Population Structure of *Prunus africana* (Hook. f.) Kalkm. and *Olea europaea* L. in South Nandi Afromontane Forest, Kenya

Abungu Eric Onyango[1*], Joseph Hitimana[2], Peter K. Sirmah[3] and Thomas Matonyei[4]

[1]*Department of Forestry,School of Natural Resources & Environmental Management,University of kabianga P.O.BOX 2030- 20200 Kericho,Kenya.Email eabungu@gmail.com*
[2] *Department of Forestry,School of Natural Resources & Environmental Management,University of kabianga P.O.BOX 2030- 20200 Kericho,Kenya.Email hitimana@yahoo.com*
[3] *Department of Forestry,School of Natural Resources & Environmental Management,University of kabianga P.O.BOX 2030- 20200 Kericho,Kenya.Email sirmahkipkosgei110@hotmail.com*
[4] *Department of Forestry,School of Natural Resources & Environmental Management,University of kabianga P.O.BOX 2030- 20200 Kericho,Kenya.Email matonyei@gmail.com*

Original Research

ABSTRACT

Prunus africana (African cherry) and *Olea eurpaea* (Olive) tree species from the moist highlands of sub-Saharan Africa are subjected to industrial-scale harvesting, and therefore endangered due to their medicinal values and fine wood. Studying their population dynamics plays an important role in identifying the conservation needs in tropical ecosystems. This paper focuses on an ecological study carried out from April-June 2017, within the South Nandi Afromontane Forest, Kenya. The objectives were to analyse population density, diameter size class distribution, and the horizontal structure of *Prunus africana* and O*lea europaea* species as indicators of their respective species stability within the forest. Two-line transects established 250 meters apart were used to lay twenty systematic sample plots of 50 m x 20 m each, along with a transect at an interval of 200 m. These sample plots were further divided into five sub-sample units of 20 m × 10 m, where the number of trees with Diameter at Breast Height (DBH) >10 cm, poles 5-10 cm, saplings 1-5 cm were assessed, while the number of seedlings with DBH < 1 cm were assessed in 50 m × 1m bands within the sample plots. Two and one-way Analysis of Variance ANOVA were applied at a 5% level of significance. The population densities ranged from 860-885 stems/hectare for *P.africana* and 569-601 stems/hectare 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 characterises stable populations that naturally replace themselves through regeneration. However, in comparison with United Nation Organisation 1994 model for structurally

**Corresponding author: E-mail: eabungu@gmail.com;*

stable East African natural forest ecosystems, the species were unstocked, which indicates 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 a need to consider population densities, regeneration, and recruitment levels in planning to restore the two species through artificial regeneration, in addition to advocate 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. INTRODUCTION

Prunus africana (Hook.f.) Kalkman and *Olea europaea* L. trees are endangered due to their medicinal value, and fine wood [1] and so far *P. africana* is included in Appendix II by Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1995 [2]. Unsustainable management has led to decline in the populations due to subsistence bark harvests for medicinal trade (Stewart, 2009), coupled with illegal harvesting, which has affected the integrity of the forest [3].

Even though several studies have been conducted on the adverse effects of over-harvesting, 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 [4].

Prunus africana is a member of the *Rosaceae* (subfamily *Amygdaloideae*) family, with its highest density in temperate regions [5]. *Prunus africana* is an important multipurpose tree species [3]. Its bark is the only source of an important drug, which is used in the treatment of benign prostatic (prostate) hyperplasia, not including other uses of the tree [6]. The bark extracts of *P. africana* have been used in the treatment of benign prostatic hyperplasia for over three decades, and the over-harvesting of this tree for bark extraction has resulted in the endangered status of the species [6]. In 1990s it was estimated that 35,000 trees were debarked annually, and have been harvested from Cameroon, Madagascar, Kenya, and Equatorial Guinea, with small amounts from other countries. The extract is manufactured into various herbal products. The most popular herbal product is a capsular form, sold under its previous scientific name, *Pygeum africanum*. Currently, the *Prunus africana* bark is entirely collected in the wild, although attempts of cultivation are underway in Kenya [7]. Prior to the discovery in 1966 of its use as a herbal 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 [8]. *P. africana* is most abundant in open areas along forest margins and in disturbed areas [9] and is not shade-tolerant [10]. [9] also found the most seedlings are found in forest gaps or fallow fields. This suggests that *P. africana* is a light-demanding, secondary-forest species. Recruitment is low or sporadic [11]. Because of deforestation at lower elevations, *P. africana* is confined to distinct “forest islands” that differ genetically [12], with the Madagascar population being the most distinct [13]. The tree occurs at altitudes between 1000 and 2500 m in montane forests [14]. Distribution appears to be related to mean annual temperature, 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 in Mt. Kenya, Aberdares, Kakamega, and Cherangani montane Forests. It also occurs in Timboroa, Nandi, Tugen Hills and the western part of the Mau Forest.

