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RESEARCH ARTICLE

INFLUENCE OF CANOPY TYPES ON NUTRIENT AVAILABILITY IN SOIL AND LITTER POOLS OF A FOREST ECOSYSTEM

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ABSTRACT

Influence of forest canopy types on nutrient availability in litter and soil pools of a forest ecosystem was studied. Four plots each were chosen randomly for open and close forest canopies. In each plot, 4 belt transects were laid, and in each transect, vegetation was sampled. Four litter traps were set in each plot, to collect litter samples in open and close canopies. In each plot, three soil samples (at 0-15 and 15-30 cm) were obtained in the open and close canopies with a soil auger and conveyed to the laboratory for analyses. The open and close canopy plots had 10 and 15 tree species. The close canopy had higher values for sand (91.19±0.01%), and silt (6.56± 0.01%) while the open canopy had high values for clay (3.13±0.01%). The pH of soil was very strongly acidic in the open (4.93±0.02) and close (4.56±0.58) canopies. Higher values for electrical conductivity (0.08±0.005 ds/m), total nitrogen (0.08±0.003 %), organic carbon (3.13±0.001 %), available phosphorus (13.06±0.01mg/kg), Ca (12.04±0.02 cmol/kg), Mg (6.62±0.58 cmol/kg), EA (2.25±0.01 cmol/kg) and ECEC (21.27±1.15 cmol/kg) were recorded in soil of the close canopy while higher values for Na (0.11±0.01 cmol/kg), K (0.13±0.02 cmol/kg) and base saturation (90.83±0.01%) were recorded in soil of the open canopy. For the litter, organic carbon (45.25±7.31%), total nitrogen (1.14±0.06%), Ca (18.33±1.45mg/kg), Mg (8.91±1.16mg/kg), K (284.89±12.25mg/kg), Na (75.71±8.32mg/kg) and P (2.60±0.41mg/kg) were higher in the close forest canopy. This study has implications in deforestation, nutrient availability and cycling as well as forest management and protection.

KEYWORDS

Physiognomy, forest canopy, nutrient cycling, deforestation, species exploitation, clearcut, decomposition

1. INTRODUCTION

According to FAO (2006), a forest consists of a land which spans more than 0.5 hectares, consisting of taller trees (above 5 m) and a canopy coverage greater than ten percent. Forest ecosystems are hotspots of biodiversity (both plants and animals) providing important ecosystem values and services to man such as food, medicine, timber, fiber, clean water, spiritual and aesthetic values as well as climate regulation (Jackson *et al*., 2005; McKinley *et al*., 2011). According to the Secretariat of the Convention on Biological Diversity (2010), over 200 million of the poor population globally, are directly dependent on the forest resources for shelter, energy, and other livelihoods. Despite the copious benefits derived from forests, a lot of them are facing anthropogenic perturbations like selective logging for timber, leading to most primary forests with close canopies transitioning to secondary forests with open canopies. These alterations in forest structure from the closed to open forests alter the composition, balance and cycling of nutrients, thereby affecting the productivity of these forest types.

Nutrient cycling and its dynamics are vital phenomena towards understanding the status and functioning of a forest ecosystem. The cycling of nutrients in forests entails flow of nutrients between the plants and the soil components. This involves uptake, retention and release of nutrients (Gautam and Mandal, 2018). These activities leading to the continuous cycling of nutrients in forests are regulated by certain factors such as moisture availability, temperature and the physical and chemical components of litter (Prescott, 2002). Of all these factors mentioned, the forest canopy is very influential on all them due to the fact that it plays a significant role in the cycling of nutrients (Prescott, 2002).

Forest canopies either open or close, are dynamic borders between the atmosphere and the organisms, providing microhabitats and microclimates that are buffered (Nakamura *et al*., 2017). Open forest canopy otherwise known as woodlands, entails forest ecosystem where the crowns of each tree species do not overlap to produce a layer of canopy that is continuous, but instead are spaced widely with open areas or patches that are sunlit (Marc, 2011). Close forest canopy on the other hand, implies trees with dense growth where the leaves and branches at the top form a canopy or ceiling which hamper light penetration to the floor of the forest (Jernigan, 2017).

