970), the niche diversification hypothesis (e.g. Connell, 1978), explanations invoking mycorrhizae (Janos, 1983), and explanations related to treefall gaps (e.g. Denslow, 1980; Brokaw, 1985) explain diversity on the basis of interspecific interactions. Many methods have been used to explain the distributions. Aerial view or use of geo-positioning system have been used but the method does not show distribution of trees based on species type. Kibonge forest has however remained largely unstudied except for our work aimed at determining the abundance and diversity of tree species in Kibonge forest using quantitative vegetation analysis method which explains vegetation status of the forest, canopy cover for a sample of trees, gives tree sizes (DBH) and tree species.

Kibonge forest is one of the legally protected tropical forests highly disturbed by human activities. It extends in a North-South direction along Elgeyo escarpment in the Great Rift Valley in Kenya. The region has more endemic species per unit area than all the world's richest biodiversity "hotspots" (Myers *et al*., 2000).

METHODOLOGY

Location of Study Area

Kibonge forest is found in Keiyo District (0^{o}10$^{/''}$47"–0^{o}26$^{/''}$37"N and 35^{o}27$^{/''}$12"-35^{o}41$^{/''}$43"E) *in* the Rift Valley Province of Kenya. It borders Eldoret East district to the West, Baringo central to the East, Eldama Ravine to the South and Keiyo North to the North (Figure 1). The district covers an area of 898 square kilometers. The study was carried out in Chepkorio division in an area of 8.7Ha. Keiyo District has a population of 143.865 (District Development plan, 2010).The forest is situated in Chepkorio Division with a population of 67,062 of which 1000 are in Nyaru town adjacent to the forest. The town is 42 km East of Eldoret town and 56km south of Iten town.

The study area is divided into three main agro-ecological zones which run parallel to each other in a North-South direction; highland, the Elgeyo escarpment and the Kerio Valley basin. The highland lies at an altitude of approximately 3000m above the sea level and extends across the constituency from North to South. The land falls precipitously in a series of steep uplands Kapchebelel ranges to the south of Nyaru town, which comprise the Elgeyo escarpment. The Kerio Valley basin is 1000m above the sea level.

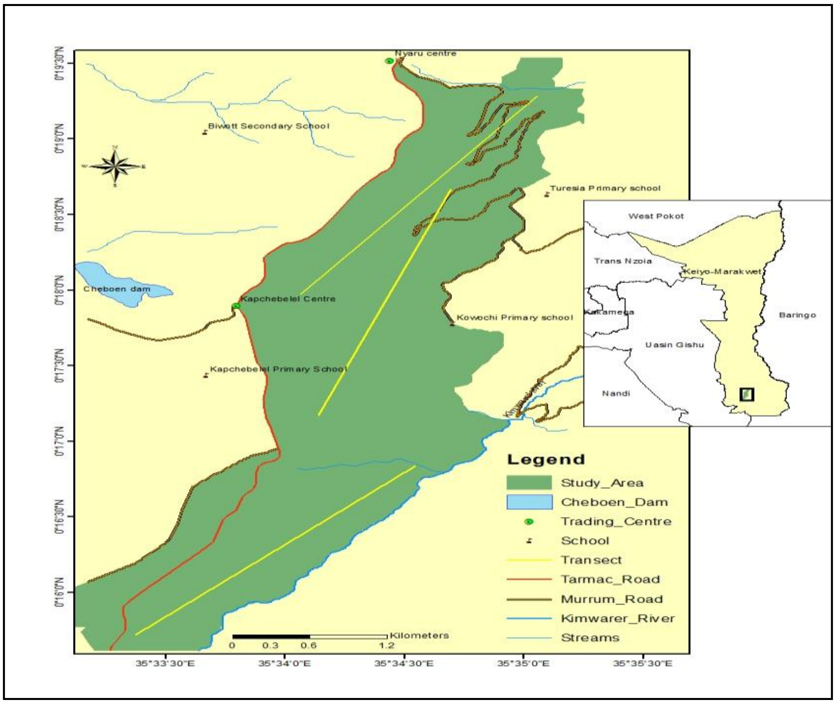

Figure 1. Map of Elgeyo Marakwet County Showing the Study Area

Method for Data Collection from Vegetation for Quantitative Analysis

Quantitative vegetation analysis method was applied. This method was adopted from a survey carried out in Udzungwa Mountains Biodiversity Survey (UMBS), (Frontier Tanzania, 2001). This aimed at sampling trees equal to or greater than 15cm diameter at breast height (DBH) and determining their canopy cover within systematically located vegetation plots in the survey area. The species composition of the forest under investigation was also determined.

