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Effects Of Logging On The Diversity Of Tree Species In Kerisoi Natural Forest, Nakuru County, Kenya

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***Abstract:** Logging is a major human activity that has resulted in deforestation and forest degradation. In Mau Forest, logging has led to reduced diversity of tree species. The present study adopted a combination of line transects and quadrat method to assess the effects of logging on the diversity of tree species in the Kerisoi Forest Reserve, one hundred quadrats measuring10x10m were laid along ten transect lines measuring 500m long. The inter-quadrat spacing was 50m along the transect lines. In each quadrat, tree species were identified and recorded. Photography and observations were also utilized to note various forest disturbances. To obtain the diversity of tree species in the forest, the Shannon-Wiener Index of Diversity was used. Twenty tree species were identified belonging to sixteen families. The most abundant species were Podocarpus latifolia with 77 counts and the least being Cassipourea malosana, Olea capensis, and Teclea simplicifolia with 1 count each. The overall Shannon Wiener diversity index was 1.58. The study concluded that the diversity of the forest was quite low. This could be attributed to human activities such as selective logging in the forest. Measures such as fencing, forest restrictions, and banning all activities in the forest should be put in place to allow forest regeneration.*

***Keywords:** Logging, diversity, human activities, encroachment, edge effect, Kerisoi forest, deforestation, degradation.*

I. INTRODUCTION

Forests have immense importance ranging from productive to ecological services. Ecologically, forests are the world's largest water towers and besides regulating the hydrological cycles and pollution, they immensely contribute to climate change mitigation (WWF, 2016). Despite this great importance of forests, deforestation, and forest degradation persist and have reduced forest cover from 4,128 billion ha in 1994 to 3,999 billion ha in 2015 worldwide (FAO, 2016). Moreover, African forests are declining at a higher rate compared to other continents. Out of ten countries with the highest net loss of forested area, six countries are from Africa (Makunga & Misana, 2017). In Kenya, for example, the canopy cover is currently at 2% down from over 20% in 1963 (Ministry of Forestry & Wildlife, 2018).

The Mau forest block of which Kerisoi forest is part of, is the largest remaining indigenous montane forest in East Africa and the largest water tower in Kenya (Omondi & Musula, 2011). It is the main water catchment area for most rivers draining their waters into Lake Victoria and Great Rift Valley's lakes among them; Lake Turkana, Lake Nakuru and Lake Baringo (Chrisphine & Maryanne, 2015). The forest is also an essential source of livelihood to the people living around through provision of ecological, productive, and supportive services (Chepngeno, 2014). Despite this importance, the forest continues to be destroyed.

The destruction of the Mau forest complex started before Kenya's independence in 1963. Approximately 30,000 ha of forest land in various parts of the Mau forest complex were excised to pave way for human settlements and tea plantations between 1930 and 1990 (Baliach, 2009). Many other excisions have followed, including the excision of over 61,000 ha in 2001 and illegal encroachment of approximately 43,700 ha in the same period (Waithiru, 2012). The causes of deforestation are many and interconnected; some are underlying causes such as population growth, institutional factors, and economic factors. These factors trigger proximate factors, such as agricultural expansion and logging; all which cause changes in land use and land cover (Geist & Lambin, 2002).

A study by Duguma et al. (2015) in Mau forest revealed that the leading causes of deforestation and forest degradation were population growth (which increased by 10% between the year 1979- 2009 (KNBS, 2010), and poverty that has led to encroachment caused by a high dependence on forest products by the local community. The rates of extraction as established by Duguma et al. (2015) include fuelwood at 74%, charcoal burning at 68%, farming at 64%, grazing at 68%, and herbal medicines at 66%. Ayuyo & Sweta (2014) established that due to these activities, Mau forest had been decreasing by 3571.69 ha per year between 1973 to 2010.

Mau forest is one of the most stable ecosystems in Kenya and its degradation threatens thousands of species. Matiru (2000) argues that apart from the Kakamega Forest, the Mau forest complex has the largest biodiversity (both flora and fauna). Tree species diversity is essential to a whole forest biodiversity, because trees not only provide resources but habitats to nearly all other forest species (Huang et al., 2003; Hall & Swaine, 1976). However, anthropogenic disturbances such as logging have undoubtedly reduced the tree species diversity in the forests affecting sustainability and resilience of the forests (Mutiso et al., 2015). Disturbances in the forest are increasing every passing year as the population increases and this has had a ripple effect leading to a reduction in the diversity of plant species. Due to these, out of 6,506 vascular plants, 4.1% of the species are threatened, and 6% are protected under category I – V by IUCN (Matiru, 2000). Mutangah et al. (1993) in their study in mau forest recorded a higher number of species per family which included; *Rubiaceae* (20 species), *Compositae* (17 species), *Acanthaceae* (14 species) and *Aspleniaceae* (14 species) compared to Mutiso et al. (2015) in their study who found out that *Rutaceae* family was the highest with six species only.

Deforestation and forest degradation in Kenya is not limited to the Mau forest. In Kakamega forest, for example, a study done by Seswa in 2016 found 82 trees species compared to 112 tree species in 2004 (Althof, 2005). In Chepalungu forest, Kiprotich (2016) found that forest cover and its diversity had reduced to shrub level, especially at the edge with only 28 tree species left down from over 40 species in 1990. Moreover, Kipkorir et al. (2013) agree that the species richness, abundance, and evenness of the forest was low due to high disturbance by anthropogenic activities in the western Mau block. The author also found out that there were 223 species belonging to 83 families, of which only 33.7% were trees.

In his study, Kinyanjui (2009) found 53 tree species and added that the encroached part in the western Mau block had lost its original forest cover, floristic composition, and structure. Losing these, in turn, has reduced the forest's seed bank and soil nutrients and consequently, the forest's potential of recovery has been reduced. Internationally there is a growing agreement on planning, conserving and monitoring world forests against degradation and deforestation threats (Schwartzman et al., 2000; Sheil, 2001; Bhagwat et al., 2008). This can only be done if there is accurate and timely data concerning the various aspects of biodiversity.

