POPULATION STRUCTURE OF *Prunus africana* (HOOK.f.) Kalkm. AND *Olea europaea.L* IN SOUTH NANDI AFROMONTANE FOREST, KENYA.

ABSTRACT

Prunus africana and *Olea eurpaea* tree species from the moist highlands of sub-Saharan Africa are subject to [redacted], and therefore endangered due to their medicinal values and fine wood. Studying their population dynamics play an important role in identifying the conservation needs in tropical ecosystems. This paper focuses on an ecological study carried out [redacted] April-June 2017, within South Nandi Afromontane Forest, Kenya. The objectives were to analyze population density, diameter size class distribution, and the horizontal structure of *Prunus africana* and *Olea europaea* species as indicators of the respective species stability within the forest. Two line transects established [redacted] apart were used to lay twenty systematic sample plots of [redacted] each, a long a transect at an interval of [redacted]. These sample plots were further divided into five sub-sample units of [redacted] where the number of trees DBH (>10cm), poles (5-10cm), saplings (1-5cm) were assessed while the number of seedlings with DBH (<1cm) were assessed in 50m x 1m bands within the sample plots. Two and one-way analysis of variance (ANOVA) was applied at 5% level of significance. The population densities ranged from 860-885 stems/ha for *P.africana* and 569-601 stems/ha for *O.europaea* and were significantly different ($p<0.05$) along the transects and between the sampled cluster sites of Chebilat,Kobujoi,Chepkongony and Kamarich within the South Nandi Forest. Diameter size class distribution took the shape of reverse 'J' curve which characterizes stable populations that naturally replace themselves through regeneration. However in comparison with UNO 1994 model for structurally stable East African natural forest ecosystem the species were unstocked [redacted] indicate low recruitment from seedlings into mature trees due to possible anthropogenic disturbances. Recruitment of both species occurred more intensively in canopy gaps but displayed inhibition near mature conspecifics throughout the forest floor. There is need [redacted] to consider population densities, regeneration and recruitment levels in planning to restore the two species through artificial regeneration in addition to advocating for strategic in-situ conservation interventions to enhance recruitment in South Nandi Forest.

Keywords; Diameter; Horizontal structure; Recruitment; Regeneration;Tree density; Tropical forest;*Prunus africana*,*Olea europaea*

1.0 Introduction

[redacted] *Prunus africana* (Hook.f.) Kalkam and [redacted] *Olea europaea* L. trees [redacted] are [redacted]

[redacted] endangered due to their medicinal values and fine wood (IUCN, 2013) and so far *P.africana* included in Appendix II by CITES in 1995 (Cunningham and Schippmann,1997). Unsustainable management has led to decline in the populations due to subsistence bark harvests for medicinal trade (Stewart, 2009), coupled with illegal harvesting, [redacted] which has affected the integrity of the forest (Cunningham and Mbenkum, 1993).

Even though several studies have been conducted on the adverse effects of over-[redacted], few studies have examined their densities, population structure, size class distribution and regeneration status. Knowledge of tree population dynamics is very important for understanding the conditions of recruitment and regeneration of the species (Tesfaye, 2010).

Prunus africana is a member of the *Rosaceae* (subfamily *Amygdaloideae*) family with its highest density in temperate regions (Cronquist, 1981). *Prunus africana* is an important multipurpose tree species (Cunningham and Mbenkum, 1993). Its bark is the only source of an important drug which is used in the treatment of benign prostatic hyperplasia [redacted] other functions of the tree (Bombarddelli and Morazzoni, 1997). The bark extracts of *P. africana* have been used in treatment of benign prostatic hyperplasia for over three decades and the harvesting of this tree for bark extraction has resulted in the species becoming endangered (Bombardelli and Morazzoni, 1997). In the 1990s it was estimated that 35,000 trees were debarked annually and have [redacted] from Cameroon, Madagascar, Kenya and Equatorial [redacted] with small amounts from other countries. The extract is manufactured into various herbal products. The most popular product is [redacted] capsular form, sold under [redacted] [redacted] scientific name, *Pygeum africanum*. Currently *Prunus africana* bark is entirely collected [redacted] the wild, although attempts at cultivation are underway in Kenya (Dawson ,Jackson,House,Prentice and Mace, 2000). Prior to the discovery in 1966 of its [redacted] remedy, *P. africana* was a relatively common, but never abundant montane species.