Olea europaea, commonly known as the Olive tree, is a member of Oleacea family, and is native to Mediterranean, Asia and Africa. Olivewood is very hard and is prized for its durability, colour, 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, the olive tree is important in the provision of shelter for different birds, and wild plants in harsh environments [4].

The wild olive tree is a species widely distributed in dry forests in Ethiopia. It is found in dry forests and forest margins between 1250 and 3100 m above sea level and is usually around 15 m high, though it can reach in some places up to 25 m in height [15]. *Olea europaea* is a long-lived tree. It shows strong xeromorphic characteristics (ability to store water in leaves and stems with minimal loss) and as an adult tree, it can survive dry microclimatic conditions [16]. It is widely used for house construction, fences, and for making household furniture. The bark, wood, leaves, and roots are burned to produce a distinctive smoke used for fermenting and flavouring of traditional beverages "Tela" and “Irgo” yoghurt.Olea also have medicinal value. In southeastern Ethiopia, the processed wood sap is used for curing skin diseases, burns, wounds, fractures and mental health problems, and its smoke is used as an insect repellent [17]). In Kenya, the root or the bark is used as a remedy for malaria [18]. Detailed medicinal values of Olea are presented by [19]. The diverse use of the species has led to its extensive harvesting in Ethiopia and other East African countries [20].

The regeneration of most of the dominant high forest species in the Afromontane zone is under the shade of mature forests [21]. The formation of a seedling-sapling bank under the forest canopy is the major regeneration route [17]. 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 of 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 Regeneration dynamics of tropical trees are still poorly known [22], especially in the case of these species in tropical dry forests [23].

Like most other perennial plants, *P. africana* and *O. europaea,* possess two modes of regeneration: sexual reproduction through seeds and clonal reproduction through some form of vegetative propagation [24]. The Clonal offspring are usually much larger than offspring produced through sexual reproduction [25].

A number of benefits have been attributed to *P. africana* and *O. europaea.* These benefits have led to their over-harvesting. The collection of the plant products, such as bark from these species, is destructive, necessitating their urgent domestication for sustainable use. The germination of seed from these trees is a 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 the limited knowledge of the species, early growth potential, and 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 the South Nandi forest.

2. MATERIALS AND METHODS

2.1 Study Area

The South Nandi Forest (Fig. 1), is located between latitudes 18N to 32S, and longitudes 37 to 37E. The South Nandi Forest was gazetted as a public and trust forest in 1936, covering 20,200 ha. Since then, 2,200 ha have been removed for settlements, 340 ha planted with tea, and 1,400 ha planted with exotic tree species. Of the remaining area, approximately 13,000 ha is closed-canopy forest, the rest being scrub, grassland or under cultivation.

The South Nandi Forest was once contiguous with the Kakamega Forest (IBA KE058), and the two forests are still no more than a few kilometres apart at their closest points. Biogeographically, the forest is often considered as an extension of Kakamega, and in effect, is a transition between the lowland forests of west and central Africa (the easternmost outlier of which is Kakamega), and the montane forests of west and central Kenyan highlands. Here rainfall ranges between, 1,600–1,900 mm/year, depending on altitude, and thus is classified as a moist forest under the Food and Agriculture Organization [26]. The forest is drained by the Kimondi and Sirua rivers, which merge to form the river Yala, flowing into Lake Victoria. The landscape slope is gently undulating between 10-40%, the altitude ranges between 1700-2000 m above sea level, and the temperature ranges from 18-24°C. The landscape is 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 high human densities 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 includes highlands bird community thus recognised as an important bird area, others are reptiles and butterflies [27].

Adjacent to the forest are mostly farming communities with major cash crops being tea and corn. The average plot of land per household around the forest is 2.5 hectares, however, most households to the west have smaller land holdings, and hence there is a lot of pressure on the forest resources.