Several studies have been conducted in the Mau forest, and especially the western and southern block, on floristic and vegetation composition, structure, and plant formations including the effect of human activities/ encroachment on vegetation (Mutiso et al., 2015; Kinyanjui, 2009; Kipkorir et al., 2013). Land-use cover and land-use change in Mau forest have also been investigated assessed, and monitored (Ayuyo & Sweta, 2014; Omondi & Musula, 2011; Baldyga et al., 2008). Most studies have used archived remote sensed data and aerial photographs to establish the relationship between human activities and Mau forest degradation. These studies have articulated the effect of human activities on the forest, but few studies done give an account of the role that logging has played on the diversity of the forest and how the land under shrubs and grasses has increased. Moreover, in Kenya, numerous studies have been done on the forest ecosystems, but there are no detailed and reliable studies documented on the tree diversity of small-sized forests such as Kerisoi.

While some of the reasons for the ongoing degradation and deforestation have been studied for the large forests that are deemed to be at the centre of the Mau Forest Complex such as the Western or Eastern Mau blocks, logging as a reason to why Kerisoi forest in particular is declining has not been studied as most studies tend to generalize the forest as part of the larger Mau Forest (Kinyanjui, 2009; Kipkorir et al., 2013; Baldyga et al., 2008). There is a need to separately articulate the human activities in Kerisoi forest and its effects, for example, on the diversity of the trees species as a way of building on the accurate data and research that is needed to aid the forest's conservation efforts. Based on this argument, the current study was carried out to determine the effects of logging on the diversity of tree species in Kerisoi forest.

II. MATERIALS AND METHODS

A. STUDY AREA

The Kerisoi Forest (Fig. 1) is located in Kiptororo ward, Nakuru County, Kenya. The forest is located within longitude $35^0$25'0" E and $35^0$35'0" E and latitude of $0^0$17'30" S and $0^0$22'30" S, with an average elevation of 2444 m above sea level (KFS, 2016). The forest has an area of about 7366.80 ha and is divided into two blocks Kerisoi and Sitoton. The largest part of the forest is a natural forest with an area of 5020.70 hectares and a plantation forest of 2346.10 hectares (KFS, 2016). Kerisoi forest forms part of the larger Mau forest complex and among the seven forest station found in Kericho ecosystem zone. The forest borders Kericho forest to the west, Londiani to the north and Molo forest to the east. (KFS, 2016).

The climate in Kerisoi is hot and temperate. Rainfall is high throughout the year, with an average rainfall of 1349mm and a variation of 151mm per year (Gichuhi, 2013). The average temperature is 14.0 degrees Celsius and varies by 2.0 degrees Celsius per year (Gichuhi, 2013). The forest is located in high altitude areas of the Mau forest complex. The tree species found in plantation are mainly exotic species such as eucalyptus and pine trees while the natural forest had species which such as *Prunus africana* (Hook,F), *Juniperus procera*, *Polyscias fulva* (Hiern), *Dobeya torida* (J.F. Gmel),

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Podocarpus latifolia (Thunb. ex Mirb). The study focused on the natural forest.

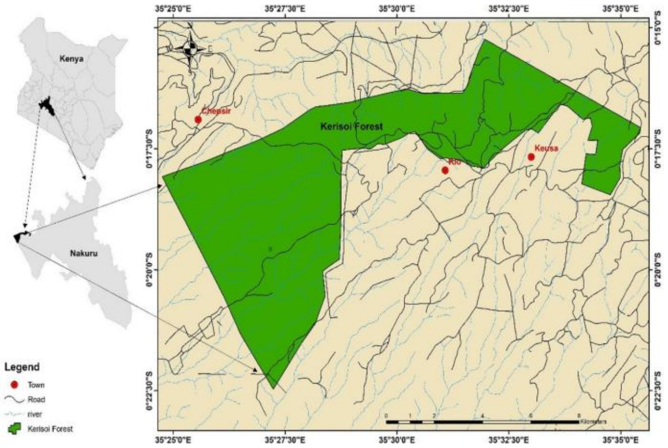

Figure 1: Study area map

B. DATA COLLECTION

This included both primary and secondary data. Primary data collection involved the use of transect and quadrat method. Secondary data involved the use of books, theses, photographs, journals, and materials from the internet.

C. ECOLOGICAL SURVEY

Systematic random sampling method using line transects and quadrats method was used (Kent & Coker, 1992; Muller-Dombois & Ellenberg, 1974). To avoid bias in the study area, an arbitrary starting point of the first transect line was established at the longest straight edge of the forest. Ten line transect were established perpendicular to the forest edge measuring 500 metres long and with an inter-transect spacing of 500m. The starting point and endpoint of each transect line were recorded using a GPS to allow waypoints to be relocated in the future.

"The minimum area principle" was applied to determine the size of a quadrat whereas in this case the vegetation sampling only involved trees. Quadrats measuring 10 by 10m ($100m^2$) were systematically laid at the centre of transects, with inter quadrat spacing of 50 metres, as applied by Seswa (2016). A total of 100 quadrats were sampled. The first quadrat in each of the ten transects was laid 5m from the edge of the forest. In the quadrats, tree species were identified and abundance recorded in the recording schedule. An observation checklist was used in the quadrats to locate and record tree trunks, deracinated roots, stripped tree barks cattle tracks, Footpaths and other indicators of human activities.