P. africana has a wide distribution in Africa. It occurs in montane regions of central and southern Africa and the islands of Bioko, Sao-Tome, and Grande Comore (Kalkman, 1965). *P. africana* is most abundant in open areas along forest margins and in disturbed areas (Ndam, 1996) and is not shade-tolerant (Kiama and Kiyiapi, 2001). Ndam 1996 also found the most seedlings in forest gaps or fallow fields. This suggests that *P. africana* is a light-demanding, secondary-forest species. Recruitment is low or sporadic (Ewusi,Eben-Ebai,Asanga and Nkongo 1992). Because of deforestation at lower elevations, *P. africana* is confined to distinct "forest islands" that differ genetically (Barker et al., 1994), with the Madagascar population being the most distinct (Martinelli, Seraglia and Pifferi, 1986). The tree occurs at altitudes between 1000 and 2500m in montane forests (Sunderland and Tako, 1999). Distribution appears to be related to mean annual temperature [redacted] rainfall and/or cloud cover. Because of their relatively large areas of montane habitat, Cameroon and Madagascar contain the largest populations of the species. In Kenya, it is common [redacted] Kenya, Aberdares, Kakamega, and Cherangani Forests. It also occurs in Timboroa, Nandi, Tugen Hills and western part of Mau Forest.

Olea europaea, commonly known as Olive tree is in the family of *Oleacea* and native to Mediterranean, Asia and Africa. Olivewood is very hard and is prized for its durability, [redacted], high combustion temperature and interesting grain patterns. Because of the commercial importance of the fruit, and the slow growth and relatively small size of the tree, olive wood and its products are relatively expensive. Besides its fruit production, olive tree is important in provision of shelter for different birds and wild plants in harsh environment. The wild olive tree, is a species widely distributed in dry forest in Ethiopia. It is found in dry forests and forest margins between 1250 and 3100 m [redacted] and is usually around 15 m high though it can reach in some places up to 25 m in height (Legesse,1993 and Friis, 1992). *Olea* *europaea* is a long-lived tree. It shows strong xeromorphic characteristics and as an adult tree it can survive dry microclimatic conditions (Coetzee, 1978). It is widely used for house construction, fences and for making household furniture. The bark, the wood, the leaves and the roots are [redacted] to produce a distinctive smoke used for fermenting and flavouring of traditional beverages "Tela" and "Irgo"([redacted]) (Legesse, 1995). Olea also has medicinal value. In southeastern Ethiopia, the processed wood sap is used for curing skin disease and mental problems, and its smoke is used as an insect repellent (Demel, 1996). In Kenya the root or the bark [redacted] is used as a remedy for malaria (Beentje, 1994). Detailed medicinal values of Olea are presented by Rizk [redacted] Gamal (1995). The diverse use of the species has led to its extensive [redacted] in Ethiopia and other East African countries (Dale [redacted] Greenway 1961, Jones 1991, Legesse 1995).

The regeneration of most of the dominant high forest species in the Afromontane zone is under shade of mature forest (Pohjonen, 1989). The formation of a seedling-sapling bank under the forest canopy is the major regeneration route (Demel, 1997). Therefore, studies of natural regeneration of the dominant species in dry Afromontane forests are relevant for rehabilitation and conservation purposes. Knowledge of factors influencing the dynamics in natural populations will lead to a better understanding of the regeneration processes of trees, and has practical applications in the management of forest tree species (Still, 1996).Regeneration dynamics of tropical trees are still poorly known (Condit et al., 1996) especially in the case of species of tropical dry forest (Gerhardt & Hytteborn, 1992).

P. africana and *O. europaea* like most perennial plants possess two modes of regeneration: sexual reproduction through seed and clonal reproduction through some form of vegetative propagation (Richards, 1986). According to (Hannachi, Elfalleh, Ennaseh, Laajei, Khouja, Ferechichi, Nasri, 2011), clonal offspring are usually much larger than offspring produced through sexual reproduction.

A number of benefits have been attributed to *P. africana* and *O. europaea*.These benefits has led to their over [illegible]. The collection of the plants products such as bark from these species are destructive necessitating their urgent domestication for sustainable use. The germination of seed from these trees is particularly complex process depending on the genetic and environmental factors, such as temperature, light, and salinity.

The early growth potential of the two species is equally not documented especially for local provenances of South Nandi region. Due to limited knowledge in the species early growth potential, their cultivation has not been done in most parts of Kenya including the study area and therefore face extinction threat in the wild.

This study assessed and determined the population density, diameter size class distribution and the horizontal structure of *Prunus africana* and *Olea europaea* in South Nandi forest.

2.0 Materials and Methods

2.1 Study Area

South Nandi forest (Figure 1) [illegible] latitude [illegible] 18N [illegible] 32S, longitude 37 to 37E.South Nandi forest was gazetted in 1936 as a Trust Forest covering 20,200 ha, since then 2,200 ha have been excised for settlement, 340 ha planted with tea, and 1,400 ha planted with exotic tree species. Of the remaining area, [illegible] 13,000 ha is closed-canopy forest, the rest being scrub, grassland or under cultivation.