In order to obtain the vegetation status of the forest, canopy cover for a sample of trees, were determined by measuring the diameter of a tree at breast height (DBH).The sum total would give the canopy cover of the forest. DBH as a measure of tree size was preferred, because the inter-observer reliability for this measure is high (Chapman *et al.*, 1992) and the square of DBH as well as the basal area (DBH^2/ 1.273), is a good predictor of leaf biomass (Enquist, 2002). Also, use of crown volume would be impractical to measure, because the canopy in the forest is often entangled with vines that make crown edges very difficult to see.

Multi-stem trees with individual stems of less than 10cm DBH, were recorded if the cumulative DBH was 10 cm or over. All stems arising from the central stem at 1.3m and below was added. The stems were marked with paint at the place where the DBH was measured. If the tree had a buttress, its DBH was measured 1.3m above the top of the buttress. Fallen trees but still alive were processed as above. Dead trees were not counted. For trees growing on a slope, the 1.3 m was measured from the uphill side of the tree. Voucher specimens were collected and pressed for further identification and analysis at Eldoret University laboratories. Figure 2 and 3 shows how to measure depth at breast height at various terrains (Miyaura and Hozumi, 1982).

Statistical Analysis of Data

The basal area was calculated using the following formula:

Basal area = DBH^2/ 1.273 (Enquist, 2002); where DBH is diameter at breast height and 1.273 is a constant.

Estimation of Canopy Cover was given in terms of percentage cover (Enquist, 2002) such that Percentage coverage is equal to the area covered by a species (Basal area) in a line transect divided by the total area covered by all the species multiplied by 100. While relative coverage is equal to coverage or dominance of a particular species divided by the total coverage (Dominance) for all the species in a stand and all multiplied by one hundred.

Measurement of Species Composition and Dominance

Species Composition was measured using method by Misra, (1989) and Sorensen, (1948)

a) Index of similarity (S) = 2c/a+b

Where, A = Number of species in the community A, B = Number of species in the community B and C = Number of common species in both the communities.

b) Index of dissimilarity = 1-S

N/B - Similarity index suggests that species present in one habitat (line transect) may occur in the other whereas dissimilarity index indicate that some trees species recordered in one line transect are not in the other one (encountered in only one line transect, in only two line transects, in all line transects).

RESULTS

Vegetation Status of Kibonge Forest Reserve

From field findings, there were many trees of various species, n= 1124 in Kibonge Forest (Appen 1). Segen region had the highest percentage frequency (74.8%) occupying a Basal Area of approximately 14.3m^2/ha while Mwen region had a lower percentage frequency (25.2%) occupying a Basal Area of approximately 9.55 m^2/ha. In Mwen majority of the tree species were *Dombeya goetenzi* (24%), *Macaranda kilimandascharica* (11%), *Albizia gummifera* (7.8%), *Nuxia congesta* (7.1%), *Cupressus lusitanica* (3.9%), *Croton macrostachyus* (9.2%) and *Prunus Africana* (11.3%). In Segen majority of the trees were *Cupressus lusitanica (57.4%), Macaranda kilimandascharica (6.8%), Dombeya goetenzi (16.8%), Prunus Africana (5.2%)* and *Vangueria madagascariensis* (11%). Other trees represented a population of less than 1% (Fig 5). Based on altitude majority of the trees, 48.8%, were sampled along altitude 2400m in both regions, followed by those in altitude 2500m, 36.7%, while the fewest below 10% were in altitude 2300m, 6.1% and at 2600m (Table 1) .However, an ANOVA test to find the relationship between canopy cover of tree species in the two regions showed no significant difference in canopy cover of tree species between the two regions (F=1.390, P= 0.239). Overall resource abundance as measured by basal area (m^2/ha) for all trees in Kibonge forest was 23.7489m^2/ha. The basal area and percentage canopy cover of all the trees are shown in Appendix 1**.** The higher the percentage frequency of trees, the greater the basal area (BA) and subsequently percentage canopy cover.

Tree Species Distribution and Altitude

A chi-square test showed a significant difference (n=1124, p ≥0.001, df =78) in tree distribution within altitudes. Most of the tree species are distributed along altitude 2400 m and 2500m (Table 1). For instance *Nuxia congesta, C. lustanica, F. cycamore, Polyscias kikuyuensis,*and *M. melanoploes,* had a higher population in altitude 2400m. *Macaranga spp* and *Dombeya spp* were evenly distributed in all altitudes. *Juniperus procera, Podocarpus gracillior* and *Uclea divinorum* are few n=1 and only found in altitude 2400 m. Exotic species, *Grevillea spp, Eucalyptus spp*. and *Acacia spp*. are also distributed in altitude 2400 m. *Olea Africana* (n=4), are only found in the steep locations of altitude 2300 m (Table 1).