D. DATA ANALYSIS

Data obtained from the quadrats were recorded in a frequency table. The diversity, of tree species were analysed using the Shannon Wiener index of diversity.

$$H = -\sum_{-i-1}^{s} piLog_e p_i$$

Where:

H' = the value of the Shannon-Wiener index of species diversity

pi = the Proportion of the *i*th species

log*e* = the natural logarithm of pi

S = the number of species in the community

III. RESULTS AND DISCUSSIONS

A. HUMAN ACTIVITIES IN KERISOI FOREST

Kerisoi forest plays an important ecological, socioeconomic, and biological role. However, these forests are threatened with excisions, conversion of the forest into agricultural farms, degradation, and deforestation of the forest. In this assessment, despite the government's strict laws and policies, deforestation and degradation were still identified. Human activities found in Kerisoi forest included; logging (firewood, timber, posts, charcoal burning and poles) herbal medicine collection, seedling collection and cattle grazing (Tab 1).

Indicators	**Frequency**
Tree stumps	394
Deracinated roots	0
Stripped barks	24
Footpaths	77
Cattle tracks	84
Charcoal Kilns	10

Table 1: Indicators of human activities in Kerisoi forest

a. TREE STUMPS

Tree stumps (394) in Kerisoi forest were indicators that logging of trees was taking place for various purpose including firewood, timber, posts, charcoal burning, and poles (Fig 2). This was the main threat to Kerisoi forest that may cause degradation of the forest. This corroborates the studies done by Seswa (2016), Kiprotich (2016), and Mitchell (2004), who noted that logging was the primary human threat to the forest, especially selective logging of trees for commercial and domestic purposes.

Figure 2: A tree stump in Kerisoi forest

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Besides, logging has contributed to approximately 70% of the forest destruction in more than 200 tropical forest reserves in the world (Mogaka *et al*., 2001).

b. FOOT PATHS

Footpaths (77) were other indicators of anthropogenic activities in the forest. (Fig 3).

Figure 3: Footpaths in Kerisoi forest

Footpaths in Kerisoi forest provided access in the forest which triggers illegal activities such as logging. According to Hiller *et al*. (2004), paths provide access to the forest core which has more trees and, in turn, encourages activities such as logging for timber, charcoal, poles, and posts which are illegal.

c. CATTLE TRACKS AND GRAZING

The presence of cattle grazing and cattle tracks in Kerisoi forest indicated that the local community used the forest as their grazing area (Fig 4). Cattle tracks are meant to provide access to the livestock movements around the forest. However, the effects of cattle presence in the forests increases the risk of soil erosion, biodiversity loss and water pollution.

Figure 4: Cattle grazing inside Kerisoi forest

Moreover, Kiprotich, (2016) found out that livestock grazing in the forest causes the trampling effect to seedlings and saplings, which decreases the ability of the forest to regenerate. Browsing, on the other hand, damages the structure and composition of the forest (Kikoti & Mligo, 2015).

d. HERBAL MEDICINE COLLECTION

The study found 24 trees with stripped barks for medicinal purposes. These tree species were *Ekebergia capensis* (11) and *Schefflera volkensii* (10) both used to treat fungal infections in children and chest infections, and *Prunus africana* (3) (Fig 5). Herbal medicine is the alternative source of conventional medicine to the rural communities as affirmed by Masinde (2010). However, stripping of barks can affect the recovery and survival of the trees. Besides, extensive debarking may cause drying and eventually death of tree species.

Figure 5: Stripped bark of Ekebergia capensis in Kerisoi forest

This corroborates Ntombizodwa (2015) that extensive bark stripping of tree has led to poor regrowth and increased mortality of such tree species. The author added that the activity opens up wounds which are entries of infections. The herbalists however, claimed to have different techniques of ensuring that the tree species stripped remained healthy including smearing cow on the affected area.

e. FIREWOOD COLLECTION

Firewood collection is an indicator of human activity occurrence in Kerisoi forest (Fig 6). Firewood is a widely used source of energy in many households in the rural areas. Moreover, the study established firewood collection was among the most important resource that was obtained from the forest. However, high demand of firewood by the community in Kerisoi forest may trigger intensive logging of trees if not properly managed leading to destruction of forest.

Figure 6: Women carrying firewood in Kerisoi forest

According to CIFOR (2016) an increased demand of firewood could lead to forest degradation, reduced canopy, slow regeneration rate, tree composition change, and increase the area of grassland in the forest.

f. CHARCOAL KILNS

The charcoal burning activity in Kerisoi forest evidenced by the presence of earth charcoal kilns (Figure 7).

Figure 7: Charcoal burning inside Kerisoi forest

Charcoal is a source of energy mainly to the urban and to a small extent the rural dwellers. The study established that charcoal burning was more rampant at the core of the forest than at the edge where there were more trees and a thick bush. The activity has been deemed as the most destructive as it triggers logging which causes both forest degradation and deforestation especially in tropical forests. The findings corroborate (Tesot, 2014) and (Nyongesa & Vacik, 2018) that the activity impacted forest vegetation through reduction of tree species richness and has increased bush fires. Moreover, Chidumayo & Gumbo (2013) added that the activity contributed to global warming and climate change as it produces approximately 7.2 million tonnes of carbon di oxide and 1.3 million tonnes of methane per year.

B. TREE SPECIES IN KERISOI FOREST AND THEIR USES

There were 20 tree species belonging to 16 families and 19 genera (Tab 2). Families with more than one tree species were *Araliaceae* (3), *Oleaceae* (2) and *Rosaceae* (2). These included *Polyscias fulva*, *Cussonia holstii*, *Schefflera volkensii*, *Olea europaea*, *Olea capensis*, *Prunus africana*, and *Hagenia abyssinica* respectively (Tab 2). The results show that the forest was not rich in terms of tree species as only three out of sixteen families had more than one species and two tree species belonging to one genus. The results of the study varied Beentje (1994) & Kinyanjui (2009) studies which covered Western blocks where they found 68 tree species and 50 tree species respectively. This is because the current study was confined to only Kerisoi forest, in addition, the time lapse between 2009 and 2018 is long enough to observe changes in the forest. Besides, Kinyanjui (2009) found 33 families, *Euphorbiaceae* family having the highest species with 5 followed by *Oleaceae* and *Araliaceae* with 3 and *Moraceae*, *Meliaceae* and *Asteraceae* with more than 2 species.