South Nandi forest was once contiguous with Kakamega forest (IBA KE058) and the two forests are still no more than a few kilometers apart at their closest points. Biogeographically, the forest is often considered an extension of Kakamega and in effect [illegible] a transition[illegible] between the lowland forests of west and central Africa (the easternmost outlier of which is Kakamega) and the montane forests of west and central Kenya highlands. Rainfall ranges between, 1,600–1,900 mm/year depending on altitude thus classified as moist forest under FAO. The forest is drained by the Kimondi and Sirua rivers, which merge to form the river Yala flowing into Lake Victoria. The landscape is gently undulating between 10-40%,the altitude ranges 1700-2000m above sea level, temperature ranges 18-24^{0}C, [redacted] underlain by granitic and basement complex rocks, which weather to give deep, well-drained, moderately fertile soils. The South Nandi area has high agricultural potential and human densities [redacted], particularly to the west. However, it is higher in altitude than Kakamega and floristically less diverse. The continuous closed forest canopy comprises indigenous tree species such as *Tabernaemontana stapfiana*, *Macaranga kilimandscharica*, *Croton megalocarpus*, *C. macrostachyus*, *Drypetes gerrardii*, *Celtis africana*, *Prunus africana*, *Neoboutonia macrocalyx*,*Olea species* and *Albizia gummifera* exotic while the open forest is dominated by *Croton spp,P.africana,O.europaea* among others.The forest generally has a rich biodiversity that include highlands bird community thus recognized as an important Bird area, others are reptiles and butterflies (KFS,2018).

The [redacted] are mostly farm[redacted] with major cash crops being tea and [redacted]. The average [redacted] of land per household around the forest is 2.5 hectares however most households to the west have [redacted] land holdings hence there is a lot of pressure on the forest resources.

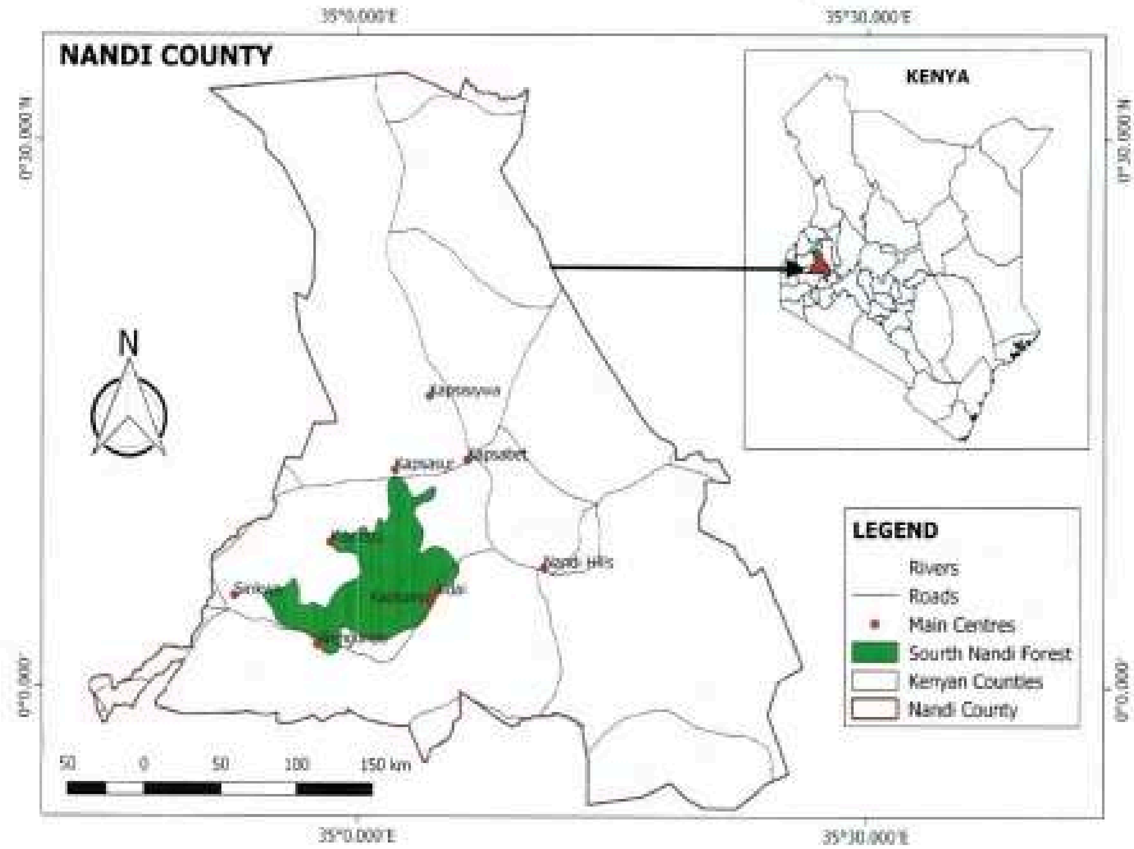

Fig 1: Map of South Nandi Forest (Author, 2018).

