INFLUENCE OF VARIATION IN BIOPHYSICAL FACTORS ON TREE SPECIES STRUCTURE AND COMPOSITION IN KAPSERET FOREST, UASIN GISHU COUNTY, KENYA

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ABSTRACT
Forests are important for survival and development of human and other fauna. However, they are under degradation due to changes in biophysical factors which affects tree species structure and composition. Understanding these variations and their influence on tree species structure and composition guides conservation of forest. This study aimed at assessing the influence of variation in biophysical factors on tree species structure and composition. Ecological survey was used whereby, tree species and soil samples were studied from 12 sample plots identified through stratified sampling techniques within Kapseret forest. Tree species were enumerated and recorded by species name and Diameter at Breast Height (DBH), those with ≥3m height and DBH > 9.5 cm were classified as trees, while those with ≤3m height and less than DBH ≤ 9.5cm were recorded as saplings. Tree species attributes assessed included: tree DBH and diversity, while biophysical variables measured were: soil organic carbon (SOC), soil texture, phosphorous and potassium. A total of 148 tree species were identified with 62.16% being saplings while 35.14% were mature trees. The CCA results indicated positive correlation between tree species diversity with variation in biophysical factors, the presence of gaps with high P levels were associated with majority of the saplings, however, the DBH class distribution did not indicate an inverse J-shape portraying high degradation. The tree species-biophysical factors should therefore be utilized with other environmental factors such as topography,light intensity,temperature and wind when planning and choosing species for rehabilitation and restoration of degraded landscapes.
Keywords: Species diversity, Diameter at breast height, Edge effect

INTRODUCTION

Forests are of immense importance to the survival and development from human beings and other fauna. Their contribution ranges from air purification, control of hydrological cycle, to provision of ecosystem goods and habitat for a great diversity of fauna, (Chaos, 2012). In developing countries, especially Sub-Saharan Africa forests play a significant role in supporting the livelihoods of communities living adjacent to them. In addition, over one million households living within a radius of five kilometers from the forests depend on forest land for cultivation, grazing, food, fuel wood, wild honey, herbal medicine, construction materials, water and other benefits (Kenya Forest Service, 2012).

Despite their importance, forests are under tremendous pressure of human population that leads to variation in biophysical factors such as soil conditions which potentially influence the composition of these forests in terms of tree species diversity. Understanding these factors that control species distributions is one major focus of ecological studies worldwide and particularly throughout the tropics. For instance, the distribution of species following biophysical factors has been documented in various parts of the tropical world (John *et al.* 2007; Peh *et al.* 2011). The way in which biophysical factors influences species distribution and particularly the importance of soil nutrients on tree species composition is still very debatable (Jactel *et al.,* 2017; Jactel *et al.,* 2018; Adamu *et al.,* 2021).

The relationship between biophysical factors,tree species composition and distribution is much more complex, whereby the soil component provides the physical anchorage and nutrients to the trees which facilitate their growth. In turn, trees contribute to the pool of soil nutrients through nutrient recycling. Several studies on soil-tree species influence have shown varied results, whereby geographical distribution of tree species have been linked with climatic conditions on both local and global scales. For instance, Yu *et al.,* (2018) indicated a correlation between tree species and soil moisture along different topographic positions.Specific studies on the relationship between soil nutrients, tree species composition and distribution include those by Both *et al.,* (2019) who reported a relationship between tree species abundance and soil nutrients in their study. Further, Wekesa *et al.,* (2019) conducted a study in Taita Hills forest on effects of disturbance as an environmental variable revealed an alteration in tree species and composition. This lead to fragmentation and loss of forest altering different ecological processes, spatial patterns of vegetation cover and influence individual tree species growth. Assessing the influence of variation in biophysical factors on tree species structure and composition is important because it will highlights the possible soil limiting factors that affects tree species DBH and diversity. Such knowledge and understanding of the ecological relationship between biophysical factors and tree species is a tool that can provide adequate ecological data for effective conservation and rehabilitation strategies for fragmented forests such as Kapseret forest and other native forests with similar ecological conditions.