Common name	**Scientific name**	**Family**	**Use**
Silibwet	*Dombeya torrida* (J. F Gmel)	*Sterculiaceae*	Firewood, bark fibres and ropes
Aonet	*Polyscias fulva* (Hiern)	*Araliaceae*	Firewood and beehives
Tendwet	*Prunus africana* (Hook F)	*Rosaceae*	Treatment of prostate cancer , charcoal burning and firewood.
Lulukwet	*Cussonia holstii* (Thunb)	*Araliaceae*	Firewood and beehives.
Keburuet	*Osyris lanceolata* (Hochst & Steudel)	*Santalaceae*	Charcoal burning, firewood, herb for treatment of joints pain and substitute for sandalwood.
Masaita	*Olea capensis* (L)	*Oleaceae*	Charcoal burning, firewood and poles.
Araruet	*Ekebergia capensis* (Sparrm)	*Meliaceae*	Chest pains treatment and minor injuries
Tinet	*Schefflera volkensii* (Engl.)	*Araliaceae*	Treatment of chest pains, coughs and joints
Kuresiet	*Euphorbia abovalifolia* (A. Rich)	*Euphorbiaceae*	Treat breathing disorders including asthma, bronchitis, and chest congestion.

Nukiat	*Dovyalis abyssinica* (A. Rich)	*Flocourtiaceae*	Edible fruits, treating stomach ache and firewood
Choruet	*Halleria lucida* (L)	*Scrophulariaceae*	Building poles and firewood
Tarakwet	*Juniperus procera* (Endl)	*Cupressaceae*	Post and poles
Saptet	*Podocarpus latifolia* (Thumb)	*Podocarpaceae*	Timber production and firewood
Kuriot	*Teclea simplicifolia* (Engl)	*Rataceae*	Charcoal burning, walking sticks, bows and treating abdominal cramps
Chepngororiet	*Pittosporum viridiflorum*(Sims)	*Pittosporaceae*	Building poles
Mangoita	*Cassipourea malosana* (Bak)	*Rhizophoraceae*	Firewood and timber
Emitiot	*Olea europaea* (L)	*Oleaceae*	Charcoal burning and firewood
Uswet	*Euclea divinorum* (Hiern)	*Ebenaceae*	Chewing sticks for oral care and firewood
Bondet	*Hagenia abyssinica* (J F Gmel)	*Rosaceae*	Bark infusion used as anthelmintic; wood used for carpentry
Simotwet	*Ficus cordata* (Thunb)	*Moraceae*	Edible fruits and latex used for attaching feathers to arrows

Table 2: Common, tree species found in Kerisoi forest and their uses

C. THE ABUNDANCE OF TREE SPECIES IN KERISOI FOREST BASED ON THE DISTANCE FROM THE FOREST EDGE

The general trend shows that close to the edges, there were fewer tree species but a substantial area of shrub and grassland (Fig. 8). However, further from the edges, more tree species could be found. At 50m, 100m and 150m the total number of tree species found were 17, 11, and 7 respectively whereas at 400m, 450m and 500m there were 38, 52, and 44 tree species. For example, at a distance of 50 metres, only one count of *Podocarpus latifolia* was recorded, but at a distance of 500m, there were 19 counts found (Tab 3). This is justified by the fact the forest edge is more prone to the effect of human activities unlike deeper into the forest. The frequency of tree species also differed within individual tree species. *Podocarpus latifolia* had the highest frequency of 77 in all quadrats, Dombeya *torrida* (52), *Polyscias fulva* (26) and *Juniperus procera* (20) counts.

Tree species	50	100	150	200	250	300	350	400	450	500	Total
Cassipourea malosana									1		**1**
Cussonia holstii				2	2	1	2	2	2	2	**13**
Dombeya torrida	5	6	2	2	5	1	10	14	1	6	**52**
Dovyalis abyssinica						1		1			**2**
Ekebergia capensis		1				1				2	**4**
Euclea divinorum									4	1	**5**
Euphorbia abovalifolia				1	1						**2**
Ficus cordata									2	1	**3**
Hagenia abyssinica								2	3		**5**
Halleria lucida	1	1			2	1	2		1	1	**9**
Juniperus procera	1				4	2	1	1	9	2	**20**
Olea capensis	1										**1**
Olea europae						1			2	1	**4**
Osyris lanceolate	4					1					**5**
Pittosporum Viridiflorum			2		1	1				4	**8**
Podocarpus latifolia	1	1		2	8	1	8	15	22	19	**77**
Polyscias fulva	4	1	1	3	2	1	6	2	3	3	**26**
Prunus Africana							1	1		1	**3**
Schefflera volkensii		1	1	2	2	1			2	1	**10**
Teclea simplicifolia			1								**1**
Total	**17**	**11**	**7**	**12**	**27**	**13**	**30**	**38**	**52**	**44**	**251**

Table 3: Tree species count based on distance from the edge in Kerisoi forest

However, most of the species in Kerisoi forest had less than 10 counts with the lowest being *Cassipourea malosana, Olea capensis,* and *Teclea simplifolia* with 1 count in all the quadrats (Tab 3). Their few numbers can be attributed to the high demand for the species itself or suitability of the tree species to the public, which resulted in selective logging. For example, *Olea europaea* and *Olea capensis* are mainly preferred for charcoal burning and firewood.