2.2 Study species/ Target Population

The target population comprised of *P. africana and O. europaea trees* from South Nandi Forest.

2.3 Sample and sampling procedures

Two line transect were established 250m apart and running parallel to each other in the north east direction were used to lay 20 systematic sample plots of 50m x 20m each, along a transect at an interval of 200m.The sample plots were further divided into five sub sample units of 20m x 10m where the number of trees (DBH≥10cm),poles (5≤DBH<10cm),saplings

(1≤DBH<5cm) were assessed while the number of seedlings (DBH<1cm) were assessed in 50mx1m bands within the sample plots as described by Hitimana Kiyiapi and Njunge,2004.

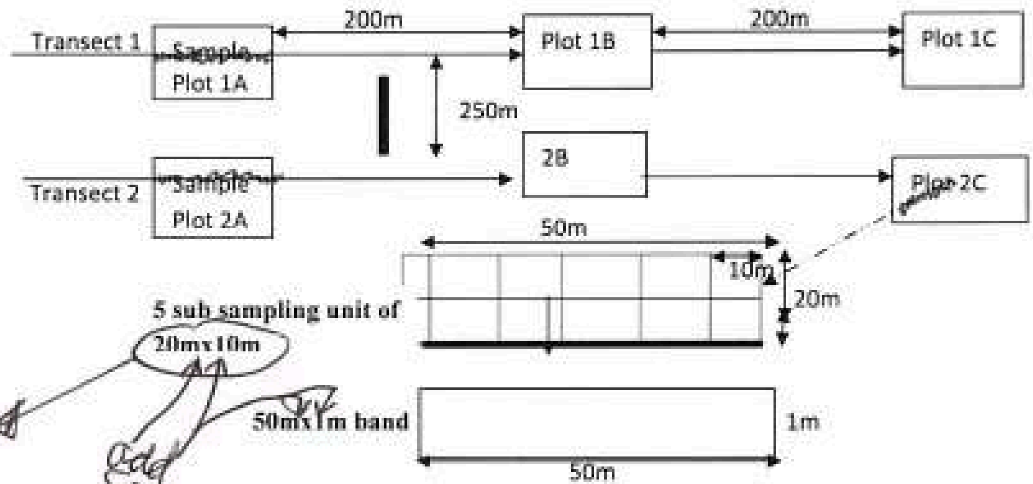

Fig. 2 Diagram illustrating transect layout and sample plots design

2.4 Data Analysis

The number of trees recorded for *P.africana* and *O.europaea* were used to determine each species density per hectare in the study area as follows;

Density= $\frac{Total\ no.recorded}{Sample\ area\ (ha)}$ .... (Formula 1). The number of trees per hectare for each DBH class recorded for *Prunus africana and Olea europaea* were plotted against DBH classes to show the pattern of diameter size distribution for the two species in the study area. The observed DBH distribution was tested against the expected reverse J-curve for stable tree species populations. Two way analysis of variance (ANOVA) was applied at 5% level of significance (Kiernan, 2014) and then results compared to the hypothetical UNO 1994 model for structurally stable East African natural forests.

3.0 Results

3.1 Population Density and structure of *Prunus africana and Olea europaea*

3.1.1 Population densities of *Prunus africana* and *Olea europaea.*

The densities of *Prunus africana and Olea europaea* tree species in each DBH class are presented in table 1. The size classes defined were; Seedlings with DBH (<1cm), saplings (1-4.9cm), poles (5-9.9cm) and mature trees (>10cm).

Table 1. Mean density ([redacted]) of *P.africana* and *O.europaea*

Tree species	Cartegory	DBH Class	Sampled Area/ha	No. of individuals in sampled area	Total no. of individuals in sampled area	Density/Stems per hactare	% density
P.africana	Seedlings	<1cm	0.2	174	578	870	75
	Saplings	1-4.9cm	4	519	3629	130	11
	Poles	5-9.9cm	4	418	3029	105	9
	Mature trees	>10cm	4	202	792	51	4
O.europaea	Seedlings	<1cm	0.2	116	577	580	72
	Splingsa	1-4.9cm	4	416	3617	104	13
	Poles	5-9.9cm	4	337	3036	84	11
	Mature trees	>10cm	4	134	793	34	4

In table 1 above, a total of 1,156 stems ha^{-1} were recorded for the *P.africana* in the study area. Seedlings were the most abundant and mature trees the least abundant, where 75.3% were seedlings (870 stems ha^{-1}), 11.2% were saplings (130 stems ha^{-1}), 9.1% were poles (105 stems ha^{-1}) and 4.4% mature trees (51 stems ha^{-1}).

Likewise a total of 802 stems ha^{-1} for *O.europaea* were recorded where seedlings were the highest and accounted for 72.3% (580 stems ha^{-1}) while mature trees were the lowest with 4.2% (34 stems ha^{-1}). The others were saplings 13% (104 stems ha^{-1}) and Poles 10.5% (84 stems ha^{-1}).