METHODOLOGY

Study Area

The Kapseret forest is Class V- vegetation forest located in Kapseret Sub-county, Uasin Gishu County, Kenya. It covers an area of 10.08 km^2 lies on latitude 00^o 28'00'' North and longitude $35^0$11'00'' East. The forest is gazetted and covers an area of approximately 1,349.50 ha. It is located at an altitude of 1997 metres above sea level (a.s.l) with reliable rainfall averaging between 900mm and 1200 mm *(*Kenya Forest Service, 2012). The forest consist of plantation (968.0 ha) and natural forest (381.5 ha).The top layer of soil is mainly red loam soils and underlying is a layer of murram. However, the main soil types are red loam, red clay brown clay and brown loam soils.

Research Design

An Ecological Survey using transects and quadrats was used to assess tree species and corresponding soil properties, because the study area included areas within the forest edge-interior gradient.

Data Collection

To characterize tree species DBH and diversity, stratified random sampling as modified from Zisadza-Gandiwa *et al.,* (2013) was used in this study with 4 transects each 100 m at an interval of 100 m between the transects from the edge up to 500 m to the forest interior. Along each transect 20 m by 20 m sampling plots were established at an equidistance interval of 100 m in order to produce 3 sample plots per transect and a total of 12 sample plots for the whole study area.

In each plot all tree species were enumerated and recorded by species name, basal area size and DBH. All individual trees that were 3 metres and above from the ground and DBH >9.5 cm were classified as trees, while individuals with less than 3m height and less than 9.5 cm DBH were recorded as saplings (Wit-Kowski and O'Connor, 1996), identification of botanical name of every tree species was done in the field by direct observation with the help of a forester.

Data on biophysical factors

The soil samples were collected to a depth of 0-100 cm at an interval of 30 cm vertically using a soil auger from the sample plot. The soil samples were air dried at room temperature and pooled to form one composite sample, where subsamples of 12 samples were obtained. The soil samples were then sieved through a 2-mm mesh to remove rocks and other organic materials such as decaying trees. The soil samples were then packed and sealed in 500g khaki bags, labeled and transported for laboratory analysis of soil biophysical properties (textural classification, soil organic carbon, phosphorous and potassium).

Data Analysis

Tree species diversity

Species diversity is the combination of species richness and species evenness. Species richness is the number of species per sampling unit. Species evenness is the distribution of individuals among the species. Shannon's Index is a measure of the amount of information needed to describe every member of the community. Species diversity was calculated by using the following formula:

$H = -\Sigma (Pi \ln Pi)\ i$

Where: H=Shannon Weiner diversity index. Pi=Fraction of entire population made up of species i

Soil Analysis

To analyze soil samples particle size distribution was estimated by measuring the number of different sizes of soil particles at different calibrated depths in a cylinder containing suspended soil samples using the Bouyoucos hydrometer method. Total organic carbon content was obtained using loss of weight on ignition method, available P obtained using Olsen's method because the soil samples were neutral or alkali (Olsen *et al*., 1954). Wet Digestion and the Atomic Absorption Spectroscopy method was used to determine the exchangeable potassium content.

Species-Biophysical factors Relationship

To investigate the differences in soil properties between transects, one-way Analysis of Variance was used. The relationship between tree species variation and biophysical variables was determined using the Canonical Correspondence Analysis, permutation tests with 1000 permutations at 0.05 significance level were run to reveal the influence of the obtained biophysical factors on tree species structure and composition (Hejcmanova-Nezerková and Hejcma, 2006). The Spearman correlation was used to examine the relationship between tree species and individual soil properties.

RESULTS AND DISCUSSION

Variability in Biophysical Factors across the Forest

To test for the variability in biophysical factors within plots, analysis of variance (ANOVA) was carried out. The mean concentrations were obtained and compared within transects. The analysis of soil organic carbon revealed that transect 3 had the highest amount of soil organic carbon at 2.91%, followed by transect 2 at 2.16% then transect 1 at 1.40% while transect 4 had the least amount of soil organic carbon with 0.74%. The mean amount of soil organic carbon across transects was 1.8017% as shown in Figure 1.

