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

ABSTRACT

Prunus Africana (African cherry) and *Olea eurpaea* (Olive) tree species from the moist highlands of sub Saharan Africa are subject 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 analyze 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 x 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 x 1m bands within the sample plots. Two and one- way analysis of variance ANOVA was 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 characterizes stable populations that naturally replace themselves through regeneration. However in comparison with United Nation Organization 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. There is need 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; **H**horizontal structure; **R**recruitment; r**R**egeneration; **T**tree density; t**T**ropical forest; *Prunus africana, Olea europaea*

1.0 Introduction

Prunus africana (Hook.f.) Kalkam and *Olea europaea* L.trees are endangered due to their medicinal values, and fine wood (IUCN, 2013) and so far *P.africana* is included in Appendix ll by Convention on International Trade in Endangered Species of Wild Fauna and Flora (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, 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 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 (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/ (prostate) hyperplasia, not including other uses 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 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 at cultivation are underway in Kenya (Dawson**, Jackson, House, Prentice and Mace***et al.*, 2000). Prior to the discovery in 1966 of its use as a**n** 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 (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 *et al.*, **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 *et al.*, **Seraglia and Pifferi,** 1986). The tree occurs at altitudes between 1000 and 2500 m in montane forests (Sunderland and Tako, 1999). 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 in the family of *Oleacea,* and native to Mediterranean, Asia and Africa. Olivewood is very hard and is prized for its durability, color, 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 (Tesfaye, 2000).

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 (Legesse, 1993 and Friis, 1992). *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 (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 burned to produce a distinctive smoke used for fermenting and flavouring of traditional beverages "Tela" and “Irgo” yoghurt (Legesse, 1995). Olea also has 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 (Demel, 1996). In Kenya, the root or the bark is used as a remedy for malaria (Beentje, 1994). Detailed medicinal values of Olea are presented by Rizk and Gamal, (1995). The diverse use of the species has led to its extensive harvesting in Ethiopia and other East African countries (Dale and Greenway, 1961,; Jones, 1991,; Legesse 1995).

The regeneration of most of the dominant high forest species in the Afromontane zone is under the shade of mature forests (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 in tropical dry forests (Gerhardt & Hytteborn, 1992).

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

A number of benefits have been attributed to *P. africana* and *O. europaea.* These benefits has 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 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 the South Nandi forest.