Table 1. Cross Tabulation of Tree Species Distribution along Various Altitudes in Kibonge Forest

Tree Species	**Altitude**				
	2300	**2400**	**2500**	**2600**	**Total**
Eucalyptus saligna	0	21	0	0	21
Nuxia congesta	0	22	5	1	28
Pepper tree	0	0	3	0	3
Cupressus lusitanica	10	227	253	4	494
Olea Africana	4	0	0	0	4
Grevillea robusta	0	3	0	0	3
Vangueria madagascariensis	6	3	0	0	9
Bersama abyssinica	0	0	3	0	3
Teclea nobilis	3	0	1	0	4
Garcinia livingstonei	2	0	7	0	9
Markhamia lutea	0	9	2	7	18
Ficus cycamorous	0	15	0	0	15
Podocarpus gracillior	0	3	1	0	4
Macaranga Kilimandascharica	5	35	28	22	90
Podocarpus falcactus	2	1	9	0	12
Polyscias kikuyuensis	8	23	0	2	33
Dombeya goetzenii	0	83	83	43	209
Ficus thonningii	2	7	2	0	11
Rhus natalensis	0	0	1	0	1
Grewia bicolor	4	2	0	0	6
Myrsine melanoploeos	2	8	0	2	12
Juniperus procera	0	1	0	0	1
Croton macrostachyus	5	26	3	2	36
Ekerbagia capensis	0	5	3	2	10
Prunus Africana	15	49	9	3	76
Uclea divinorum	0	1	0	0	1
Acacia mearnsii	0	5	0	6	11
Total	**68**	**549**	**413**	**94**	**1124**

Table 2: Tree Frequency Distribution in Altitudes 2300m, 2400m, 2500m, and 2600m in Kibonge Forest

Altitude(m)	**Frequency**	**Percent**
2300	69	6.1
2400	549	48.8
2500	413	36.7
2600	94	8.4
Total	1125	100.0

From Figure 2 and Figure 3, it is clear that in Segen majority of trees sampled were *Cupressus lusitanica* n=483, (57.4%) covering (2.64 m^2/ha) of the forest unlike in Mwen were majority of trees sampled were *Dombeya goetenzii* n=68, (24%) with a canopy cover of 2.94 m^2/ha.

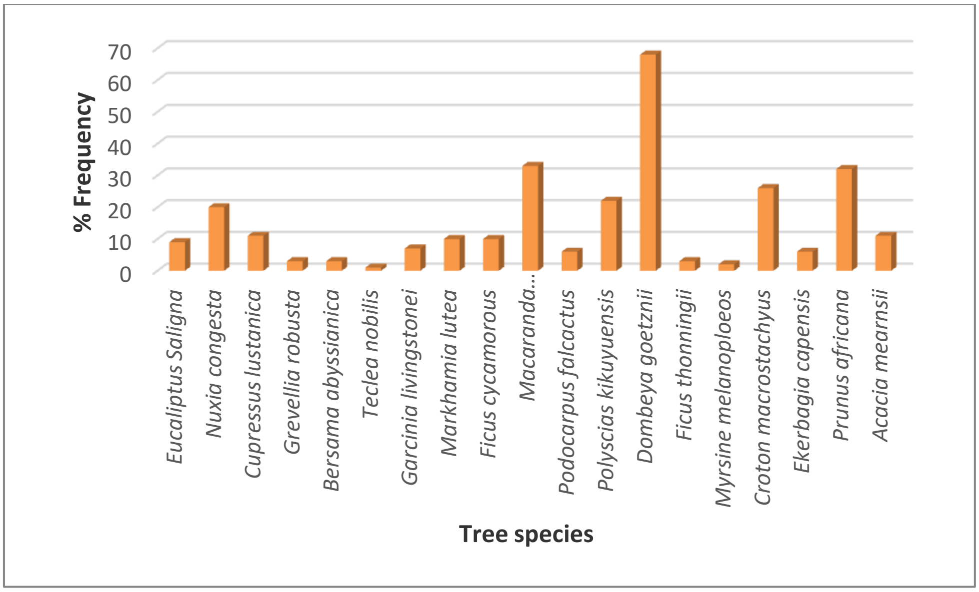

Figure 2. Frequency Distribution of Trees in Mwen Region of Kibonge Forest. *D. goetenzii*, *P. africana* and *C. macrostachyus* are the Dominant Species