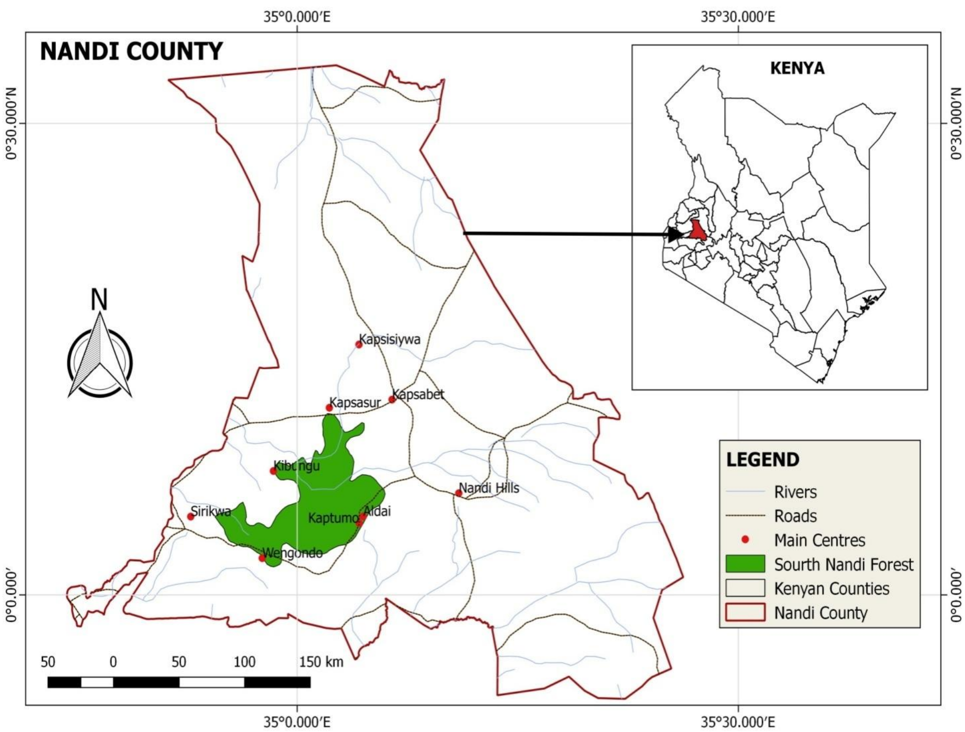

Fig. 1. Map of South Nandi Forest, adapted from Kenya Forest Service ((Sheila, 2018)

2.2 Study Species/ Target Population

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

2.3 Sample and Sampling Procedures

Two-line transects were established 250 m apart, running parallel to each other in the northeast direction, were used to lay 20 systematic sample plots of 50 m × 20 m each, along with a transect at an interval of 200 m. The sample plots were further divided into five sub-sample units of 20 m × 10 m, where the number of trees DBH ≥ 10 cm, poles (5 ≤ DBH < 10 cm), saplings (1 ≤ DBH < 5 cm) were assessed while the number of seedlings (DBH < 1cm) were assessed in 50 m ×1 m bands within the sample plots as described by [28].

2.4 Data Analysis

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

$$\text{Density}=\frac{Total\ no.recorded}{Sample\ area\ (ha)} \ldots .\ \text{(Formula 1)}$$

The number of trees, poles, saplings, and seedlings per hectare (for each Diameter at Breast Height (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 the 5% level of significance [29], and then results were compared with the hypothetical United Nations Organisation 1994 model for structurally stable East African natural forests.

3. RESULTS

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

This section contains results for observed and statistical analyses, presented on the population density and structure of *Prunus africana* and *Olea europaea* tree species in South Nandi Forest, Kenya.

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 < 1 cm, saplings 1-4.9 cm, poles 5-9.9 cm and mature trees > 10 cm).