Figure 8: Degraded Kerisoi forest edge

Podocarpus latifolia was found to be the most abundant tree species in Kerisoi forest and among the top five dominant tree species. This is despite being the best timber species (Beentje, 1994) and often targeted by the commercial loggers. Kinyanjui (2009) noted that *Podocarpus latifolia* tree was highly valued culturally by the Ogiek community, which also helps in the protection of the species. *Polyscias fulva* was also rated as among the most abundant tree species in Kerisoi forest. This corroborates Kinyanjui's (2009) study that found the species highly dominant with a relatively high frequency and Diameter at Breast Height (DBH). This is due to the non-commercial value to the community who do not exploit it.

Juniperus procera was also among the tree species, which were moderately abundant despite being highly targeted by both the local community and the commercial loggers for construction poles and posts. The moderate opening of the canopy forest favoured its regeneration as noted by Pohjomen (1991).

On the other hand, *Olea spp* and *Prunus africana* were less abundant because they were targeted by the community for charcoal and firewood for both subsistence and commercial purposes just as previously reported by Kinyanjui in his 2009 study. Kikoti & Mligo (2015) also noted that *Prunus africana* and *Cassipourea malosana* were profoundly affected by the effects of grazing and browsing of livestock. In their study, the species were only found in ungrazed sites. They also observed that *Olea europaea* and *Euclea divinorum* were highly palatable trees species to livestock and often suffer the effect of livestock grazing and browsing. Trees of these species found in the grazing areas were deformed, crooked in structure, and reduced in diameter. The observed disturbances indicated that *Teclea simplicifolia* tree species was targeted for charcoal production as alternatives to *Olea spp* and *Prunus africana* that are now becoming rare in the forest. On the other hand, species such as *Osyris lanceolata* thrive well where the original vegetation has been cleared, thus its high abundance at the edge (Beentje, 1994).

Regarding the relationship between the distance from the forest and the total number of tree species, the results shows a positive gradient and a strong relationship (R^2 = 0.729) (Fig 9). This implies that an increase of the distance from the edge towards the core leads to an increase in the total number of tree species and that the core was more rich in species than the edges. This is attributed to harmful edge effect cause by human activities.

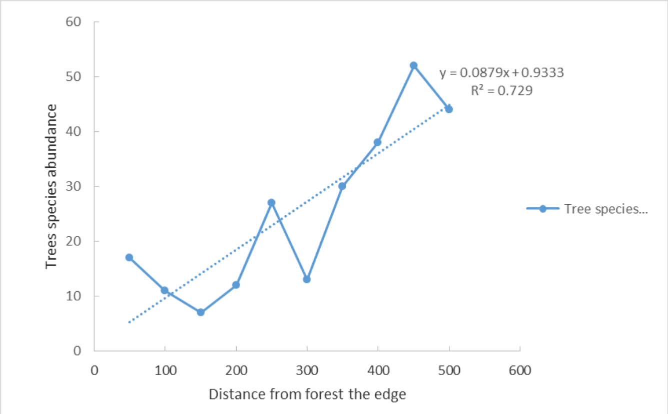

Figure 9: Relationship between tree species abundance and the distance from the forest edge

The findings corroborates Kacholi (2014) results that edge and the intermediate habitats of the forest are different from the forest core in terms of species richness and abundance. He added that the core was more rich in tree species than the edge due to the effect of anthropogenic activities.

D. DIVERSITY OF TREE SPECIES IN KERISOI FOREST

The overall Shannon Weiner index of Kerisoi forest was 1.58. The Shannon Wiener diversity index values normally range between 0 to 5 but typically range between 1.5 to 3.5 (McCarthy & Magurran, 2004). High diversity means that chance of picking two plants of the same species is low. The findings indicated that Kerisoi forest diversity was quite low since its index was slightly greater than 1.5 which denotes low diversity. This was accredited to the effects of human activities and also frequent fire incidences. In the recent past, serious fires occurred in 2010, 2014 and 2017 between the month of January and February.

The findings corroborate with Verma et al. (2017) that fire may cause significant change in diversity and regeneration. In their study, they indicated that there was a decrease in diversity of tree species but increase in dominance immediately after fire due to stem mortality and that diversity increases after five years of five occurrences but takes 15 years to stabilise. This is contrary to the studies by Gould et al. (2002) and Mondal & Sukumar (2015) who argued that fire occurrence favour regeneration of tree seedlings because fire breaks dormancy, reduces pathogens and pests, and increase the nutrients availability in the soils hence high diversity of tree seedlings.

In addition, regression results between logging and diversity gave a P value of 0.000, which indicated a strong relationship between effects of logging and diversity of Kerisoi forest. This justifies that logging of trees in the forest significantly affects the diversity of the forest. Hence the hypothesis that stated logging has a significant impact on the diversity of tree species in Kerisoi forest was accepted.

a. DIVERSITY OF TREE SPECIES IN KERISOI FOREST BASED ON THE DISTANCE FROM THE EDGE

In Kerisoi forest, the Shannon Wiener diversity index at the distance of 50 was 0.23 whereas at the distance of 500 m was 0.51 (Fig 10). Although the most diverse distance was at 350 m, the results shows a positive but weak relationship (R^2 = 0.3642) between diversity and the distance from the edge. This indicated that the diversity at the edge of Kerisoi forest was low but increased towards the core. This is ascribed to harmful edge effect and fragmentation.