The number of individuals for the two species in the sampled area ranged from 116-174 for seedlings,416-519 for saplings,337-418 for poles and 134 ,202 for mature trees. The density of mature trees with DBH >10cm varied from 34 stems/ha for *O.europaea* to 51stems/ha for *P.africana.*

Along the transects and among the four sites (Chebilat, Kobujoi, Chepkongony and Kamarich), density for mature trees was highest in Kamarich (58 stems ha^{-1}) and lowest in Chepkongony (46 stems ha^{-1}) for *P.africana* while for *O.europaea* it was highest in Kobujoi (43 ha^{-1}) and lowest in Kamarich (28 ha^{-1}) as indicated in table 2 below.

Table 2: Mean Population density of *P.africana* and *O.europaea* at different sampling sites

Species	Sites	Mean population densities(stems/hectare)			
		Mature trees	Poles	Saplings	seedlings
P.africana	Chebilat	53	110	121	860
	Kobujoi	47	102	136	885
	Chepkongony	46	105	133	870
	Kamarich	58	103	130	865
O.europaea	Chebilat	36	80	96	601
	Kobujoi	43	86	104	580
	Chepkongony	29	74	109	570
	Kamarich	28	96	107	569

Two way analysis of variance ANOVA(Appendix A & B) established that there was a significant difference in the densities of *P.africana*; $F(9,48)=36.561$, $p=0.001$([illegible]) and *O.europaea*;$F(9,48)=20.512$,$P=0.001$([illegible]) in the DBH size classes among the four forest sites.

The results shows that there [illegible] significant variation in the number of *P. africana and O.europaea* development stages in the four sites.

The frequency of the two species in each DBH class are presented in Fig 3 and 4.

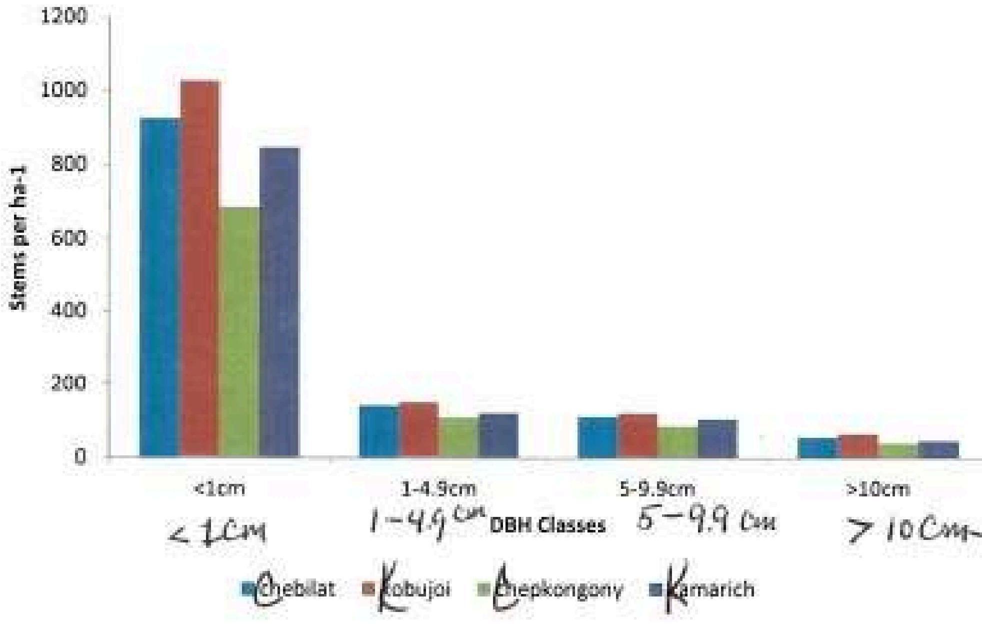

Figure 3: Population density of *Prunua africana* in each DBH class in four sites