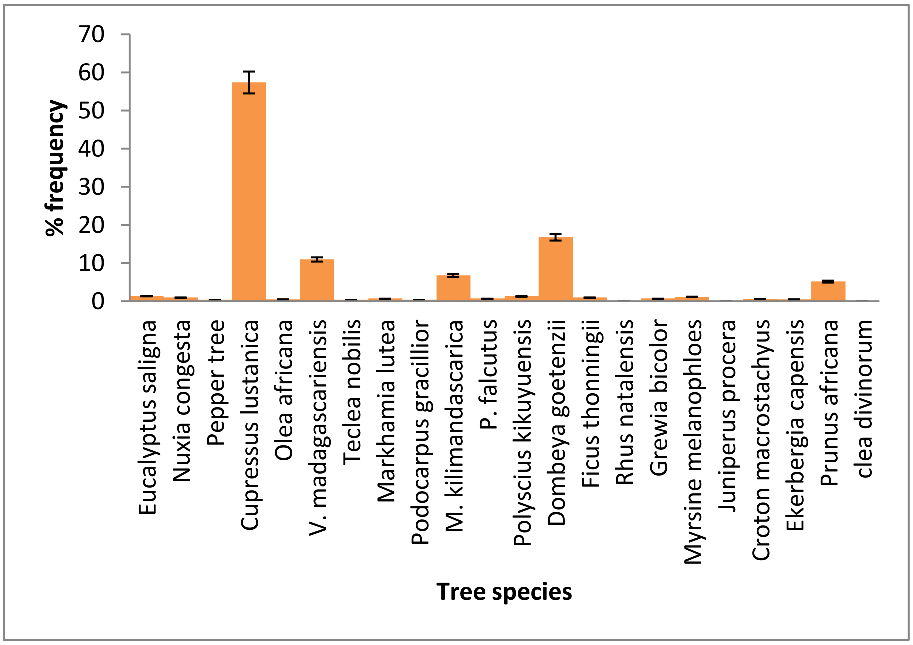

Figure 3. Tree Frequency Distribution in Segen Region of Kibonge Forest. *C. lustanica* and *D. goetenzii* are the Dominant Species

Tree Measurements and Tree Composition

The species similarity index was high, S=0.94, showing that the two regions, Mwen and Segen, were composed of diverse species. Species in one region could also be found in the other region. Also the dissimilarity index=0.6 is an indication that some species were in one region and not in the other.

Diameter at Breast Height (DBH) of all Trees in the Forest

The DBH of all trees in Kibonge grouped at intervals of width 10 are shown in table 3 below. Majority of trees fell within DBH range 30-40cm (37%) while fewer were within range 0-10cm (6%).There was a significant difference in DBH of trees between regions Mwen and Segen (df=1123,F= 4.194, p= 0.041).

Table 3. Tree Frequency Distribution Grouped at Intervals of 10 in Kibonge Forest

DBH GROUP	Frequency	Percent
0-10	6	.5
10-20	221	19.7
20-30	143	12.7
30-40	416	37.0
40 and above	338	30.1
Total	1124	100.0

From Figure 4, the trees which fell under DBH range of above 40 cm are *R. natalensis* and *Ficus thoningii* with the greatest DBH (>120 cm), *Prunus africana, P. kikuyunensis* and *Grewia bicolor* had their DBH fall within the range 40-60 cm. Other trees had a DBH below 40 cm as shown in the figure below.