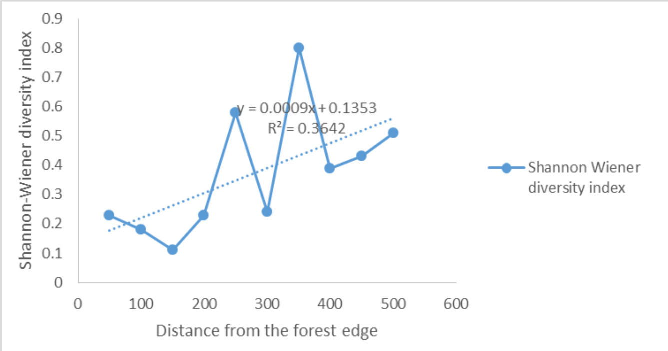

Figure 10: Diversity of tree species in Kerisoi Forest from the edge to the core

Similarly, the world forest ecosystems have been highly fragmented such that approximately 70% of the forest lies within 1km from the forest edge (Haddad *et al*. 2015). The boundaries created may cause edge effect which impacts on species composition, abundance and diversity of the forest (Haddad *et al*. 2015). The lower diversity at the edge is similar to other previous studies done on disturbed forest habitats

(Ding *et al.*, 2012; Norden *et al.*, 2012; Santos *et al.*, 2010; Letcher *et al.*, 2012). This shows that tree species close to the edge are more prone to human interference compared to species that are further away from the edge due to inaccessibility. Brown *et al.* (2013) added that the characteristics of plant species community at the forest edge is contributed by the anthropogenic activities of community living near the forest edge.

This is contrary to Wekesa *et al.* (2016) findings in Taita hills forest fragments where there was no noticeable change in tree species diversity between the edges, intermediate forest, and the interior forest. The authors argued that the dynamics of the forest edge are highly unpredictable because tree community factors significantly change over time, this may lead to disappearance of the edge effects over the years.

b. DIVERSITY OF TREE SPECIES IN KERISOI FOREST PER TRANSECT

The diversity of tree species in Kerisoi forest varied from one transect to another depending on where the transect was laid. Generally, there was positive gradient between the diversity and transect number. However, R^2 of 0.1339 shows a very weak relationship between the two variable (Fig 11). This infers increase in transect number does lead to an increase in diversity but depended on several factors such as where the transect was laid.

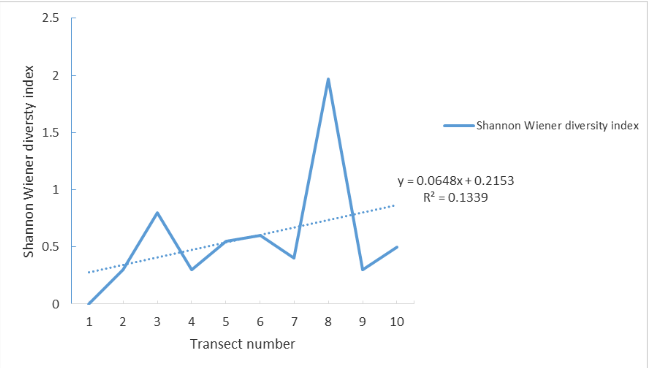

Figure 11: Diversity of tree species in Kerisoi forest per transect

The most diverse transect in Kerisoi forest was 8 with Shannon Wiener diversity index of 1.97 and the least was transect 1 with Shannon Wiener diversity index of 0 (Fig 11). Transect 8 was located near the forest guards' camp resulting to less interference from illegal loggers and other human disturbances. Transect 1 was laid on a severely disturbed site where footpaths and cattle tracks were many, and this resulted in a low diversity index. This corroborates Borah *et al.* (2014) who noted that absence of anthropogenic effect may create more favourable ecological conditions for establishment and growth of tree species, this may result to higher diversity in undisturbed forests compared to the disturbed forests.

Borah *et al.* (2014) additionally argued that lower diversity in a disturbed site is attributed to anthropogenic disturbances that cause an immediate decline in species diversity. However, Wekesa *et al.* (2016) observed that the disturbed site in the forest had a higher diversity compared to the undisturbed site. They credited the high diversity to forest canopy opening creating gaps leading to increased regeneration of species. This is agreed by Egbe *et al.* (2012) that ecologically, forest gaps have been determined to offer maintenance of high species diversity in tropical forests.

IV. CONCLUSION AND RECOMMENDATIONS

Kerisoi forest had 20 tree species belonging to 16 families and Shannon Wiener diversity index of 1.58 shows that the forest is highly disturbed. Only 3 families only with more than one species two species found belonging to one genera showed that the forest was not rich and that the overall diversity of the forest was quite low. It is therefore recommended that Kenya Forest Service should:

- ✓ Prohibit logging and livestock grazing in Kerisoi forest in order to allow forest regeneration
- ✓ Rehabilitate of heavily disturbed site.
- ✓ Conservation measures such as environmental education, natural regeneration should be promoted.

REFERENCES

[1] Althof, A. J. (2005). Human impact on flora and vegetation of Kakamega Forest, Kenya. structure, distribution and disturbance of plant communities in an East African Rainforest. (PhD Dissertation, University of Koblenz-Landau, Koblenz, Germany)

[2] Ayuyo, I. O., & Sweta, L. (2016). Land Cover and Land Use Mapping and Change Detection of Mau Complex in Kenya Using Geospatial Technology. International Journal of Science and Research (IJSR), 5(2), 1655-1666.

[3] Baldyga, T. J., Miller, S. N., Driese, K. L., & Gichaba, C. M. (2008). Assessing land cover change in Kenya's Mau Forest region using remotely sensed data. African Journal of Ecology, 46(1), 46-54.- doi:10.1111/j.1365-2028.2007.00806. x.

[4] Baliach, C. (2009). Why Mau Forest complex is the real emergency [Online August 7, 2009] URL: https://www.standardmedia.co.ke/article/1144020897/why-mau-forest-complex-is- the- real-emergency.

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

[6] Brown, K.A., Johnson, S.E., Parks, K.E., Holmes, S.M., Ivoandry, T., Abram, N.K., Delmore, K.E., Ludovic, R., Andriamaharoa, H.E., Wyman, T.M. & Wright, P.C. (2013) Use of provisioning ecosystem services drives loss of functional traits across land use intensification gradients in tropical forests in Madagascar. Biological Conservation, 161, 118–127.

[7] Borah, N., Athokpam, F. D., Garkoti, S., Das, A.K., & Hore, D. (2014). Structural and compositional variations in undisturbed and disturbed tropical forests of Bhuban hills in south Assam, India. International Journal of Biodiversity Science, Ecosystem Services & Management, 10(1), 9-19.-doi:10.1080/21513732.2013.873823.