The canopies of forests create an ecosystem that is stratified vertically which connects with other strata (Nakamura *et al*., 2017). Forest canopies have effects on the composition and amount of litter produced by plants species which regulates availability of nutrient by controlling the quantity of nutrients required for recycling (Prescott, 2002). Before now, the effects tree species have on nutrient availability in soil were believed to have been caused by the variations in leaf litter decomposition, but studies have shown that these effects are better explained by the quantity and nutrient composition produced by the litter, thus total return of nutrients, than from decay rate of litter (Prescott, 2002). Since the forest canopy is very instrumental in nutrient cycling processes, it is very pertinent to investigate the amount of nutrients that are stored or returned to various nutrient pools under these canopy types.

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Studies have reported that canopy removal during harvesting in forest ecosystems, results in changes regarding nutrient cycling. For instance, Keenan and Kimmins (1993) reported that harvesting through clearcutting in forests, enhances soil nutrient availability as well as high nutrient loss to leaching. Dahlgren and Driscoll (1994) from their studies also stated that clearcutting during harvests in forests favoured the high nitrification and nitrogen mineralization rates in the soil. Some scholars attributed this phenomenon to reduction in uptake of nutrient by plant species, high decomposition rates of organic matter culminating from moist and warmer conditions from the openings, and degeneration of debris from logging (Bormann and Likens, 1979; Emmet et al., 1991). Also, forest openings of about 0.1 ha, 0.25 ha, and 0.07 ha, is associated with high availability of nitrate as well as nitrogen mineralization as reported by Prescott et al. (1992), Bauhus and Barthel (1995) and Prescott et al. (2000). This, they attributed to the fact that, natural forest perturbations or partial harvesting which increases the complexity of canopy by producing gaps, also upsurge the spatial differences in nitrogen availability and cycling in the forest soil. Nonetheless, species composition in forest canopy has also been implicated to be influential on availability of nutrients and the quality of litter due to variations in chemical constituents of litter (Precott, 2002). For instance, high nitrogen content and mineralization was reported under nitrogen fixing plant species like *Albizia* and Alnus (Binkley 1983; Kaye et al., 2000) while high calcium content was reported in forest soil of *Acer saccharum* (Sugar maple) and *Thuja plicata* (Cedar) (Finzi et al., 1998; Prescott et al., 2000). This variation in availability of nutrient in various stands of tree species were linked to divergences in litter or foliar decomposition.

Despite the importance of forest ecosystems to humanity, the availability and cycling of nutrients in forest are still understood poorly especially with regards to forest physiognomy and anthropogenic perturbations. Most studies conducted on forest ecosystems have centered mainly on plant species diversity, regeneration potentials of species, relationship between plant species and soil properties with paucity of information on how the forest canopy types influence or regulate the amount of nutrients present in the soil. Knowledge on the quantity of nutrients in relation to the changes in forest canopies will help to provide insights regarding forest ecosystem functioning, monitoring and management. The lacuna in this regard is what necessitated the study.

2. Materials and Methods

2.1 Study Area

This study was conducted in a forest ecosystem in Ikot Efre Itak in Ikono Local Government Area of Akwa Ibom State, Nigeria. Ikot Efre Itak is located between latitudes 4º 30' and 5º 30'N and longitudes 7 º31' and 8 º20' E. Its area is about 29.57 km^2 hectare. The average yearly rainfall ranges from 2400 mm to 3000 mm. The average minimum and maximum temperatures are 26 ºC and 30.5 ºC, respectively, while the average relative humidity of the area is approximately 83 %. The forest is evergreen having an area of 3.2 ha managed by the Ikot Efre Itak community as a sacred grove. The forest is only accessed through the consent of the village council who gives such permission. The forest has rich diversity of plant species. However, the forest is facing various perturbations arising from human activities such as unregulated tree species exploitation, encroachment by infrastructural development and incessant logging.