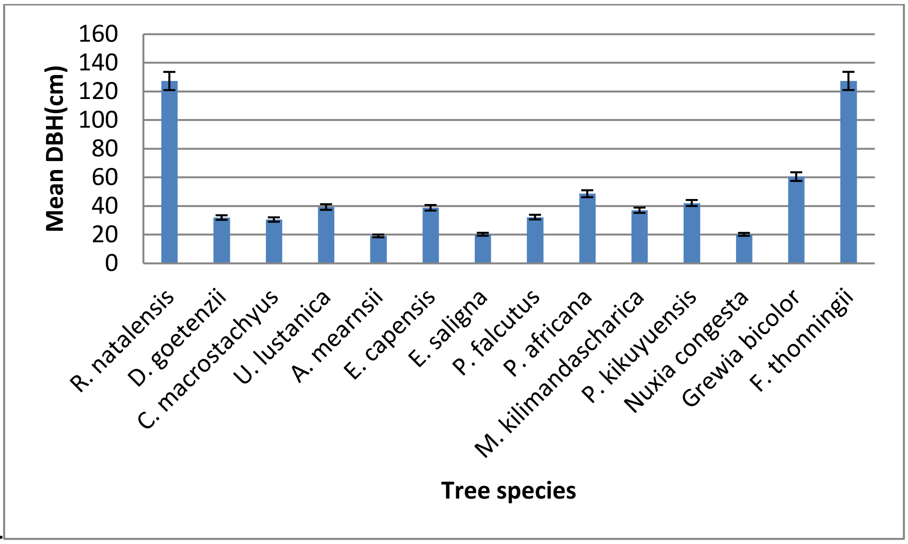

Figure 4. Mean ± SE Diameter at Breast Height of Tree Species in Kibonge Forest

DISCUSSION

Tree Species Diversity

The 29 tree species captured in the study sites reflects a relatively species-diverse forest, typical of tropical forests. According to research done by Mutangah *et al.*, (1992), 147 plant species was recorded in Kakamega tropical rainforest, (Mutiso *et al.*, 2015) found 52 species while studying the floristic composition, affinities and plant formations in tropical forests in Mau Forests, Kenya. Omoro *et al.*, 2010 on the other hand captured 58 species in Taita hills forests while in Kakamega forest. Fashing (2004), recorded 64 spp. In Oban forest in Nigeria, Aigbe and Omokhua, (2015) found a total of 72 species distributed into 30 families and 65 genera were identified in the study area. The highest documented species richness in any of Kenya's indigenous forests was 280 plant species for the Mau Forest Reserve Complex, which covers an area of about 360,000 ha (Mutangah *et al.,* 1993).

From the study it is apparent that, there is a decline in species diversity, probably due to the constant overexploitation of the forest resource such as clearing of forest for human settlement, logging and charcoal making among others. As in most tropical countries where human populations are ever-escalating, forest conservation is a vital issue in Kenya (MEMR, 2012). By the late 1980s/early 1990s only two percent of Kenya remained covered by indigenous forest (Wass, 1995), and 80% of this remaining forest cover occurred in agricultural areas with high human densities (Tsingalia, 1988). In Kibonge forest few species diversity as compared to other region indicate there is a reduction in species density due to conversion of forest into farmlands. Fewer species reported leaves a limited range of food to be selected by colobus monkey and increases competition for the same. Those animals who may fail to choose from the available foods may naturally get eliminated or move away or seek for an alternative diet from the farmlands. This causes animal human conflict which may endanger the animals' life.

Forest Biodiversity and Distribution

Kibonge forest was subdivided into two regions Mwen and Segen. The status of the forest was further verified through ground truthing to establish the actual number of trees in the area of study. Population data of undisturbed trees and disturbed were collected from 87 vegetation plots for both regions, A total of 1123 trees in different girth classes were measured in 90 temporary sample plots of size 20 m x 10 m, from the Kibonge forest which amounted to an area of 8.7ha with a density of 129 trees/ha which relates to diverse findings from research conducted across different eco-regions of the tropics. In tropical Barro Island, Panama, Chave *et al.* (2003) reported 152/ha; while Ho *et al.* (1987) found 104/ha in tropical Jengka Reserve, Malaysia.

Tree species composition varied significantly among the different elevations along the Elgeyo escarpment where the forest is located, when traversing from lower elevation through the middle to the top. Our results showed that most of the tree species for instance *Nuxia congesta, C. lustanica, F. cycamore, P. kikuyuensis* and *M. melanoploes*, had a higher population in altitude 2400 m. *Macaranda spp* and *Dombeya spp* were evenly distributed in all altitudes. *Juniperus procera, Podocarpus gracillior* and *Uclea divinorum* are few and only found in altitude 2400 m .Exotic species, *Grevellia spp, Eucalyptus spp*. and *Acacia spp*. are also distributed in altitude 2400 m. *Olea Africana* are only found in the steep locations of altitude 2300 m a similar finding were the most widespread montane association are the moist *Oncotea spp – Polyscias spp* and drier *Podocarpus spp – Cassipourea spp.* while *Junisperus spp – Olea spp* dominates the upper slopes (Peltorinne, 2004).