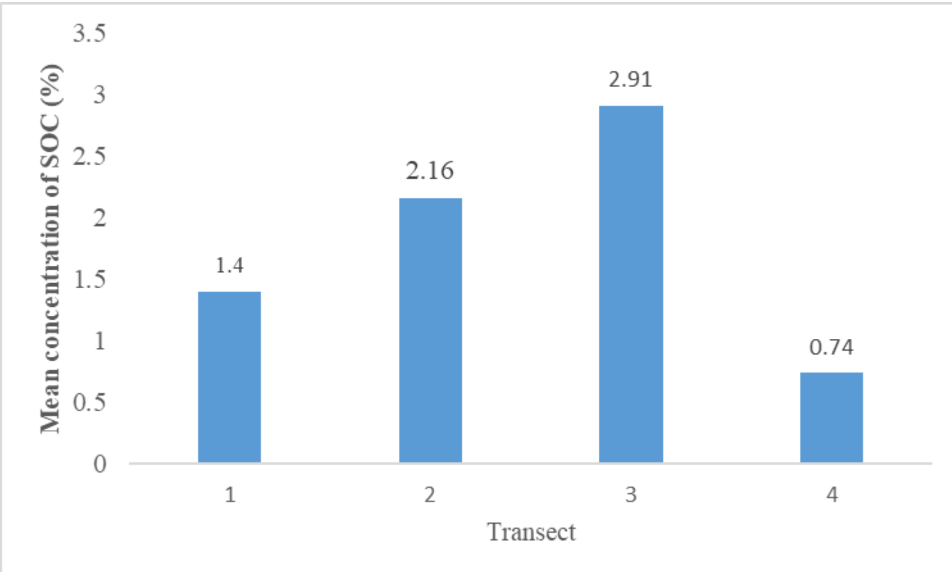

Figure 1: Mean concentration Soil Organic Carbon between transects

The results obtained revealed variation in the amount of soil organic carbon, this difference in SOC means across the transects was linked with grazing of herbivorous, who through grazing drop their dung in the forest, also the leaf fall which root and decay adds to the soil organic carbon. However, the lowest mean in transect 4 was attributed with encroachment due to deforestation. This finding agrees with Kibet *et al.*, (2021) who documented that encroachment is associated with decline in grasses and other palatable resources for livestock leading to decrease in soil carbon and decline in biodiversity. The findings also indicated that soil organic carbon was highest in transects 2 and 3, this could be less anthropogenic activities such as deforestation, it showed that soil organic carbon could decrease towards the forest interior, these findings are consistent with that of Njeru (2016) in his study on soil carbon variability in agro-ecosystems along an altitudinal gradient in Taita Hills of Kenya. The findings also revealed that cultivation of forest land causes soil organic carbon loss as indicated in transect 4, this conforms with Arunrat *et al.*, (2020) who reported that cultivation reduced soil organic carbon through high decomposition and minimum protection of soil organic carbon stocks.

Analysis of available phosphorous indicated that transects 1 and 4 had the highest mean concentrations at 2.41 ppm and 1.81 ppm respectively, transect 3 had an amount of 0.55 ppm, while transect 2 had the lowest mean amount of 0.51 ppm. The mean amount of phosphorous across the forest transects was 1.3208 ppm as shown in figure 2. The findings indicated that the mean amounts of available phosphorous was highest in transects 1 and 4, this is attributed to the addition of fertilizers by farmers who carry out cultivation in forest land through CFA. However, high amounts in transect 4 is due to illegal charcoal burning in the forest interior where ashes dissolves and leach into the soil adding to amounts of available phosphorous. These findings were consistent with Henriquez (2002) who reported that addition of organic and inorganic fertilizers modifies biophysical factors such as phosphorous cycle by increasing the available phosphorous in time and intensity.