2.2 Vegetation Litter Collection and Soil Sampling

Four plots each for open and close canopies were chosen randomly for this study. In each plot, 4 belt transects were laid, and in each transect, vegetation were sampled and parameters such as frequency, stand density, height and canopy cover were determined. In each plot, four litter traps were set at 8m apart in each plot to randomly collect litter samples in the open and close canopies. These were pooled into one composite sample per plot preserved in well labeled ziplock bags and conveyed to the laboratory for nutrient analysis. Three soil samples in the open and close canopies were also collected in each plot where the litter were collected with the aid of a soil auger. The soil samples were obtained at the depths of 0 to15 cm and 15 to 30 cm. The soil samples were bulked into one composite samples per plot, preserved in ziplock bags that were well labeled and conveyed for nutrient and physicochemical analyses in the laboratory.

2.3 Determination of Vegetation Parameters

2.3.1 Tree Stand Density

The density of tree stands was calculated using the outlined procedure of Cochran (1963). Here, all the plants in each chosen plot were counted. The number of each plant species was used as a proportion of the number of transects to give the average of species. The average number of species was used a proportion of the area of quadrat to produce density in m^2 which was multiplied by 10,000 m^2 to produce density per hectare.

2.3.2 Frequency

The frequency of tree species was determined using the formula below

$$\text{Frequency} = \frac{\text{Number of occupied quadrat for a species}}{\text{Total number of quadrats thrown}} \times 100$$

2.3.3 Height

A Haga altimeter was used in measuring the height of tree species. At 15 m from the base of tree species where the coverage was sighted, the first upper reading was taken with the altimeter. The lower reading from the altimeter was taken at the base of the tree species. Height of tree species was determined using the formula below;

$$\text{Height (m)} = \frac{(\text{upper reading} + \text{lower reading}) \times \text{horizontal distance from observer}}{\text{scale factor of the altimeter}}$$

2.3.4 Canopy Cover

The canopy cover of the tree species was calculated using the outlined method of Muller- Dombios and Ellenberg (1974). This entails measuring the projection of the crown diameter of all woody species on the ground. Here, from one end of the ground perimeter to the other, a tape was laid. This produced the first diameter reading. The second reading of the crown diameter was also measured similarly, but this time perpendicular to the first reading. These resulted in two diameter readings. The canopy cover for the woody species was calculated using the formula below;

$$\text{Crown cover (m}^2\text{/ha)} = \left(\frac{d_1 + d_2}{2}\right)^2 \frac{\pi}{4}$$

Where d_1 = first diameter reading, d_2 = second diameter reading and π = 3.142

2.3 Soil Nutrient Analyses

2.3.1 Soil Sample Digestion

Samples were ground, mixed, and divided into fine particles that could pass through a 0.5 mm sieve. Soil samples were digested by adding 2 g of soil to 15 ml of concentrated nitric acid and perchloric acid at a ratio of 1:1, and allowed to stand for 135 minutes until the mixture became colourless. The samples were filtered and washed with 15 ml of deionized water, and made up the filtrate to 100 ml in a standard flask.

2.3.2 Determination of Physicochemical Parameters of Soil

Standardized methods were used in soil analysis. Hydrometer, Walkey Black wet oxidation, Bray No 1 and Micro-Kjeldahl methods were used in determining the particle size classes (sand, silt and clay), organic carbon, available phosphorus and total nitrogen. pH, electrical conductivity and exchangeable acidity were determined using Beckman's glass electrode pH meter (Mcclean, 1961), conductivity meter, and titration with 1N KCL (Kramprath, 1967), respectively. Potassium and sodium were determined using photometry method while Ca and Mg were determined by EDTA titration. Summation method (addition of the exchangeable bases and exchange acidity) was used in calculating the Effective Cation Exchange Capacity (ECEC) while the base saturation was obtained by dividing the total exchangeable bases by ECEC and multiplying with 100.

2.3.3 Nutrients Determination in Litter

Ground litter samples (2 g) were put in a glass tube for digestion. Hydrochloric acid (12 ml) was added to the sample in the glass tube. This mixture was allowed to stay overnight under room temperature. To the mixture, perchloric acid (4 ml) was added and kept for digestion in fume blocks. Gradually, the temperature was raised from 50 ºC to 150 ºC. At between 70 and 85 minutes, white fumes appeared which indicated the completion of the sample digestion process. After allowing the mixture to cool, it was transferred to a volumetric flask (100 ml) and distilled water was added to increase the volume of the mixture to 100 ml. The digested solution was transferred to well labelled plastic bottles and stored appropriately for analysis of minerals.