There are multiple theories concerning natural patterns of species richness on elevational gradient and their determinants (Ghazoul and Sheil, 2010). On mountains, area effects have been shown to affect species richness patterns (McCain, 2009). Many studies indicate a so called ''mid-domain effect'' in which species richness increases and then declines with increasing elevation and that can be seen as a natural consequence of species range patterns and elevation limits as seen in this study (Cardelús *et al*., 2006). Tree species richness was found to be varied along the valley when traversing from lower elevation through the middle to the top. This result can be based on altitude where in our study 48.8% of the trees were sampled along altitude 2400 m in both regions, 36.7% in altitude 2500 m, 10% in altitude 2300 m, 6.1% in altitude 2600 m. Our study relates to findings by Brown, (2001) and Lomolino, (2001) who discovered diverse plant and animal species along elevation gradient on mountainous ecosystem as well as varied climate and soil differentiation. The study also confirms works by (Rahbek, 1995; Austrheim, 2002; Vetaas and Gerytnes 2002) where species richness along elevation gradient across habitats has been established.

It can also be deduced from this study that, the habits of the plant species as one travels from lower elevation to upper elevation changes from species of forest ecosystem to that of savannah ecosystem. The middle elevation level comprise species of both forest and savannah ecosystem. These changes may be attributed to two main factors: firstly, the water availability is high and decreases as the altitude increases and secondly, the soil nutrient contents might be high at the lower and the middle elevations than the top elevation. This is because the top soil nutrients at the top elevation might have suffered from erosion and be deposited on the lower elevation. This might also explain why the tree richness was poor at the top elevation and rich at the lower elevation. Similar trend emerged with the sizes of the trees where the basal areas of the trees at the lower elevation were also larger than those of trees found at the higher elevations (Rahbek, 1995; Austrheim, 2002; Vetaas and Gerytnes, 2002). The reason for the low species richness and poor basal area of trees at the middle to top site could be due to the steepness of the mountain side and associated leaching of nutrients which will make it hard for trees to grow under such conditions.

Basal Area and Canopy Cover

Overall resource abundance as measured by basal area (m^2/ha) for all trees in Kibonge forest was 23.7489 m^2/ha. Total basal area for Mt. Elgon forest (28.7 m^2/ha) (Hitimana *et al.*, 2004). The value obtained in the forest reserve is within the ranges reported by Hitimana *et al. (*2004) for other tropical forest of the world though higher than the 15 m^2 obtained by Alder and Abayomi, (1994), for a well-stocked tropical rainforest in Nigeria. Equable tropical climate of the study area may have contributed to high tree growth rates and high tree basal area. The high basal area value obtained in this study is attributed to the high number of an exotic tree species, *Cupressus lusitanica* which had a large DBH and highest population. This tree species was highly preffered by *C. angolensis* at all seasons. The high basal area, is also an indication that Kibonge forest is probably one of the richest of the tropical rainforest left in Kenya. This may also indicate that, the reserve is probably well regulated. The higher the percentage frequency of trees, the greater the basal area and subsequently percentage canopy cover (Fashing *et al.*, 2004). The population was commonly observed in forests of mixed vegetation with numerous tree species at various heights (Anderson *et al*., 2007c). The areas inhabited tree species reaching approximately ten meters and above except from the perennial plantations were the average tree height was three meters.

CONCLUSIONS AND RECOMMENDATIONS

There were more tree species concentrated on higher altitude (2400 m) which was a steep slope in Kibonge. The majority of these trees were exotic spp. such as *Cupressus lusitanica* and also indigenous species (*Nuxia congesta*). Preference of exotic species gives a conclusion that they can be planted to act as buffer zones between human habitation as well as provide alternative source of materials for use by humans. Other exotic species may be planted to provide more wood for humans and other animals.

Forest loss and ongoing tree extraction in Elgeyo Marakwet County, is a dynamic and ongoing process even in protected government forests such as Kipkabus and Kaptagat forest reserves. The high degree of human communities showing a high affinity for extracting the trees has serious repercussions on the future biodiversity of the area of study. It calls for maintenance of large, closed canopy forests within the district and to restore degraded habitat through afforestation whenever possible as well as establishing buffer zones of exotic tree species to act as refuge zones. This will require improved law enforcement of illegal logging, proper forest management to allow forests to regenerate and the promotion of alternative human resources.

Further studies may be done to establish other species of exotic trees having fast growth and woody value to provide the necessary requirements for construction and other livelihoods.

ACKNOWLEDGEMENT

This study was funded by the National Council of Science, Technology and Innovation (NACOSTI) Kenya. The Technician Mr. Wanjohi Benard (University of Eldoret) assisted in field identification of trees. The chief of my study area Mr. Silah and field assistants, Mr. Evans Korir, Mr. Carlos Kiplagat, and Mr. Jesse Nyamu assisted in data collection and identification of trees using vernacular names. Finally to God who gave the strength to work harder, in identifying Humanity problems and finding their solutions.