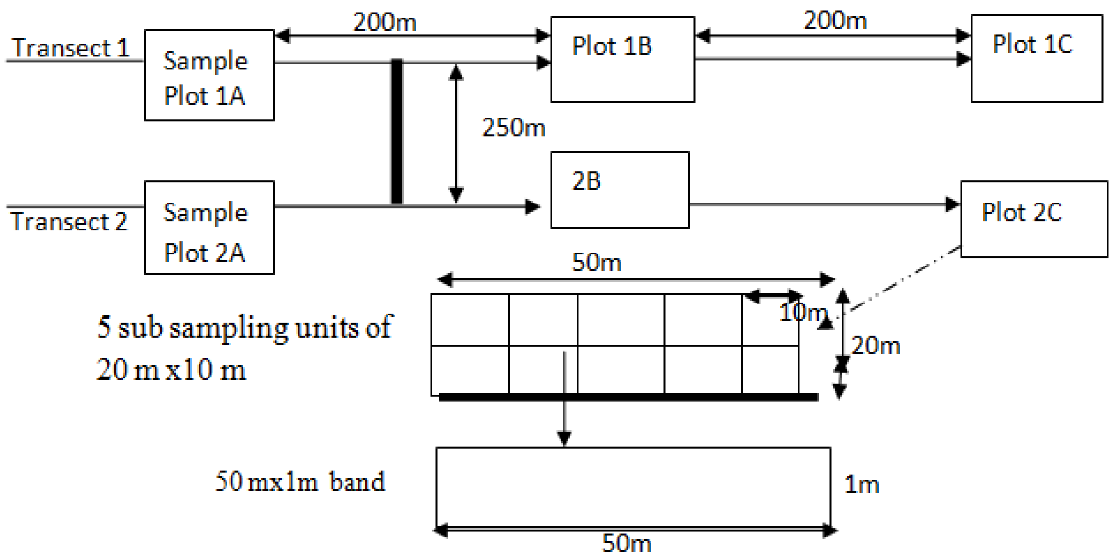

Fig. 2. Diagram illustrating transect layout and sample plots design (Author, 2018)

Table 1. Mean density per hectare [ha^{-1}] of *P. africana* and *O. europaea*

Tree species	Category	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	< 1 cm	0.2	174	578	870	75
	Saplings	1-4.9 cm	4	519	3629	130	11
	Poles	5-9.9 cm	4	418	3029	105	9
	Mature trees	> 10 cm	4	202	792	51	4
O. europaea	Seedlings	< 1 cm	0.2	116	577	580	72
	Saplings	1-4.9 cm	4	416	3617	104	13
	Poles	5-9.9 cm	4	337	3036	84	11
	Mature trees	>10 cm	4	134	793	34	4

In Table 1, a total of 1,156 stems ha^{-1} were recorded for the *P.africana* in the study area. Seedlings were most abundantwhile mature trees were 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 >10 cm varied from 34 stems/ha^{-1} for *O. europaea* to 51stems/ha^{-1} for *P. africana.*

Along thetransects and among the four sites (Chebilat, Kobujoi, Chepkongony and Kamarich), the 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.

Two way ANOVA (Appendices A and B) established that there was a significant difference in the densities of *P. africana;* $F\ (9.48) = 36.561$, $p = 0.001$ and *O. europaea* ; $F\ (9.48) = 20.512$, $p = 0.001$ in the DBH size classes among the four forest sites.

The results show that there was 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 is presented in Figs. 3 and 4.