[8] Chepngeno, B. N. (2014). A Struggle Between Livelihoods and Forest Conservation: A Case of Mau

Forest in Kenya. (Master's thesis, Nairobi University, Nairobi, Kenya).
[9] Chidumayo, E. N., & Gumbo, D. J. (2013). The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. Energy for Sustainable Development, 17(2), 86-94. doi: 10.1016/j.esd.2012.07.004.
[10] Chrisphine, U., & Maryanne, A. O. (2015). Assessment of Hydrological Impacts of Mau Forest, Kenya. Journal of Waste Water Treatment & Analysis, 07(01).-doi:10.4172/2157-7587.1000223.
[11] Ding, Y., Zang, R., Letcher, S. G., Liu, S., & He, F. (2012). Disturbance regime changes the trait distribution, phylogenetic structure and community assembly of tropical rain forests. Oikos, 121, 1263–1270.
[12] Duguma, L., Atela, J., Minang, P.A., & Mbow, C. (2015). 'We love to have the forest, but we have no alternative': Unpacking the realities behind deforestation and forest degradation. Paper presented at xiv world forestry congress, South Africa.
[13] Egbe, E. A., Chuyong, G. B., Fonge, B. A., & Namuene, K. S. (2012). Forest Disturbance and Natural Regeneration in an African Rainforest at Korup National Park, Cameroon. International Journal of Biodiversity and Conservation, 4, 77-384.
[14] Food and Agriculture Organization. (2016). Global Forest Resources Assessment 2015. In how are the world's forests changing? (Second edition) [Online 7 march 2019] URL: http://www.fao.org/3/a-i4793e.pdf.
[15] Geist, H. J., & Lambin, E. F. (2002). Proximate Causes and Underlying Driving Forces of Tropical Deforestation. Bioscience, 52(2), 143. - Doi: 10.1641/00063568(2002)052[0143: pcaudf] 2.0.co; 2.
[16] Gichuhi, M. (2013). Ecological Management of the Mau Catchment Area and Its Impact on Lake Nakuru National Park. Journal for Ecological Management, 15(1), 81- 92.
[17] Gould, K., Fredericksen, T., Morales, F., Kennard, D., Putz, F., Mostacedo, B., & Toledo, M. (2002). Post-fire tree regeneration in lowland Bolivia: implications for fire management. Forest Ecology and Management, 165(1-3), 225-234.- doi:10.1016/s0378-1127(01)00620-x.
[18] Haddad, N.M., Brudvig, L.A., Clobert, J., Davies, K.F., Gonzalez, A., Holt, R.D., Lovejoy,T.E., Sexton, J.O., Austin, M.P., Collins, C.D., Cook, W.M., Damschen, E.I., Ewers, R.M., Foster, B.L., Jenkins, C.N., King, A.J., Laurance, W.F., Levey, D.J., Margules, C.R., Melbourne, B.A., Nicholls, A.O., Orrock, J.L., Song, D.-X. & Townshend, J.R. (2015) Habitat fragmentation and its lasting impact on Earth's ecosystems. Science Advances, 1, e1500052.
[19] Hall, J. B., & Swaine, M. D. (1976). Classification and ecology of closed-canopy forest in Ghana. Journal of Ecology 64, 913-951.
[20] Hiller, T. Chabeda & Barthe, J. (2004). Resilience of Traditional Livelihood Approaches Despite Forest Grabbing: Ogiek to the West of Mau Forest, Uasin Gishu County. Land, 7(4), 140. - doi:10.3390/land7040140.
[21] Huang, W. V., Pohjonen, S., Johanson, MIL, Katigula, & Lukkanen, O. (2003). Species diversity, Forest structure and species composition in Tanzanian tropical forests, Forest Ecology and Management, 173 11-24.-doi:10.1016/S0378-1127 (01)00820-9.
[22] Jama, M. (1991). Forest utilisation by people living adjacent to West Mau, South-western Mau, and Transmara forest reserves. KIFCON Report, Nairobi.
[23] Kent, M, & Coker, P. (1992). Vegetation Description and Analysis. A practical approach. John Wiley and Sons, New York, Pp.363.
[24] Kenya Forest Service. (2016). Kenya Forest Service - Kerisoi Forest Station. [online 28 march 2018]URL:http://www.kenyaforestservice.org/index.php/2016-04-25-20-16-21/2014-11-26-08-43-45/tourists-code-of-conduct/169-forests-in-kenya/mauconservancy/kericho-ecosystem/597-kerisoi-forest-station
[25] Kenya National Bureau of Statistics, issuing body. (2010). The 2009 Kenya population and housing census. Nairobi.
[26] Kikoti, I. A., & Mligo, C. (2015). Impacts of livestock grazing on plant species composition in montane forests on the northern slope of Mount Kilimanjaro, Tanzania. International Journal of Biodiversity Science, Ecosystem Services & Management, 11(2), 114-127. -doi:10.1080/21513732.2015.1031179.
[27] Kinyanjui, J. M. (2009). The Effect of Human Encroachment on Forest Cover, Structure, and Composition in the Western Blocks of the Mau Forest Complex. (PhD thesis, Egerton university, Nakuru, Kenya).
[28] Kipkorir, J. N., Onkwaro, A. O., Kimtai, N., Mulei, J. M., & Ndara, P. C. (2013). Vegetation Composition and Natural Regeneration in a Tropical Montane Forest Following Anthropogenic Disturbances. African Journal of Education, Science, and Technology. 1(2), 176- 182.
[29] Kiprotich, R. L. (2016). An Assessment of Effects of Human Activities on Vegetation Characteristics in Chepalungu Forest; Bomet County, Kenya. (Master's thesis, Kenyatta university, Nairobi, Kenya).
[30] Letcher, S.G., Chazdon, R.L., Andrade, A.C.S., Bongers, F., van Breugel, M., Finegan, B., Laurance, S.G., Mesquita, R.C.G., Martínez-Ramos, M. & Williamson, G.B. (2012) Phylogenetic community structure during succession: Evidence from three Neotropical forest sites. In Perspectives in Plant Ecology, Evolution and Systematics, 14, 79–87.
[31] Makunga, J. E., & Misana, S.B. (2017). The Extent and Drivers of Deforestation and Forest Degradation in the Masito-Ugalla Ecosystem, Kigoma Region, Tanzania. Open Journal of Forestry, 07(02), 285-305. -doi:10.4236/ojf.2017.72018.
[32] Matiru, V. (2000). Forest Cover and Forest Reserves in Kenya: Policy and Practice.
[33] McCarthy, B. C., & Magurran, A.E. (2004). Measuring Biological Diversity. Journal of the Torrey Botanical Society, 131(3), 277. - doi:10.2307/4126959.
[34] Masinde, S. (2010). Book Review: Medicinal plants of East Africa. 3rd edition. East African Medical Journal, 87(2). doi:10.4314/eamj. v87i2.60594
[35] Ministry of Environment and Forestry. (2018). Task Force Report on Forest Resources Management and Logging activities in Kenya. [Online 28 march 2018]