REFERENCES

Alder, D. and Abayomi, J. O. (1994). Assessment of data requirements for sustained yield calculations. *Unpublished report prepared for the Nigeria Tropical Action Programme, FORMECU, Federal Department of Forestry, Ibadan, Nigeria*, 28.

Anderson, M. C., Allen, R. G., Morse, A. and Kustas, W. P. (2012). Use of Landsat thermal imagery in monitoring evapotranspiration and managing water resources. *Remote Sensing of Environment*, *122*, 50-65.

Austrheim, G. (2002). Plant diversity patterns in semi-natural grasslands along an elevational gradient in southern Norway. *Plant Ecology*, *161* (2), 193-205.

Brokaw, N. V. L. (1985). Treefalls, regrowth, and community structure in tropical forests. In: S. T. A. Pickett and P. S. White (eds.), Natural Disturbance and Patch Dynamics. Academic Press, Toronto, pp. 53-69.

Cardelús, C. L., Colwell, R. K. and Watkins Jr, J. E. (2006). Vascular epiphyte distribution patterns: explaining the mid‐elevation richness peak. *Journal of Ecology*, *94* (1), 144-156.

Chave, J., Condit, R., Lao, S., Caspersen, J. P., Foster, R. B. and Hubbell, S. P. (2003). Spatial and temporal variation of biomass in a tropical forest: results from a large census plot in Panama. *Journal of Ecology*, *91*(2), 240-252.

Connell, J. H. (1978). Diversity in tropical rain forests and coral reefs. Science199:1302-9.

Denslow, J. S. (1995). Disturbance and diversity in tropical rain forests: the density effect. *Ecological applications*, *5* (4), 962-968.

Enquist, B. J. (2002). Universal scaling in tree and vascular plant allometry: toward a general quantitative theory linking plant form and function from cells to ecosystems. *Tree physiology*, *22*(15-16), 1045-1064.

Fashing, P. J. (2004). Mortality trends in the African cherry (Prunus africana) and the implications for colobus monkeys (Colobus guereza) in Kakamega Forest, Kenya. *Biological conservation*, *120* (4), 449-459.

Fashing, P. J. (2004). Mortality trends in the African cherry (Prunus africana) and the implications for colobus monkeys (Colobus guereza) in Kakamega Forest, Kenya. *Biological conservation*, *120*(4), 449-459.

Gentry, A. H. (1988). Changes in plant community diversity and floristic composition on environmental and geographical gradients. Ann. Miss. Bot. Gard.75:1-34.

Gerytnes, J. A. and Vetaas, O. R. (2002). Species richness and altitude: a comparison between simulation modes and interpolated plant species richness along the Himalayan altitudinal gradient, Nepal. *American Naturalist*, *159*, 294-304.

Ghazoul, J. and Sheil, D. (2010). *Tropical rain forest ecology, diversity, and conservation* (No. 577.34 G4).

Hitimana, J., Kiyiapi, J. L. and Njunge, J. T. (2004). Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon Moist Lower Montane Forest, western Kenya. *Forest Ecology and Management*, *194* (1-3), 269-291.

Ho, C. C., Newbery, D. M. and Poore, M. E. D. (1987). Forest composition and inferred dynamics in Jengka Forest Reserve, Malaysia. *Journal of tropical Ecology*, *3*(1), 25-56.

Huston, M. A. (1994). Biological Diversity. Cambridge University Press, Cambridge, England.

Janos, D. P. (1983). Tropical mycorrhizas, nutrient cycles and plant growth. *In: S. L. Sutton, T. C. Whitmore and A. C. Chadwick (eds.), Tropical Rain Forest: Ecology and Management*. Blackwell Scientific, Oxford, pp. 327-345.

Janzen, D. H. (1970). Herbivores and the number of tree species in tropical forests. Am. Nat.104:501-28.

Khan, M. L., Menon, S. and Bawa, K. S. (1997). Effectiveness of the pro-tected area network in biodiversity conservation: a case study of Meghalaya state. Biodiver. Conserv. 6, 853-868.

Kumar, A., Gupta, A. K., Marcot, B. G., Saxena, A., Singh, S. P. and Marak, T. T. C. (2002). Management of forests in India for biological diversity and forest productivity, a new perspective. Volume IV: Garo Hills Conservation Area (GCA). Wildlife InstiMe of India – USDA Forest Service collaborative project report, Wildlife Insti-tute of India, Dehra Dun, 2002, p. 206.

Leigh, E. G. J. (1999). Tropical Forest Ecology: a View from Barro Colorado Island. Oxford University Press, New York.

McCain, C. M. and Grytnes, J. A. (2010). Elevational gradients in species richness. *Encyclopedia of life sciences (ELS)*, 1-10.