Nitrogen, organic carbon, and potassium were determined using Kjeldahl, dichromate oxidation/titrating with ferrous ammonium sulphate (Moore and Chapman 1986), and flame photometry methods while calcium,

magnesium, phosphorus and sodium were determined using Atomic absorption Spectrophotometer (AAS).

2.4 Data Analysis

The means together with the standard errors of triplicates were calculated using Graph Pad Prism 6.0. Student T- test analysis was carried out using SPSS (Statistical Package for Social Sciences) (20.0) to compare the mean values obtained for nutrients in soil and litter of the open and close forest canopies.

3. Results

3.1 Floristic Inventory of the Close and Open Canopies

The floristic inventory of the open and close canopy plots is presented in Tables 1 and 2. In the open canopy plots, a total of 10 tree species belonging to 10 distinct families were encountered. *Pentaclethra macrophylla* had the highest frequency (40 %) while *Khaya senegalensis* (10 %), *Cola argentea* (10 %) and *Pycnanthus angolensis* (10 %) had the least frequency. *Pentaclethra macrophylla* had the highest stand density (80.00 ± 7.50 stems/ha) while *Khaya senegalensis* (10.00 ± 3.00 stems/ha) and *Pycnanthus angolensis* (10.00 ± 1.68 stms/ha) had the least stand density. The tallest and shortest tree species were *Piptadeniastrum africanum* (14.20 ± 3.21 m) and *Maesoboytra dusenii* (3.14 ± 0.08 m), respectively. Species with the largest and least canopy cover were *Cola argentea* (5.80 ± 0.08 m^2/ha) and *Pycnanthus angolensis* (1.30 ± 0.02 m^2/ha), respectively. The total tree stand density and canopy cover were 314 stems/ha and 35.36 m^2/ha.

In the close canopy, a total of 15 tree species belonging to 11 distinct families were recorded *Calamus deeratus* had the highest frequency (60 %) while *Alstonia boonei* (10 %), *Cola argentea* (10 %), *Coula edulis* (10 %), *Erythrophleum ivorense* (10 %) and *Guarea cedrata* (10 %). *Afzelia africana* had the highest stand density (190.00 ± 15.30 stems/ha) while *Alstonia boonei* (10.00 ± 1.00 stems/ha), *Cola argentea* (10.00 ± 1.03 stems/ha), *Coula edulis* (10.00 ± 1.00 stems/ha), *Erythrophleum ivorense* (10.00 ± 0.80 stems/ha) and *Guarea cedrata* had the least stand density. The tallest and shortest tree species were *Berlinia confusa* (19.03 ± 3.05 m) and *Anthonatha macrophylla* (2.61 ± 0.30 m). *Khaya ivorensis* had the largest canopy cover (15.52 ± 2.30 m^2/ha) while *Anthonatha macrophylla* had the least canopy cover (1.25± 0.001 m^2/ha). The total stand density and canopy cover were 710 stems/ha and 93.17 m^2/ha.

Table 1: Floristic Inventory of The Open Canopy Plot

Plant species	Family	Habit	Frequency (%)	Stand density (stems/ha)	Height (m)	Canopy cover (m^2/ha)
Calamus deeratus Mann and Wendl	Arecaceae	Tree	20	40.00 ± 16.00	5.37 ± 0.36	4.05±0.03
Cola argentea Mast.	Sterculiaceae	Tree	10	12.00 ± 1.03	6.20 ± 0.19	5.80 ± 0.08
Khaya senegalensis (Desr.) A.Juss.	Meliaceae	Tree	10	10.00 ± 3.00	4.15 ± 0.73	5.28 ± 0.40
Maesoboytra dusenii (Pax) Hutch.	Euphorbiaceae	Tree	20	52.00 ± 7.80	3.14 ± 0.08	1.91 ±0.01
Mansonia altissima (A.Chev.) A.Chev.	Malvaceae	Tree	30	50.00 ± 7.50	10.57 ± 1.80	4.12 ± 0.63
Musanga cecropioides R. Br	Papilionaceae	Tree	30	30.00 ± 3.20	11.69 ± 5.54	2.63 ± 0.41
Pentaclethra macrophylla Benth	Fabaceae	Tree	40	80.00 ± 7.50	9.88 ± 3.50	4.91 ± 0.51
Piptadeniastrum africanum Hook.f	Leguminosae	Tree	10	10.00 ± 1.02	14.20 ± 3.21	2.00 ± 0.03
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	Tree	10	10.00 ± 1.68	8.58 ± 0.05	1.30 ± 0.02
Synsepalum dulcificum (Schum and Thonn.) Daniell	Sapotaceae	Tree	20	20.00 ± 2.01	12.68 ± 4.01	3.36 ± 0.85
Total				**314**		**35.36**