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

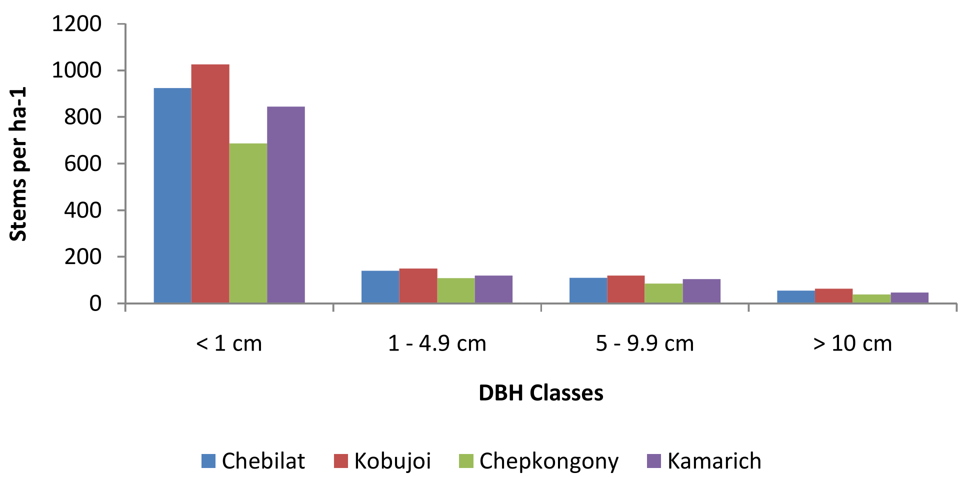

Fig. 3. Population density of *Prunua africana* in each DBH class in four sites

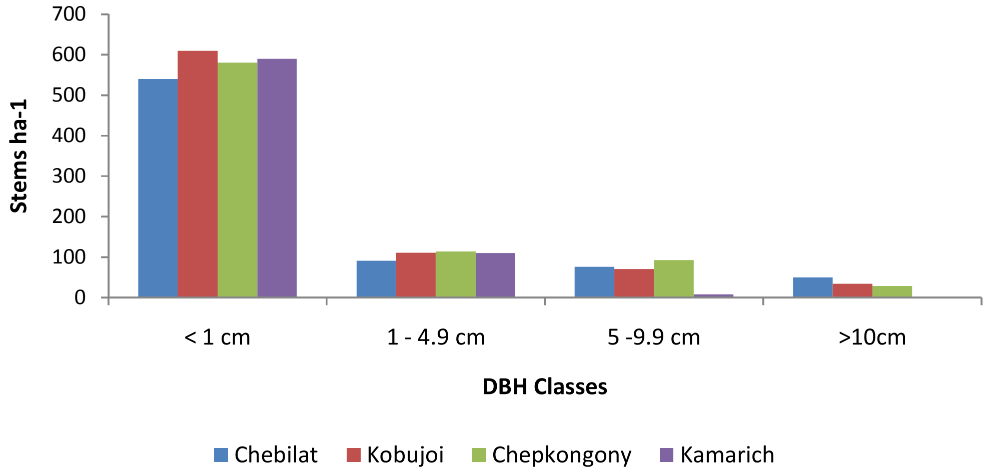

Fig. 4. Population density of *Olea europaea* in each DBH class in four sites

It was observed that the survival of the 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 activities including 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 [30].

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

The population structure distribution in various DBH size classes was analysed per hectare for the two species as indicated in Figs. 5 and 6 below.

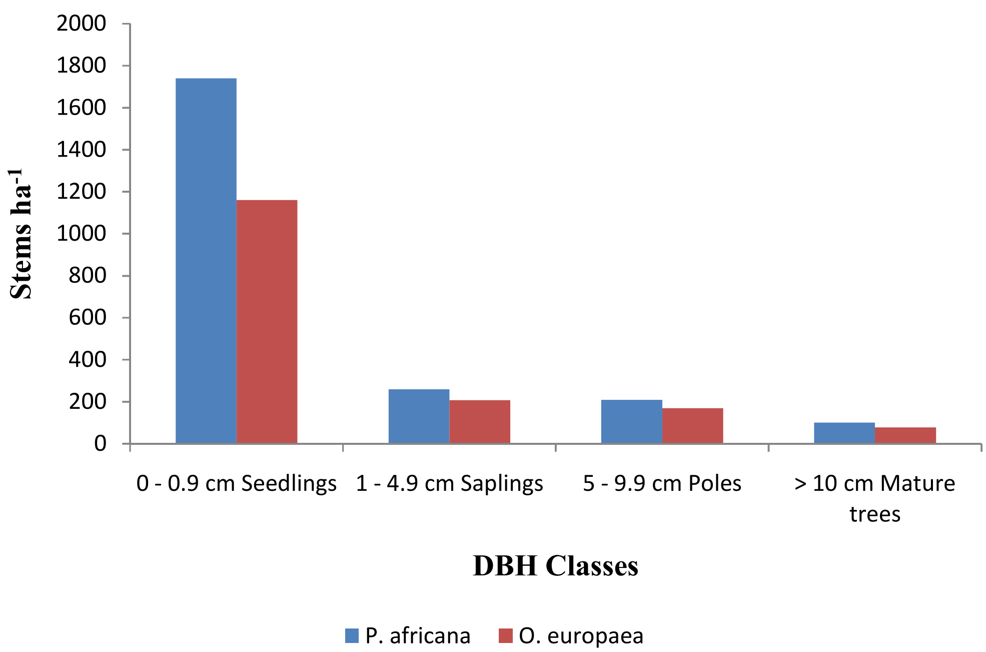

Fig. 5. Population density of *P. africana* and *O. europaea* in different size classes