The analysis for potassium across transects indicated that transect 1 had the highest amount of potassium at 610.67 ppm, followed by transect 2 and 4 both at 440.33 ppm, while transect 3 had the least amount with a mean of 368.67 ppm. The mean amount for exchangeable potassium across transects was 465.00 ppm as indicated in Figure 3.

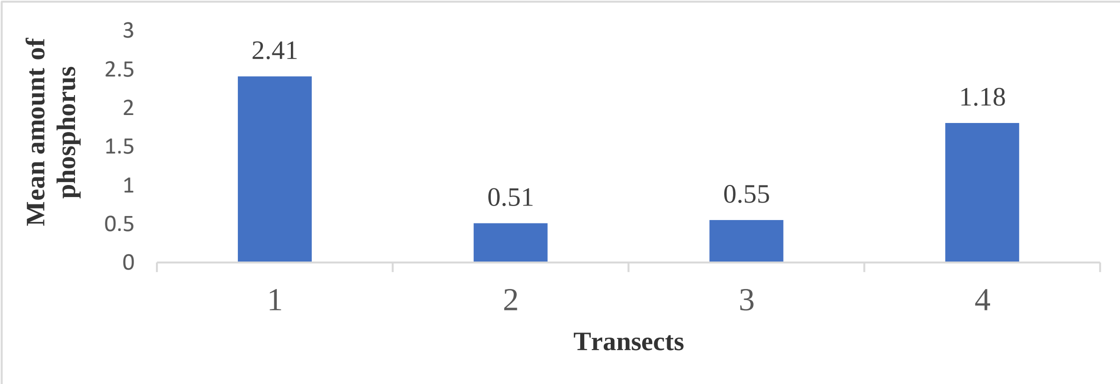

Figure 2 :Mean amount of phosphorus between transects

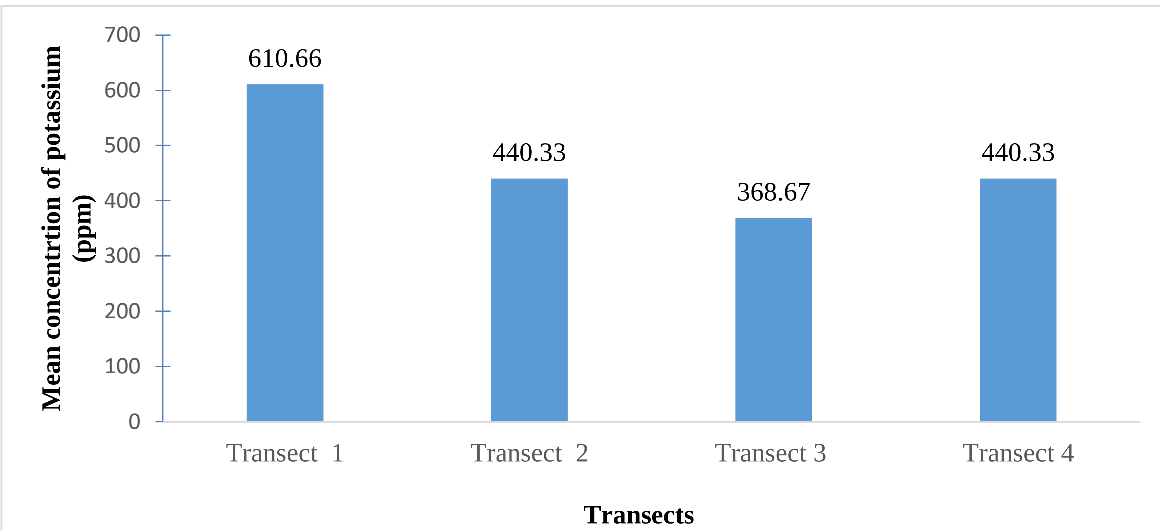

Figure 3: Mean concentration of potassium between transects

Variability in K was due to excessive application of fertilizer in the farmland and cultivated forest land, where through surface runoff and leaching findings its way in the forest and thus influencing tree species growth. The findings indicted that there were no significant differences in the soil parameters. However, there was significant difference in the mean of exchangeable potassium (F=7.041, P=0.012) within the sample plots. This implies that the selected soil parameters did not exclusively explain the difference in soil nutrients at 95% confidence level. Further, the results indicated that there was no significant difference in the mean of soil properties across all transects as indicated in table 2. Transects 2 and 3 presented the highest values for soil organic carbon.