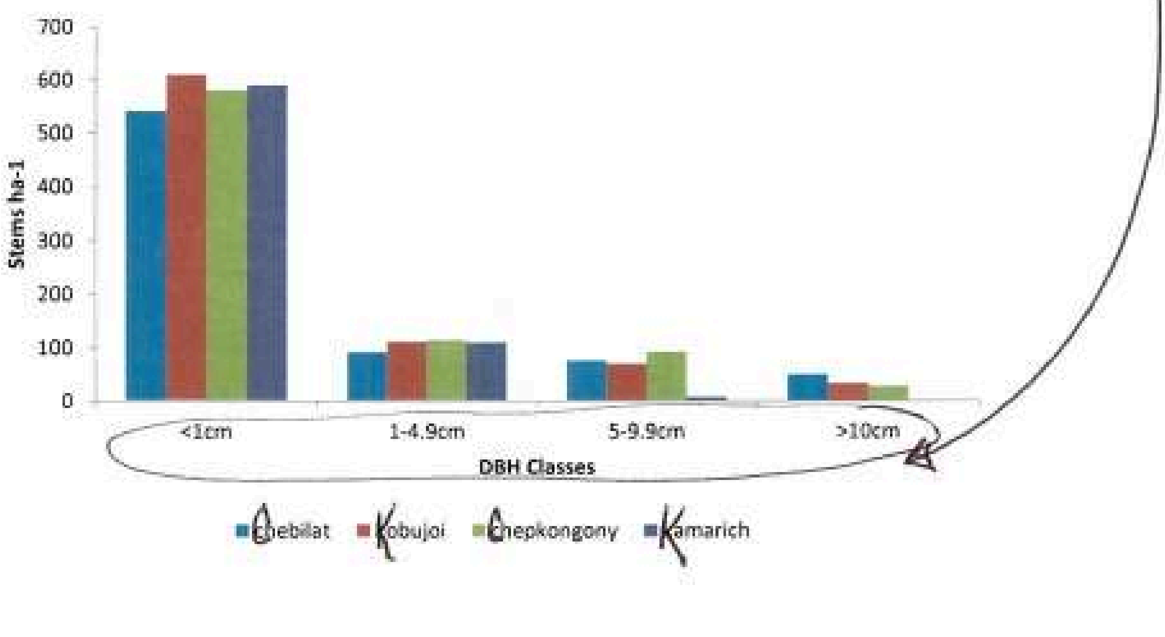

Figure 4: Population density of *Olea europaea* in each DBH class in four sites

It was observed that the survival of seedlings of the two species to sapling stages was extremely poor at the few sites examined. Poor recruitment into saplings, poles and mature trees of the two species was also observed and could be attributed to induced disturbance [redacted] charcoal burning, uncontrolled grazing and illegal logging noted along the transect lines in the area. This is an indication that the population densities of these two species will continue to decline in the foreseeable future (Rono, Sirmah and Hitimana, 2018).

3.1.2 Population structure of *P.africana* and *O.europaea*

The population structure distribution in various DBH size classes were analyzed per hectare for the two species as indicated in Fig 5 and 6 below.

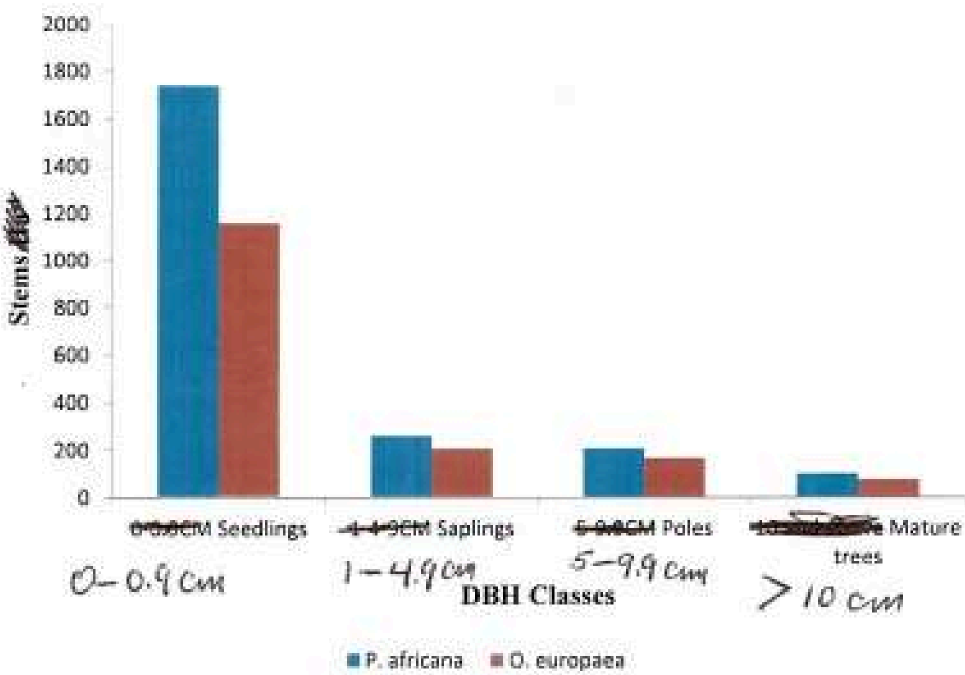

Figure 5: Population density of *P. africana* and *O. europaea* in different size classes