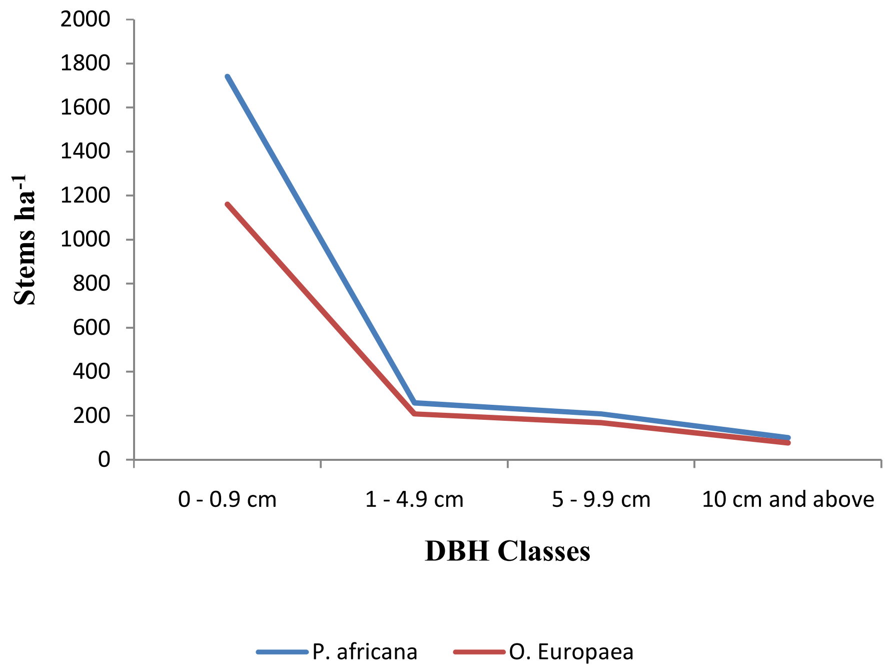

Fig. 6. Diameter size class distribution profile for *Prunus africana* and *Olea europaea*

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

The density levels (Number of stems ha^{-1}) 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)

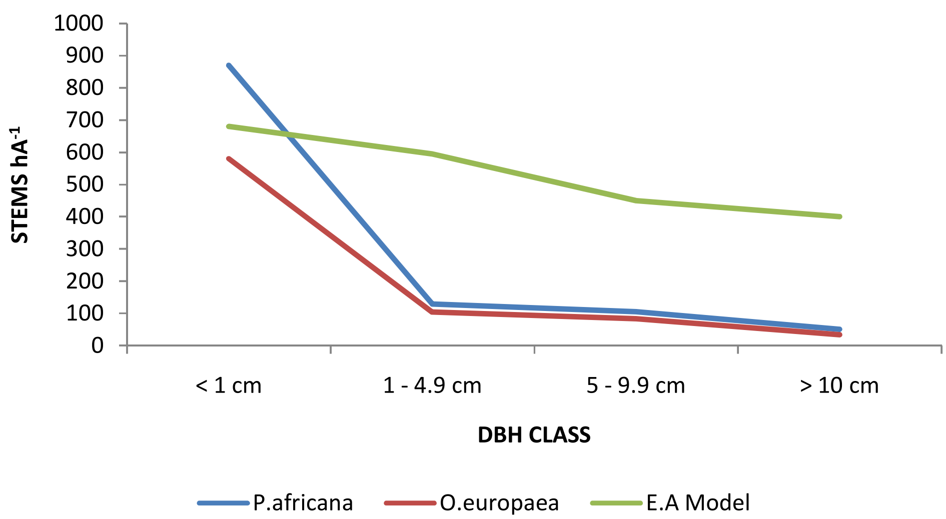

Fig. 7. Diameter size distribution for *Prunus africana*, *olea europaea* in hypothetical model for structurally stable East African Natural forest

4. DISCUSSION

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

Regeneration can alter the ecology of rainforest 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 [31]. The 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, which could be attributed to the poor establishment as a result of a low population of the dispersal agents, coupled with a reduction in the densities of potential host trees that occurred due to human disturbances. Several other potential agents causing the low density of the two species include disease [32], insect attack and climatic fluctuation [33] which were not properly examined during this study and merit future investigation.

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 [10]; [34]. Human 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 clear fell, may play an inhibiting role for the *Prunus africana* and *Olea europaea* saplings survival as much as it may do in the forests of Mount Oku, [35].

Conservation *of P. africana* and *O. europaea* offers a formidable challenge, since the species appear to require disturbance for regeneration [10], yet at sites where disturbance is occurring, *P. africana* is often a target of bark harvesters engaging in unsustainable levels of harvesting [3], [14].

To help to meet the increasing demand for *P. africana* bark extract, there is a need to start projects that will generate income for the locals which will reduce pressure on the natural forest population. Surrounding communities should be encouraged to establish *P. africana* plantations [36].