Biophysical Factors and Tree Species DBH

To determine the influence of biophysical factors of tree species structure, stand structure was studied based on the distribution of tree species diameter class distribution. Tree diameter class distribution across the forest edge-interior gradient reveals that majority of the tree species were in the range of ≤ 9.5 cm in all the four transects, trees in the range of 9.5-19.5 cm was least represented in transects 1,2 and 3. However, trees in the range of more than 49.5 cm were highly represented in transect 3 but least in transect 4, while in transect 1 DBH class of more than 49.5 cm was not represented (Figure 4). These data reveal that the forest is highly degraded such that majority of the trees are young and in growing stage.

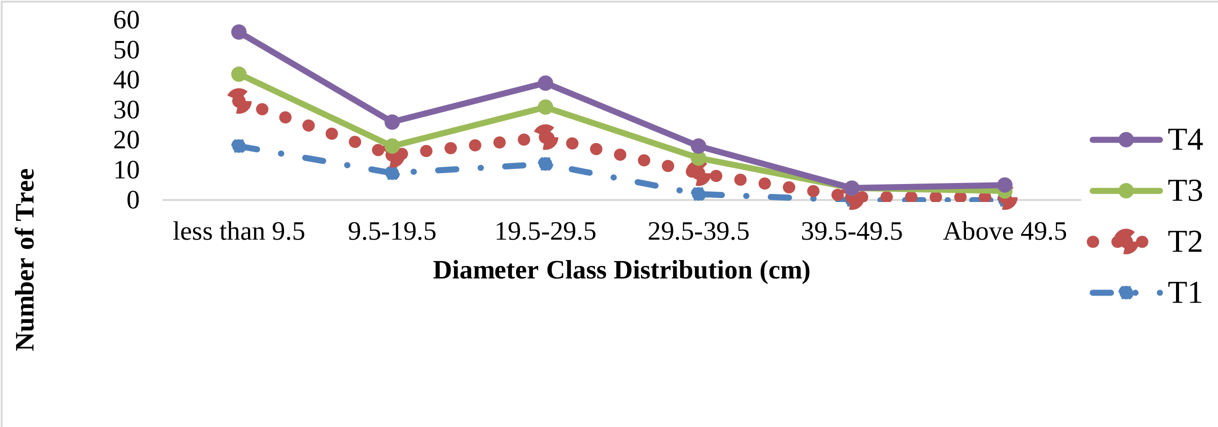

Figure 4: DBH class distribution between transects

The findings revealed that there were many saplings and medium trees of class 19.5-29.5 cm in all transects, however highest in transect four compared to others as indicated by the inverse J-sharp curve in figure 6. This implies that the anthropogenic such as grazing of livestock feed on saplings inhibiting the regeneration of degraded spots which could be naturally reestablished. This was due to availability of gaps in the forest which allowed for succession by pioneer species dominated by *Markhamia lutea* as observed.

This was due to rapidly recovering in terms of numbers of small sized trees though most of them belong to one species. This may indicate a rapid recovery in forest cover but does not replace the forest composition (Yirdaw *et al.*, 2019). However, such ideal conditions are unavailable in less degraded where closed forest affected the regeneration of species.

To ascertain regeneration potentials of the forest, DBH class distribution for all transects, the findings indicated that majority of the trees were in the range of 19.5-29.5 cm, followed by those in the range of 9.5-19.5 cm, 29.5-39.5 cm, 39.5-49.5 and over 49.4cm respectively. These findings reveal that the forest is highly degraded such that majority of the trees are young and in growing stage because of succession. The reverse J- curve was plotted for the four transect so as to check on generative potentials of the forest, the findings were as shown in figure 5.