URL:http://www.environment.go.ke/wp-content/uploads/2018/05/Task-Force-Report.pdf.

[36] Mitchell, N. (2004). The exploitation and disturbance history of Kakamega Forest, Western Kenya, BIOTA East Report No. 1, (Bielefelder Ökologische Beiträge, Band 20, Bleher, B. & Dalitz, H. eds.). Nairobi press, Kenya.

[37] Mogaka, H., Simons, G., Turpie, J., Emerton, L., & Karanja, F. (2001). Economic Aspects of Community Involvement in Sustainable Forest Management in Eastern and Southern Africa. In IUCN Policy Brief, 2001. Nairobi, Kenya.

[38] Mondal, N., & Sukumar, R. (2015). Regeneration of Juvenile Woody Plants after Fire in a Seasonally Dry Tropical Forest of Southern India. Journal of Biotropica, 47(3), 330-338. - doi:10.1111/btp.12219.

[39] Mueller-Dombois, D., & Ellenberg, H. (1974). Aims and Methods of Vegetation Ecology, Wiley & Sons, New York, pp 193.

[40] Mutangah, J., Mwangangi, O., & Mwaura, P. (1993). Mau forest complex vegetation survey, KIFICON Report. Natural Resources Institute, Chat tam Maritime, UK. National Museums of Kenya, Nairobi.

[41] Mutiso, F. M., Mware, M. J., Cheboiwo, J., Sang, F., & 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. - doi: 10.5923/j.ijaf.20150502.02.

[42] Norden, N., Letcher, S.G., Boukili, V., Swenson, N.G. & Chazdon, R. (2012). Demographic drivers of successional changes in phylogenetic structure across life-history stages in plant communities. Ecology, 93, 70–82.

[43] Ntombizodwa, N. (2015). Bark re-growth and wood decay in response to bark stripping for medicinal use (Master's thesis). Retrieved from ProQuest Dissertations and Theses database.

[44] Nyongesa, K., & Vacik, H. (2018). Fire Management in Mount Kenya: A Case Study of Gathiuru Forest Station. Forests, 9(8), 481. doi:10.3390/f9080481

[45] Omondi, L., & Musula, P. (2011). Land Degradation of the Mau Forest Complex in Eastern Africa: A Review for Management and Restoration Planning. Environmental Monitoring. - doi: 10.5772/28532.

[46] Santos, B.A., Arroyo-Rodríguez, V., Moreno, C.E. & Tabarelli, M. (2010). Edge-related loss of tree phylogenetic diversity in the severely fragmented Brazilian Atlantic forest. PLoS ONE, 5, e12625.

[47] Seswa, F. (2016). Assessment of Human Activities on the Vegetation of Tropical Rainforest in Kakamega County, Kenya. Master's thesis, Kenyatta University, Nairobi, Kenya.

[48] Schwartzman, S., Moreira, A., & Nepstad, D. (2000). Rethinking tropical forest conservation: perils in parks. Conservation Biology. 14: 1351-1357.

[49] Sheil, D. (2001). Conservation and biodiversity monitoring in the tropics: realities, priorities, and distractions. Conservation Biology. 15: 1179-1182.

[50] Tesot, A. K. (2014). Environmental Implications of the Charcoal Business in Narok-South Sub-County, Narok County. (Master's thesis, Kenyatta University, Nairobi, Kenya).

[51] Verma, S., Singh, D., Mani, S., & Jayakumar, S. (2017). Effect of forest fire on tree diversity and regeneration potential in a tropical dry deciduous forest of Mudumalai Tiger Reserve, Western Ghats, India. Ecological Processes, 6(1). - doi:10.1186/s13717-017-0098-0.

[52] Waithiru K. P. (2012). An Assessment of the Challenges and Opportunities of Restoring the Mau Narok Forest at Mau Narok Division Njoro District, Nakuru County, Kenya. (Phd thesis, Environmental Studies Department, Kenyatta University, Nairobi, Kenya)

[53] Wekesa, C., Leley, N., Maranga, E., Kirui, B., Muturi, G., Mbuvi, M., Chikamai, B. (2016). Effects of Forest Disturbance on Vegetation Structure and Above-Ground Carbon in Three Isolated Forest Patches of Taita Hills. Open Journal of Forestry, 06(02), 142-161. doi:10.4236/ojf.2016.62013.

[54] WWF. (2016). Living Forest Report. [online 29 March 2018] URL: http://wwf.panda.org/our_work/forests/forest_publications_news_and_reports/living_forests_report/