In developing forest management strategies for the 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 the on-farm cultivation of these two species in the long term. Even though the trees grow slowly, 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 analysed regeneration patterns indicate that there is fluctuating forest regeneration as a result of natural phenomena in addition to human-induced processes. However, a detailed analysis revealed that each species is unique, and requires specific silvicultural interventions.

5. CONCLUSION

The results show 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 the South Nandi Forest. The DBH and size classes' distribution for the two species gave a reverse J-shaped curve.

The results for diameter size distribution indicated a reverse J-shaped 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 the UNO 1994 model for structurally stable East African natural forest ecosystems, the species were unstocked, which indicates 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.

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

ACKNOWLEDGEMENTS

I am indebted to a number of people and organisations who have assisted me at various levels in ensuring the success of this study. Special thanks to the University of Kabianga for granting me the opportunity to undertake the study and Albert Baker Fund through Christian Science Church that financed a part of this study. I would also like to express my deep gratitude to my supervisors: Mr Joseph Hitimana, Dr Peter Sirmah and Dr Thomas Matonyei for their guidance and constructive criticism that stimulated me to think broadly in many areas while undertaking this study. I acknowledge the staff of Natural Resources and Environmental Management, University of Kabianga, Kenya Forest Service, KEFRI and colleagues for the help, encouragement and assistance in various ways. I also thank my family for the prayers, love and financial support during this study. Last but not least I thank God, the almighty for giving me the strength, knowledge, finance and good health that enabled me to undertake and complete this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. IUCN Red List of Threatened Species (2016). World Conservation Press. Retrieved from http://www.iucnredlist.org
2. Cunningham, M., Cunningham, A.B. and Schippmann, U. (1997). *Trade in Prunus africana and the Implementation of CITES.* Results of the R+D Project 808 05 080, German Federal Agency for Nature Conservation.
3. Cunningham, A.B.and Mbenkum, F.T. (1993). *Sustainability of harvesting Prunus africana bark in Cameroon: A medicinal plant in international trade*. People and Plants Working Paper , Paris. UNESCO
4. Tesfaye B., (2000).Plant population dynamics of *Dodonaea angustifolia* and *Olea europaea* in dry montane forests of Ethiopia
5. Cronquist,A.(1981) An integrated system of classification of flowering plants, Colombia University- Press, New York, pp 245-250.
6. Bombarddelli, E. and Morazzoni, P . (1997). Biological activity of Procyanidins from Vitis vinifera:Biofactors, Vol 6 ,issue 4, pp 429-431. Retrieved from https://doi.org/10.1002/biof.5520060411 on 30 April, 2018.
7. Dawson T.P., Jackson S.T., House J.I., Prentice, I.C. and Mace, G.M.(2017). Beyond predictions: Biodiversity conservation in a changing climate.science.vol.332,Issue 6025, pp.53-58. doi:10.1126/science.1200303.
8. Kalkman, C. (1965*). The old-world species of Prunus subg. Laurocerasus including those* formerly referred to Pygeum. Blumea 13, 1–174. Retrieved from http://www.repository.naturalis.nl/record/526237, on 28 February, 2018
9. Ndam, N. (1996). *Recruitment patterns of Prunus africana (Hook f.) Kalkman on Mount Cameroon: a case study at Mapanja*. In: A Strategy for the Conservation of *Prunus africana* on Mount Cameroon. Technical Papers and Workshop Proceedings, 21–22 February, 1996
10. Kiama, D., & Kiyiapi, J. (2001). Shade tolerance and regeneration of some tree species of a tropical rain forest in Western Kenya. *Plant Ecology* ,156, 183–191.
11. Ewusi, B., Tako, C., Nyambi, J. and Acworth, J. (1996). *Bark extraction: The current situation of the sustainable cropping of Prunus africana on Mount Cameroon*. In: A Strategy for the Conservation of *Prunus africana* on Mount Cameroon. Technical Papers and Workshop Proceedings, 21–22 February, 1996.
12. Barket J.S.F., Tan S.G., Moores S.S. and Byrne K.A. (1994). Heredity: Pathogenesis and immunity.
13. Martinelli, E.M., Seraglia, R. and Pifferi, G. (1986*). Characterization of Pygeum africanum bark extracts by HRGC with computer assistance.* Journal of High Resolution Chromatography and Chromatography Communications 9, 106–110.
14. Sunderland, T.C. and Tako, C.T. (1999). *The Exploitation of Prunus africana on*