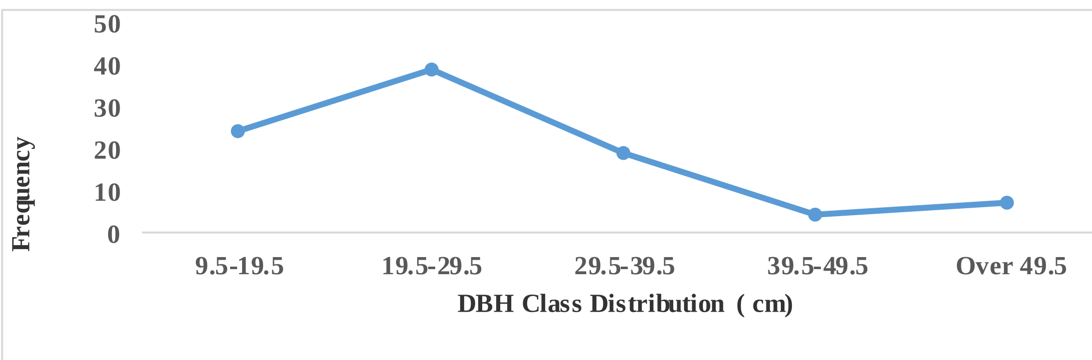

Figure 5: Diameter at breast height class distribution for all transects

The low representation of big trees could be due to illegal logging for construction poles by the local communities surrounding the forest, these finding agreed with Hayward *et al.*, (2021) who recorded that the prevalence of large trees suggested the effects of intensive and selective tree logging which often target specifically big trees, inducing the loss of tree of big size, tree species 39.5-49.5 cm were least represented having 4 species this is because majority of these were keystone species which are always least represented in any of the forest ecosystems. Moreover, under natural conditions an old big emergent tree may fall down without coppicing creating gaps.

The DBH class distribution clearly did not assumed a reverse J- shaped curve as indicated by Lisao *et al.*, (2018), reveals that the forest is severely degraded and there is no sustainable regeneration. These findings were also consistent with those of Volis and Deng (2020) who reported that some tree species may not show inverse J-shaped curve DBH distribution pattern due to differences in growth rate among size classes. However, the domination of species at equal to or less than 30 cm majorly the saplings was an indicator of good species regeneration and self-maintenance of the forest.

Across transects, the saplings majorly for *Markhamia lutea*, *Prunus africana* and *Albizia saman* posed the highest frequencies among the entire tree saplings. These species could be having good regeneration potentials and dispersion capabilities. Jew *et al.,* (2016) reported that disturbed forest with in J- shaped curves has good regenerative and recruitment potentials. Despite the regenerative potentials these species were least represented in mature tree stratum this is due to illegal logging. This finding is consistent with Asinwa *et al.,* (2018) who documented that felling of mature tree for timber, clearing for crop production coupled with farmers' encroachment most likely to influence species quantity and quality in many forest ecosystems, this could be due to changes in biophysical factors within the forest which cannot support its growth and development.

In general, it was observed that there were more saplings in the very transect four compared to the other transects as indicated by the sharp curve that collapsed to near zero in the big tree diameter-class distribution. According to Sahle *et al.,* (2018) this was due to availability of space as a result of spot degradation into which the pioneer species establish such as *Markhamia lutea*. However, such site conditions were unavailable in other transects where the closed canopy controlled the number of saplings resulting to a gentle curve as observed in the forest interior.

Biophysical Factors and Tree Species Diversity

The tree species in the forest showed much variation in terms of species diversity. These heterogeneity in tree species could be related to the fact that different tree species have different adapting mechanisms to changes in biophysical factors and anthropogenic activities within their environment. Tree species population in table 1 indicates that the highest number of individual tree species were along belt 1 (40 individuals) while the least was in transect 3 (33 individuals). Shannon Weiner diversity was highest in belt 2 (1.6238) but least in belt 4 (1.3440) as shown in table 1.