Table 2: Floristic Inventory of The Close Canopy Plot

Plant species	Family	Habit	Frequency (%)	Stand density (stems/ha)	Height (m)	Canopy cover (m^2/ha)
Afzelia africana Sm. ex Pers.	Fabaceae	Tree	40	190.00 ± 15.30	5.62 ± 0.63	4.06 ± 0.42
Alstonia boonei De Wild	Apocynaceae	Tree	10	10.00 ± 1.00	4.57 ± 0.05	4.56 ± 0.09
Anthonatha macrophylla P. Beauv.	Fabaceae	Tree	20	30.00 ± 1.54	2.61 ± 0.30	1.25± 0.001
Bambusa vulgaris Schrad. Ex Wend	Poaceae	Tree	20	90.00 ± 10.82	5.59 ± 0.29	5.20 ± 0.89
Barteria nigritiana Hook. f	Passifloraceae	Tree	20	30.00 ± 2.81	6.97 ±0.29	6.58 ± 0.007
Berlinia confusa Hoyle	Leguminosae	Tree	20	20.00 ± 1.11	19.03 ± 3.05	5.78 ± 1.05
Calamus deeratus Mann and Wendl	Arecaceae	Tree	60	175.00 ± 16.00	6.31 ± 0.63	3.62±0.06
Cannarium schweinfurthii Engl.	Burseraceae	Tree	20	40.00 ± 6.01	7.52 ± 2.00	6.35 ± 0.03
Coelocaryon preusii Warb.	Myristicaceae	Tree	40	30.00 ± 3.17	14.36 ± 3.83	8.56 ± 0.71
Cola argentea Mast.	Sterculiaceae	Tree	10	10.00 ± 1.03	5.87 ± 0.28	6.50 ± 0.08
Coula edulis Baill.	Olacaceae	Tree	10	10.00 ± 1.00	15.50 ± 5.12	5.10 ± 1.80
Elaeis guineensis Jacq.	Arecaceae	Tree	20	35.00 ± 4.51	7.20 ± 0.39	6.51 ± 1.08
Erythrophleum ivorense A. Chev.	Fabaceae	Tree	10	10.00 ± 0.80	6.23 ± 2.10	7.23 ± 0.06
Guarea cedrata (A. Chev.) Pellegrin	Meliaceae	Tree	10	10.00 ± 1.10	5.21 ± 1.00	6.35± 0.71
Khaya ivorensis A. Chev.	Meliaceae	Tree	20	20.00 ± 3.01	8.50 ± 2.50	15.52 ± 2.30
Total				**710**		**93.17**

3.2 Physicochemical Characteristics of Soils in Open and Close Forest Canopies

The physicochemical characteristics of the soil in the open and close canopies are presented in Table 3. For the particle size, the close canopy had higher values for sand (91.19±0.01%), and silt (6.56± 0.01%) while the open canopy had high values for clay (3.13±0.01%). The pH of soil in the open (4.93±0.02) and close (4.56±0.58) were both very strongly acidic. The close canopy had higher values for electrical conductivity (0.08±0.005 ds/m), total nitrogen (0.08±0.003 %), organic carbon (3.13±0.001 %), available phosphorus (13.06±0.01mg/kg), Ca (12.04±0.02 cmol/kg), Mg (6.62±0.58 cmol/kg), EA (2.25±0.01 cmol/kg) and ECEC (21.27±1.15 cmol/kg) while the open canopy had higher values for Na (0.11±0.01 cmol/kg), K (0.13±0.02 cmol/kg) and base saturation (90.83±0.01%). The values obtained for EC, organic carbon, total nitrogen, Ca, Na, EA, and ECEC were different significantly at $P<0.05$.