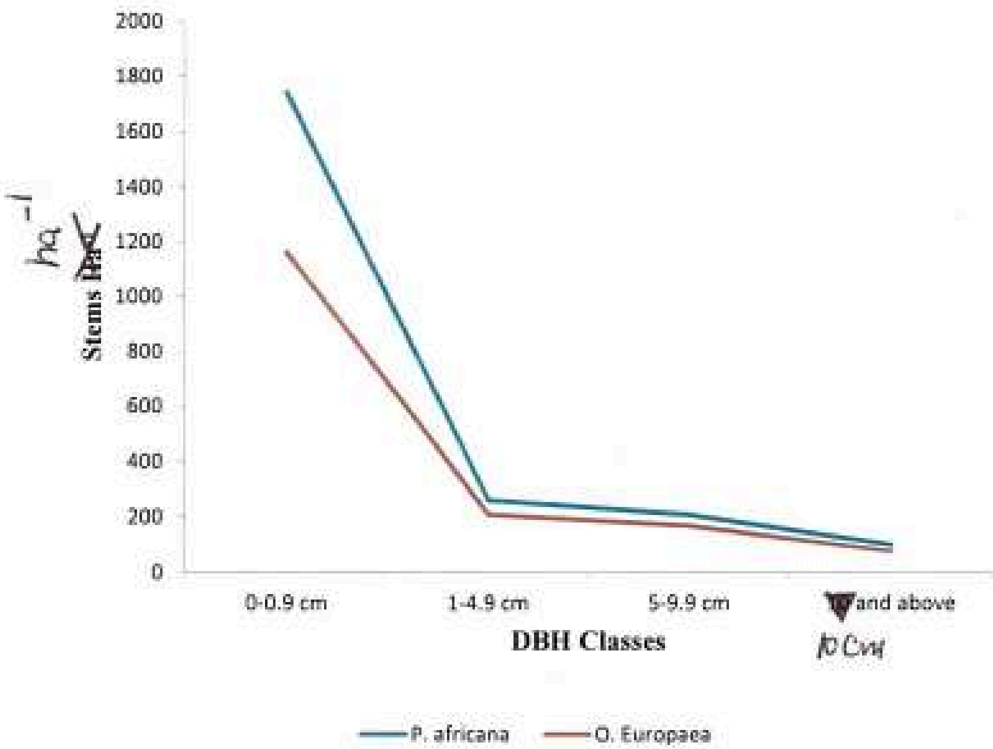

Figure 6: Diameter size class distribution profile for *Prunus africana* and *Olea europaea*

The population structure of *P.africana and O.europaea* had reverse J-shaped curve size class distribution with a smooth decline in the number of individuals from smaller to larger size classes. Such a trend is an indication of a stable population that naturally replacing themselves through good regeneration.

The density levels of stems) for the two species in the study area were also low in comparison with the expected stocking level of a typical balanced stable East African natural forest (UNO, 1994).Fig 7.

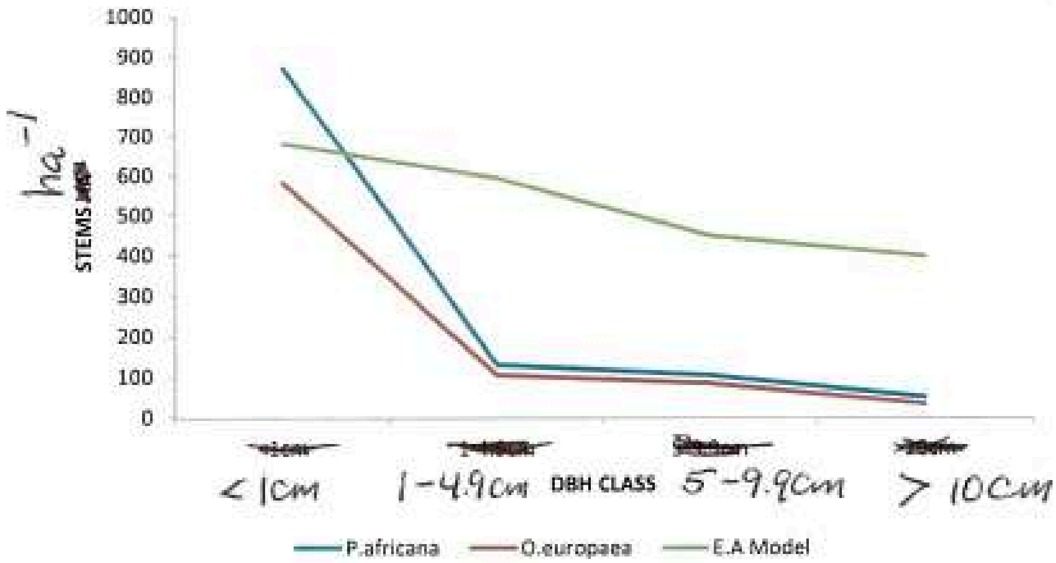

Figure 7: Diameter size distribution for *Prunus africana* *olea europaea* in hypothetical model for structurally stable East African Natural forest.

4.0 Discussion

Variation in stem densities within the forest could have resulted from ~~clearfell~~ and disturbance over the years, which normally leads to canopy gaps that stimulate growth of both herbaceous and woody plants that may suppress tree regeneration.