Table 1:Shannon Weiner Diversity indices

	Transect 1	Transect 2	Transect 3	Transect 4
Individuals	40	39	33	36
Shannon index	1.5190	1.6238	1.5624	1.344

The tree species survey showed a total of 148 tree species, with 52 mature tree species and 92 saplings. The tree species diversity varied among transects. There was low species diversity index in belt 4 (1.3440), this could be due to variation in biophysical factors which are unfavorable for some tree species, since the variation in microclimate from the forest edge to the interior can to larger extend influence tree species structure and composition within the forest (Ghimire *et al*., 2008).

However, higher tree species diversity in belt 2 (1.6238) could be because of the moderate disturbance from anthropogenic activities, for instance from construction of forest roads and other external disturbance such as increased transpiration. This was in accordance to intermediate disturbance hypothesis, which states that a moderately disturbed area is much more diverse in species than highly disturbed and least disturbed areas (Dai *et al*., 2020).

The diversity index was found to be lowest in transect 4 (1.344), this is due to low soil nutrients which is linked with anthropogenic disturbance, such as unsustainable crop production through shamba system and illegal logging in the forest interior which can deplete soil nutrients and influence tree species structure, composition and distribution.

These findings were consistent McEwan *et al*., (2020) who conducted a similar study and recorded a major decline in diversity status due to timber harvesting, agriculture and other developmental activities which takes place in forests. Despite the varied species diversity indices, the composition of tree species in the study area indicated a mixture of indigenous and exotic species. While most indigenous species were remnants of natural forests, the exotic species especially *Gravellia robusta* were mainly due to dispersal from the exotic plantation.

To test the influence of biophysical factors on tree species diversity, correlation techniques were used to examine these influences. The correlation between tree species diversity and biophysical factors were used to assess the nature of influence and to identify key environmental variables that influence tree species. Canonical Correspondence Analysis was thus performed in this study to relate the tree species diversity to biophysical factors.

Table 2: CCA descriptive statistics

Variable	Observations	Minimum	Maximum	Mean	Std deviation
Species diversity	12	0.836	2.199	1.512	0.351
OC %	12	0.660	4.050	1.802	1.136
Av P mg/Kg	12	0.420	5.980	1.321	1.757
Ex K Ppm	12	281.000	710.000	465.00	109.205
Sand %	12	60.000	88.000	74.167	8.963
Clay %	12	3.000	29.000	14.667	7.808
Silt %	12	5.000	17.000	11.167	2.623

Using 1000 permutations, the pseudo-F statistics was found to be 0.027 with its associated probability of 0.929 indicated that, there is no statistically significant linear influence of biophysical factors on tree species, thus this variation in tree species diversity across the transects indicates that it is linked with environment variables coupled with anthropogenic activities.

According to a study conducted by Wekesa *et al.*, (2019) the findings showed that soil variables do not affect diversity and spatial distribution of plant communities, they recommended that other factors such as anthropogenic activities and geodynamics do affect its diversity. However, in determining the sensitivity of tree species to biophysical factors, triplot was considered.

The research findings indicated the occurrence of tree species diversity especially *Markhamia lutea,* in this forest were strongly associated with soil texture with high clay composition and low silt composition, this is due to impacts of clay content on the soil aeration condition and exchangeable nutrients. With their ascertained nutrient availability and higher water-holding capacity, clay soils were considered as more favorable to species occurrences, given their possibility for niche diversification. This correlation shows that some tree species have preference for silty substrate and this could be due to high water retention (Hussain *et al.,* 2020). However, Mengel *et al*., (2010) noted unexpected negative relationship between several tree species and clay content, since higher values of clay content could indicate an improved amounts of soil nutrient which promotes regeneration of tree species.