Table 3: Physicochemical Characteristics of Soils in Open and Close Forest Canopies

Parameters	Open canopy	Close canopy
Sand (%)	90.90±0.03[a]	91.19±0.01[a]
Silt (%)	5.97±0.58[a]	6.56±0.01[a]
Clay (%)	3.13±0.01[a]	2.25±0.03[a]
pH	4.93±0.02[a]	4.56±0.58[a]
EC (ds/m)	0.02±0.00006[a]	0.08±1.15[b]
Organic Carbon (%)	1.73±0.001[b]	3.13±0.001[a]
Total Nitrogen (%)	0.04±0.001[b]	0.08±0.003[a]
Available Phosphorus (mg/kg)	12.22±0.01[a]	13.06±0.01[a]
Ca (cmol/kg)	10.30±0.12[a]	12.04±0.02[b]
Magnesium (cmol/kg)	5.31±0.01	6.62±0.58
Soduim (cmol/kg)	0.11±0.01[a]	0.06±0.01[b]
Potassium (cmol/kg)	0.13±0.02[a]	0.12±0.01[a]
EA (cmol/kg)	1.60±0.03[a]	2.25±0.01[b]
ECEC (cmol/kg)	17.45±0.03[a]	21.27±1.15[b]
Base Saturation (%)	90.83±0.01[a]	89.42±0.01[a]

± = Standard error

EA = Exchange Acidity; ECEC = Effective Cation Exchange Capacity

Mean values having different superscripts on the same row are different significantly at $p<0.05$.

3.3 Nutrient Composition in Litter of Open and Close Canopies

The nutrient composition in litter of open and close forest canopies is presented in Table 4. Organic carbon (45.25±7.31%), total nitrogen (1.14±0.06%), Ca (18.33±1.45mg/kg), Mg (8.91±1.16mg/kg), K (284.89±12.25mg/kg), Na (75.71±8.32mg/kg) and P (2.60±0.41mg/kg) were higher in the close forest canopy. However, the values obtained for organic carbon, Ca, Mg and K in both forest canopies were different significantly at $p<0.05$.

Table 4: Nutrient Composition in Litter of Open and Close Forest Canopies

Nutrients	Open canopy	Close canopy
Organic carbon (%)	35.45±3.15[a]	45.28±7.31[b]
Total nitrogen (%)	1.07±0.10[a]	1.14±0.06[a]
Ca (mg/kg)	14.15±1.47[a]	18.33±1.45[b]
Mg (mg/kg)	5.67±0.43[a]	8.91±1.16[b]
K (mg/kg)	128.45±51.69[a]	284.89±12.25[b]
Na (mg/kg)	74.98±22.23[a]	75.71±8.32[a]
P (mg/kg)	1.77±0.30[a]	2.60±0.41[a]

± = Standard error

Mean values having different superscripts on the same row are different significantly at $p<0.05$.

4. Discussion

The open and close canopy plots revealed variations in the tree species composition of the forest. While the open canopy had 10 tree species, the close canopy had 15 tree species. This variation in tree species composition may be allied to varying levels of anthropogenic perturbations in various plots of the forest. The close canopy had higher tree stand density than the open canopy. The low tree stand density in the open canopy may be linked to indiscriminate exploitation and selective logging of some species for timber. The high value in height and total canopy cover of tree species under the close canopy may be a function of minimal anthropogenic disturbances in the plots.