the Island of Bioko, Equatorial Guinea. Unpublished Report Prepared for the People and Plants Initiative, WWF-Germany, and the IUC/SSC Medicinal Plant Specialist Group
15. Friis, L. (1992). Forests and forest trees of northeast Africa.
16. Coetzee, J.N. (1978). Genetic circularity of the *Puoteus mirabilis*
17. Demel,T.(1996).Some biological characteristics that foster the invasion of *Prosopsis juliflora*
18. Beentje H, J.(1994). *Kenya trees, shrubs and lianas*. National Museums of Kenya.
19. Rizk.,A.M. and El-Ghazaly,G. (1995). Medicinal and poisonous plants of Qatar
20. Dale,I.R.and Greenway,P.S. (1995). Trees and Shrubs of Kenya
21. Pohjonen, J. (1986).Sustainable forestry challenges for developing countries.
22. Condit,R.,Hubbell,S.,Lantrenkie,J.V.,Sukumar,R.,Manokeran,N.,Foster,R.B.and Ashton,P.S.(1996).Special area and species individual relationship for tropical trees;Journal of ecology 1996,84,549-562.
23. Gerhardt,K and Hytteborn (1992).Natural dynamics and regeneration methods in tropical dry forests.
24. Richards, P.W. (1981). The Tropical Rainforest. An Ecological study.Royal meteorological society, Cambridge University Press:1952 Pp.xiii, 450. doi 10.1002/qs.4970793425.
25. Hannachi, H., Elfalleh, W., Ennaseh, I.,Laajei, M.,Khouja, M.L.,Ferchichi, A. and Nasri, N.(2011).Chemicals profiling and antioxidants activities of Acacia seeds. J*ournal of medicinal plant research* 5(31):6869-6875.
26. Food and Agriculture Organization. (2018) *Forest Genetic Resources.Food and Agriculture Organization of the United Nations* No. 27: 27-33., Rome, Italy.
27. Kenya Forest Service, (2018). *A guide to South Nandi Forest*. Retrieved from https;//softkenya.com/Kenya/south-nandi-forest/ on 28 February, 2017.
28. Hitimana, J., Kiyiapi J.C. and Njunge J.J.(2004).Forest structure characteristics in disturbed and undisturbed sites of Mt Elgon moist lower montane Forest,Western Kenya. *Forest Ecology Management*, 194,269-708.
29. Kiernan, D. (2014).*Natural Resources biometrics*. State University of New York at Genesco: Open SUNY Textbooks, Milne (IITGP).
30. Rono,D.K.,Sirmah,P.k.&Hitimana,J.(2018).Variation in Regeneration density and population structure of *P.africana* across human disturbance gradient in South West Mau forest,kenya.Journal of Natural Ressource Ecology and management;3(1):1-8 doi:10.11648/j.ijnrem.20180501.11
31. Jansen, D.H. (1983). Regeneration by fragmentation in Tropical montane forest shrubs. America journal of Botany Vol 77. No 12.pp 1626-1633. Retrieved from https://www.jstor.org/stale/2444494, on 30 July, 2018.
32. Franklin,J.E., Shugart,H.H. and Harmon, H.E. (1997).Tree death as an ecological process:the causes,consequences and variability of tree mortality.Bioscience 37,550-556.
33. Cunningham, A.B., Ayuk, E., Franzel, S., Duguma, B. and Asanga, C. (2002). *An economic evaluation of medicinal tree cultivation*: *Prunus africana in Cameroon*. People and Plants Working Paper 10. Paris: UNESCO.
34. Nguta, E.M., 'Distribution and Population Structures of *Prunus Africana* in Mount Kenya Forest',Thesis,February 2012
35. Stewart, K.M. (2010). The Commercial Bark Harvest of the African Cherry (Prunus africana) on Mount Oku, Cameroon*: Effects on Traditional Uses and Population Dymanics*. Ph.D. Dissertation. Florida International University.
36. Stewart,K.M.,(2003).The African cherry:can lessons be learned fron an over exploited medicinal tree? Journal of Ethnopharmacology 89,3-13

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)

Variable 1- The four sites(Chebilat, Kobujoi, Chepkongony, and Kamarich).

Variable 2-Development stages (Seedlings,Saplings,Poles ,and Mature trees)
Variable 3-Dependent variable (densities of development stages in the four sites)
Variable 1*Variable 2-The interaction of sites and the development stages

The Adjusted R squared value shows the correlation between the independent variables and the depedent variable.For the two species there is a strong relation for *P.africana* (99.6%) while for *Olea europaea* (99.9%)