2.0 Materials and Methods

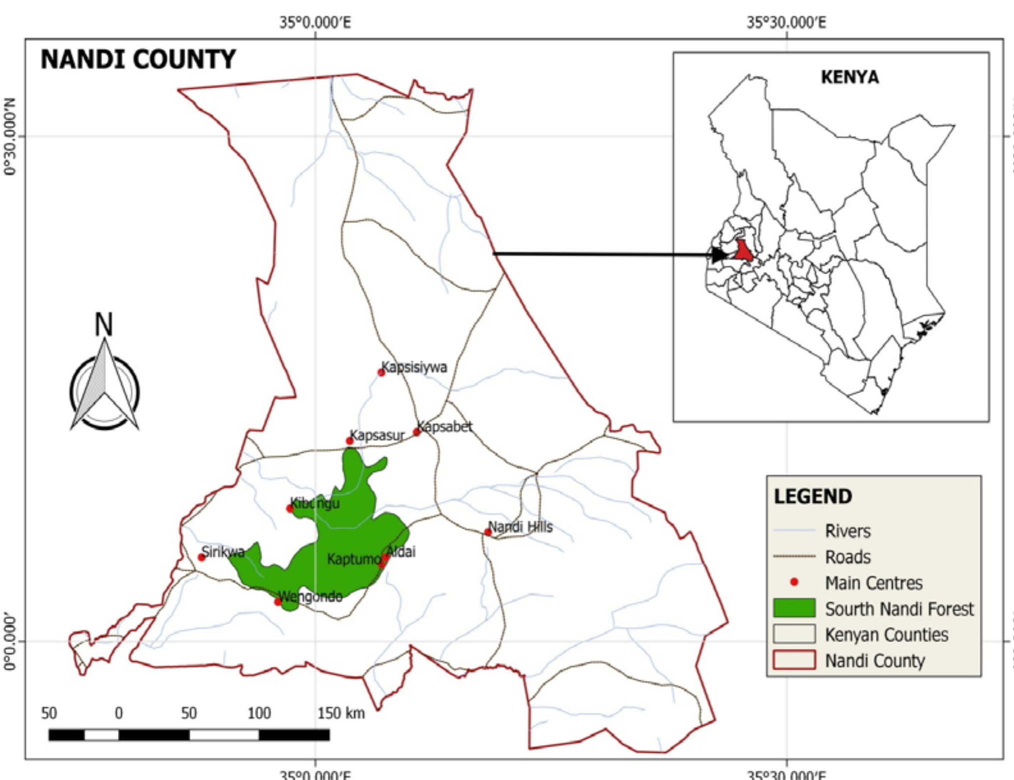
2.1 Study Area

The South Nandi Forest (Figure 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 kilometers apart at their closest points. Biogeographically, the forest is often considered 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. 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 (FAO). 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^{0}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 include highlands bird community thus recognized as an important Bird area, others are reptiles and butterflies (Kenya Forest Service, 2018).

The communities 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, hence there is a lot of pressure on the forest resources.



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, and running parallel to each other in the north east direction, were used to lay 20 systematic sample plots of 50 m x 20 m each, along a transect at an interval of 200 m.The sample plots were further divided into five sub sample units of 20 m x 10 m, where the number of trees DBH ≥ 10 cm, poles (5 cm ≤ DBH < 10 cm), saplings (1 cm ≤ DBH < 5 cm) were assessed while the number of seedlings (DBH < 1 cm) were assessed in 50 m x1 m bands within the sample plots as described by Hitimana et al., **,Kiyiapi, and Njunge,** (2004).

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

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. 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 (Kiernan, 2014), and then results compared to the hypothetical United Nations Organization 1994 model for structurally stable East African natural forests.

3.0 Results

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

This section contain 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).

Table 1. Mean density per hectare [ha^{-1}]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	< 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 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 >10 cm varied from 34 stems/ha^{-1} for *O.europaea* to 51stems/ha^{-1} for *P.africana.*

Along the transects 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 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 Kobujoi Chepkongony Kamarich	36 43 29 28	80 86 74 96	96 104 109 107	601 580 570 569

Two- way **analysis of variance** ANOVA (Appendixces A **&**and B) established that there was a significant differences 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 shows 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 are presented in Figures 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 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 (Rono *et al.*, **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 Figures 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 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 (**N**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)

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 illegal harvesting and disturbances 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 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 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 (Kiama and Kiyiapi, 2001; Nguta, 2012). 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 is may to do in the forests of Mount Oku, Cameroon (Stewart, 2010).

Conservation *of P.africana* and *O.europaea* offers a formidable challenge, since the species appear 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 harvesting (Cunningham and Mbenkum, 1983; Sunderland and Tako, 1999).

To help 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 (Stewart, 2003).

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 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 regeneration patterns analyzed indicates that there is fluctuating forest regeneration as a result of natural phenomena in addition to human-induced processes. However, detailed analysis revealed that each species is unique, and requires 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 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 Africa 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 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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Appendix A;Tests of Between-Subjects Effects for *P.africana*

Dependent Variable:VAR00003

Source	Type III Sum of Squares	df	Mean Square	F

Corrected Model	7.507E6[a]	15	500494.933	1.102E3	
Intercept	5345344.000	1	5345344.000	1.177E4	

VAR00001	1044454.000	3	34818.000	76.635
VAR00002	7253472.000	3	2417824.000	5.322E3

VAR00001 * VAR00002	149498.000	9	16610.889	36.561
Error	21808.000	48	454.333	

Total	1.287E7	64		
Corrected Total	75292232.000	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%)