Regeneration can alter the ecology of rain forest remnants in many ways, but its long term effects on tree communities are poorly understood. One phenomenon that has received little attention is tree regeneration in fragmented forests (Janzen, 1983). Patterns of regeneration are important because they will ultimately determine the floristic structure and composition of the tropical forests.

The regeneration pattern of the tree species varied in the forest, this could be attributed to poor establishment as a result of low population of the dispersal agents coupled with reduction in the densities of potential host trees that occurred due to human disturbance. Several other potential agents [redacted]causing low density of the two species include disease (Franklin *et al*, 1987), insect attack (Cunningham *et al*, 2002) and climatic fluctuation (Evenson, 1983) were not properly examined during this study and [redacted] future investigation[redacted].

Though the seeds of the two species germinate in shaded conditions, the seedlings of *P.africana* appear to require light gaps in the canopy for survival to the pole stage (Kiama and Kiyiapi, 2001).[redacted]uman disturbance has not been sufficient to create light gaps for successful regeneration of *Prunus africana*. In addition the undergrowth which is believed to be a product of clearfell may play an inhibiting role for the *Prunus africana* and *Olea europaea* saplings survival much as it [redacted] do in the forest of [redacted]ount Oku, Cameroon (Stewart, 2010).

Conservation *of P.africana* and *O.europaea* offers a formidable challenge since the species appear[redacted] to require disturbance for regeneration (kiama and kiyiapi, 2001),yet at sites where disturbance is occurring, *P.africana* is often a target of bark harvesters engaging in unsustainable levels of [redacted] (Cunningham and [redacted]benkum, 1983; Sunderland and Tako, 1999).

To help meet the increasing demand for *P.africana* bark extract, there is need to start projects that will generate income [redacted] the locals which will reduce pressure on the natural forest population, surrounding communities should be encouraged to establish *P.africana* plantations (Stewart, 2003).

In developing forest management strategies for south Nandi forest, it would be important to focus on the protection of the two species from depletion by encouraging the community to explore alternative tree species with similar properties. The ongoing participatory forest management should focus on on-farm cultivation of these two species in the long term. Even though the trees grow slowly [redacted] their incorporation into agroforestry systems would eventually develop alternative stocks that would help in reducing the forest degradation and depletion of the two species.

The regeneration patterns analyzed indicates that there is fluctuating forest regeneration as a result of natural phenomena [redacted] human–induced processes. However, detailed analysis revealed that each species is unique and require specific silvicultural interventions.

5.0 Conclusion

The results showed that the population densities for *P.africana* ranged from 860-885 stems/ha and 569-601 stems/ha for *O.europaea* along the line transects. These population densities were significantly different ($p<0.05$) between the sampled cluster sites of Chebilat,Kobujoi,Chepkongony and Kamarich within Nandi South Forest. The DBH and size classes distribution for the two species gave a reverse J-shaped curve.

The results for diameter size distribution indicated [redacted] curve for both *P.africana* and *O.europaea* structures suggesting stable populations of the two species that naturally replace themselves through successful regeneration. However in comparison with UNO 1994 model for structurally stable East Africa natural forest ecosystem the species were unstocked [redacted] indicate low recruitment from seedlings into mature trees due to possible anthropogenic disturbances. Recruitment of both species occurred more intensively in canopy gaps but displayed inhibition near mature conspecifics throughout the forest floor.

There is need therefore to consider population densities,regeneration and recruitment levels in planning to restore the two species through artificial regeneration in addition to advocating for strategic in-situ conservation interventions to enhance recruitment in South Nandi Forest.

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APENDICES

Appendix A.Tests of Between-Subjects Effects for *P.africana*

Dependent Variable:VAR00003

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.507E6[a]	15	500494.933	1.102E3	.000
Intercept	5345344.000	1	5345344.000	1.177E4	.000
VAR00001	104454.000	3	34818.000	76.635	.000
VAR00002	7253472.000	3	2417824.000	5.322E3	.000
VAR00001 * VAR00002	149498.000	9	16610.889	36.561	.000
Error	21808.000	48	454.333		
Total	1.287E7	64			
Corrected Total	7529232.000	63			

a. R Squared = .997 (Adjusted R Squared = .996)

Appendix B.Test of between subjects Effects for *O.europaea*

Dependent Variable:VAR00003

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.130E6[a]	16	195612.983	2.987E3	.000
Intercept	1350912.657	1	1350912.657	2.063E4	.000
VAR00001	3133.022	4	783.256	11.961	.000
VAR00002	3080701.914	3	1026900.638	1.568E4	.000
VAR00001 * VAR00002	12088.759	9	1343.195	20.512	.000
Error	3077.750	47	65.484		
Total	5724583.000	64			
Corrected Total	3132885.484	63			

a. R Squared = .999 (Adjusted R Squared = .999)