The significant correlation between tree species diversity and available phosphorus was not disputable since, phosphorus plays a crucial role in photosynthetic process through chlorophyl formation and rooting system (Verma and Verma, 2007), this allows the plant to access nutrients which are easily leached.in this study, tree species diversity was found to positively correlate with soil organic carbon, potassium and phosphorus especially *Markhamia lutea* was most abundant in all the transects.

These findings were in agreement with a study conducted in southern Nigeria by Iwara *et al., (*2011) who found that phosphorus and silt influenced the distribution of tree species in. Moreover, in northern Iran, Adel *et al.,* (2017) found that phosphorus, organic carbon, potassium and calcium were the most important biophysical factors that influenced the growth and distribution of tree species communities.

Chemicals play a crucial role in determining plant community composition and distribution, but they vary due to environmental differences between sites. In the Tana River system, Ca, Mg, K and significantly influenced the distribution of tree species inside and outside the floodplain, moreover the influence of moisture, P, N and C outside, and pH inside the floodplains were also reported to be significant.

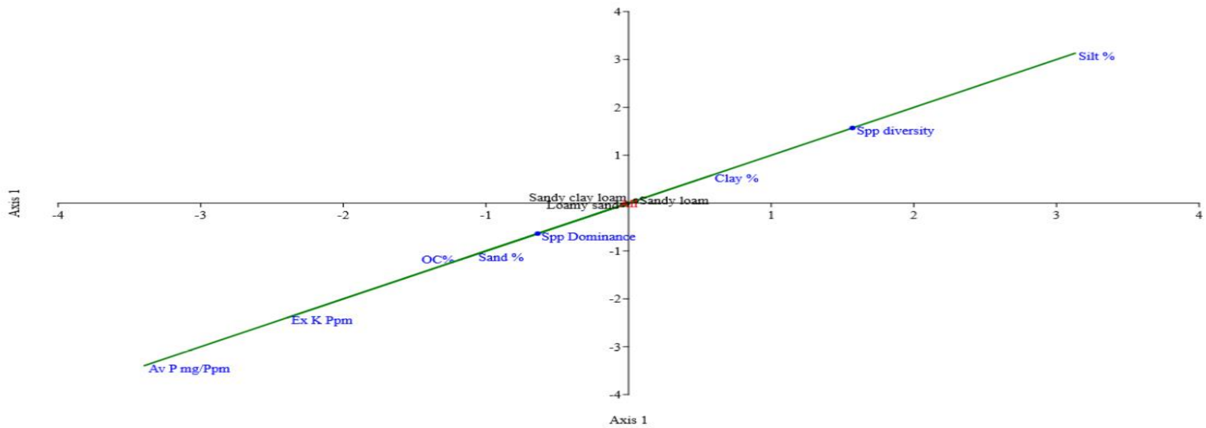

Figure 2: Triplot of frequencies and response of tree species diversity to biophysical factors

CONCLUSION

There was correlation between tree species structure and composition and variability in biophysical factors across the forest edge-interior gradient. However, various lines of evidence show weak correlation between tree species structure and composition with biophysical factors. The structure and distribution of tree species was closely associated with changes in biophysical factors across the forest edge-interior gradient, where soil parameters were most factors for tree species structure and composition.

Significant differences between forest edge and interior were observed in terms of tree species DBH and diversity, it is certain therefore that, variation in biophysical factors influence this structure and composition. However, anthropogenic disturbance was found to might have accounted for the change in tree species structure and composition. Low species of large trees were within the forest and should be conserved for stocking, while high frequencies of endemic species especially *Markhamia lutea* was associated with transect 4 which had high disturbance while their population remains intact. This suggests that these species could be used in restoration and rehabilitation process.

RECOMMENDATIONS

Since the saplings were found to respond most to presence of gaps especially in transect 4, the study suggests that conditions for regeneration should be taken into account for instance preparing gaps for restoration. The high frequency of some species especially *Markhamia lutea*, *Albizia saman* and *Croton* species indicates their good adaptive and regenerative potentials. These species should be used for rehabilitation and restoration programmes.

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