Variations were also observed in the nutrient contents of the soil and leaf litter samples of open and closed canopy coverages in the forest. This highlights the intrinsic influence of forest canopy on nutrient recycling and availability. The close canopy had higher values for sand and silt and low value for clay while the open canopy had low values for sand and silt and high value for clay. Although the values for the particle sizes in the open and close canopies were not significantly different, this trend indicates the influences of the forest canopies (either open or close) on the soil textural class. Roba et al. (2017) had also alluded this in their study. The high silt in the closed canopy as reported in this study corroborates with the results of Roba et al. (2017). These researchers reported a higher mean value for silt particles in soil under tree shade when compared to soil in an open area. The high silt content in the close canopy may be a function of increased biological activities which aided and improved weathering process as well as moisture availability (Roba et al., 2017). According to them, soils under shade has more decomposers and microorganisms responsible for enhancement of silt contents. They further stressed that sand and clay particles may have varied in the open and close canopies as a result of the parent materials. The slightly higher value of sand in the closed canopy may be linked to the accumulation of aeolian materials in their canopy (Isichei and Muoghalu, 1992).

The pH of the soil in both open and close canopies, were very strongly acidic and were not significantly different. Similar finding was reported by Jiregna et al. (2005) in soil pH under the canopy coverages of *Croton macrostachyus* and *Cordia africana* in comparison to areas that were left open. Electrical conductivity (EC) was significantly different in soils of the open and close canopies with the close canopy having higher values. Same finding was reported by Hailemariam et al. (2010). This variation may be allied to higher leaf biomass and dropping of fruits which decompose to release nutrients that are soluble into the soil (Tanga et al., 2014). However, the result of this study contrasts with that of Gebrewahid et al. (2019) who reported a high EC value in an open area. Total nitrogen, organic carbon, and available phosphorus were also higher in soils of close canopy than in the open canopy. The elevated quantity of these nutrients in close canopy soil tangles with the findings of Tanga et al. (2014), Asaye (2017) and Gebrewahid et al. (2019). Asaye and Zewdie (2013) attributed the high soil organic carbon to increased leaf abscission from the tree species followed by decomposition of litter. Isichei and Muoghalu (1992) had put forward that the high organic carbon in the soil stems from the production of organic matter in high quantity and its slow mineralization rate under tree canopies due to temperature reduction there.

The higher value for nitrogen in the close forest canopy may be a function of increased inputs of organic matter from litter fall and degeneration of fine roots accompanied by activities of microorganisms under tree crown (Manjur et al., 2014). The high available phosphorus in soil under close canopy cover may also be linked to high rate of litter fall and biological activities which might have facilitated the phosphorus release from organic and inorganic matter (Belsky et al., 1989). The high Effective Cation Exchange Capacity (ECEC) under the close forest canopy stems from increased accumulation of organic matter. A recent study maintained that, as the organic matter increases under tree canopies, the total positive charge of the soil increases, which in turn elevates the cation exchange capacity of the soil (Jones, 2001). This phenomenon may also account for high basic cations such as Ca and Mg. Further asserted that leachates from tree canopies, nutrient addition emanating from throughfall and transport of nutrients by tree roots from rooting zone to tree canopies may also be sources of nutrients under the closed canopies (Isichei and Muoghalu, 1992). The high nutrient in the close canopy might have also risen from the fact, that the tree-vegetation which were relatively dense and increased litter accumulation prevented nutrients from being leached from the soil, thus, improving the activities of nutrients (Gautam and Mandal, 2018).

The low cations such as Na and K in the close canopy may be attributed to the absorption of these cations in large amounts at a rate faster than their replenishments in the soil. Just like in the soil, variations in nutrient contents were also evidenced in the litter samples of the open and closed canopies. This may expound that the tree canopies house nutrients in forest ecosystems. Organic carbon, total nitrogen, calcium, magnesium, potassium, sodium and phosphorus were all higher in the open canopy than in the close canopy. This may not be unrelated to the constant and high rate of litter fall under the close canopy (Isichei and Muoghalu, 1992; Asaye and Zewdie, 2013). Litter fall and its accumulation have been reported to be a major source of nutrients in forest ecosystems (Brady and Weil, 2010, Manjur et al., 2014). This is synonymous to this study.

5. Conclusion

The result of this study shows that close canopies are very instrumental in nutrient retention and availability in various pools (soil and litter) of forest ecosystems. Cutting of trees and leaving behind large gaps in forest results in nutrient reduction in forests. Therefore, this study argues against forest disturbances, deforestation and tree cutting as these unwholesome acts create gaps which are detrimental for nutrient cycling, retention and availability in forest ecosystems.

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