Misra, R. (1968). Ecology Workbook. Oxford & IBH Co, New Delhi, 1968, p. 244.

Miyaura, T. and Hozumi, K. (1988). Measurement of litterfall in a Japanese larch (Larix leptolepis Gordon) plantation by the cloth-trap method. *Journal of the Japanese Forestry Society*, *70* (1), 11-19.

Mutangah, J. G., Mwangangi, O. and Mwaura, P. K. (1992). Kakamega: A Vegetation Survey Report. Kenya Indigenous Forest Conservation Programme, Nairobi, Kenya.

Mutiso, F. M., Mugo, M. J., Cheboiwo, J., Sang, F. and Tarus, G. K. (2015). Floristic composition, affinities and plant formations in tropical forests: A case study of Mau forests in Kenya. *International Journal of Agriculture and Forestry*, *5* (2), 79-91.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403* (6772), 853.

Omoro, L. M., Pellikka, P. K. and Rogers, P. C. (2010). Tree species diversity, richness, and similarity between exotic and indigenous forests in the cloud forests of Eastern Arc Mountains, Taita Hills, Kenya. *Journal of Forestry Research*, *21* (3), 255-264.

Peltorinne, P. (2004). The forest types of Kenya. *Expedition reports of the Department of Geography, University of Helsinki*, *40*, 8-13.

Rahbek, C. (1995). The elevational gradient of species richness: a uniform pattern?. *Ecography*, *18* (2), 200-205.

Rohde, K. (1997). The larger area of the tropics does not explain latitudinal gradients in species diversity.Oikos79:169-72.

Rosenzweig, M. L. (1995). Species Diversity in Space and Time. Cambridge University Press, Cambridge.

Stevens, G. C. (1989). The latitudinal gradient in geographical range: how so many species coexist in the tropics. Am. Nat. 133:240-56.

Tanzania, F. (2001). Amani nature reserve: A biodiversity survey. *Forestry and Beekeeping Division and Metsähallitus Consulting: Dar es Salaam, Tanzania and Vantaa, Finland*.

Tsingalia, H. M. (1988). *Animals and the regeneration of a canopy tree in an African tropical forest* (Doctoral dissertation, Ph. D. Thesis. University of California, Berkeley).

Wass, P. (1995). *Kenya's indigenous forests*. IUCN, Gland, Switzerland, and Cambridge, UK in collaboration with ODA.

Wilson, E. O. (1988). Biodiversity. National Academy Press, Washington, DC.

APPENDIX 1: TREE SPECIES (DBH=>10 CM) OF KIBONGE FOREST

Scientific Name	Vernacular Name (Kalenjin)	Family Name	%Canopy Cover
Acacia mearnsii	Wattle	Mimosaceae	0.151
Bersama abyssianica	Kopoymetiet	Melianthaceae	0.019
Croton macrostachyus	tebeswet	Myacea	2.914
Cupressus lusitanica	cypres	Cupressaceae	26.676
Dombeya goetznii	silipchet	Sterculiaceae	33.446
Ekerbagia capensis	Teldet	Meliaceae	0.574
Eucalyptus saligna	Bluegum	Myrtaceae	0.358
Ficus cycamorous	Mogongwet	Moraceae	0.264
Ficus thonningii	simotwet	Moraceae	15.014
Garcinia livingstonei	Merkwet	Clusiaceae	0.365
Grevellia robusta	Grevellia	Proteaceae	0.027
Grewia bicolor	Siteito	Malvaceae	0.89
Juniperus procera	Tarakwet	Cupressaceae	0.0304
Macaranda kilimandascharica	sebesebet	Euphorbiaceae	5.228
Markhamia lutea	mochet	Bignoniaceae	0.443
Myrsine melanoploeos	sitotwet	Myraceae	0.352
Nuxia congesta	chorwet	Sterculiaceae	0.441
Olea africana	Emitit	Oleaceae	0.371
Pepper tree (Common name)	Chupuchupu	Anacardiaceae	0.05
Podocarpus falcactus	Septet	Podocarpaceae	0.477
Podocarpus gracillior	Penet	Podocarpaceae	1.226
Polyscias kikuyuensis	seyat	Araliaceae	2.379
Prunus africana	tendwet	Rosaceae	6.927
Rhus natalensis	Siryat	Anacardiaceae	0.535
Teclea nobilis	Kuryot	Rutaceae	0.153
Uclea divinorum	Uswet	Ebenaceae	0.035
Vangueria madagasariensis	Komolwet	Rubiaceae	0.266
	Total		**99.9994**