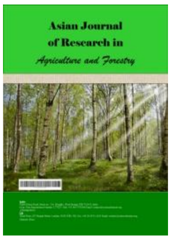

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Influence of Trees Species on Nutrient Availability in the Forest Ecosystem

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AGE and JCA designed the study, Authors AGE and JCA collected the samples in the field and Author JCA carried out the laboratory experiments. Authors AGE, OTU, and JCA organized data and authors VEU and AOO managed the literature searches, Author OTU wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study assessed the influence of tree species on the availability of nutrients in the forest ecosystem. Systematic sampling technique was employed in sampling the vegetation using a quadrats size of 10 m x 10 m spaced at regular intervals of 20 m. Seven (7) woody species were selected for this study. Soil samples were collected from the sampled plots closer to the base of the species using a soil auger at a depth (0-30 cm), these were stored in well labelled Ziploc bag and taken to the laboratory for physicochemical analyses using standard methods. The result revealed that the Organic Matter (3.13 ± 0.001%) and Total Nitrogen (0.08 ± 0.001%) were higher in soils of *Musanga cecroploides* while available Phosphorus (14.14 ± 1.15 mg/kg) and Calcium (14. 20 ± 0.01 cmol/kg) were higher in soils of *Cola argentea.* Sodium was higher in soils of *Mansonia altissima* (0.10 ± 0.01 cmol/kg) and *Musanga cecropioides* (0.10 ± 0.01 cmol/kg) while Potassium was higher in soil of *Coelocaryon Preussii* (0.16 ± 0.01 cmol/kg). *Pentaclethra macrophylla* had the least values for Magnesium (5.01 ± 1.15 mg/kg) while *Coelocaryon preussii* (0.07 ± 0.01 cmol/kg) and *Synsepalum dulcificum* (0.07 ± 0.02 cmol/kg) had the least values for sodium. The nutrient compositions across the soil of selected woody species in the forest were significantly different

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($p<0.05$). The study shows that woody species vary in their soil nutrient return and also exert great influence on soil nutrient composition in the forest ecosystem and also that trees are ecosystem engineers and are able to generate species-specific effect on soil properties that could potentially lead to feedback effect.

Keywords: Feedback effect; forest ecosystem; trees species; nutrient availability.

1. INTRODUCTION

A forest is an ecological habitat where trees, other plants and many animals co-exists. It is a biological community dominated by trees and other woody vegetation. Forest ecosystems are complex webs of organisms that include plants, animals, fungi and bacteria. They are so much more than a collection of trees and are essential for life on earth. The FAO (food and agriculture organization) [1] has defined forest as a land with tree crown cover or equivalent stocking level of more than 10% and area of more than 0.5 hectares, the trees should be able to reach a minimum height of 5 m at maturity in site. Forest can develop wherever the average temperature is greater than 10^0c in the warmest month and rainfall exceeds 200 mm annually [1]. In any area that have conditions above this range, there exists a variety of tree species grouped into a number of forest types, that are determined by the specific conditions of the environment there [2] including the climate, soil geology and biotic activity. Forests are broadly classified into types such as taiga (consisting of pines, spruce) the mixed temperature forests (with both coniferous and deciduous trees), the temperature forests, the sub-tropical forests and the equatorial rain forest [3]. Biodiversity of forests is important for many reasons, including its role as a storehouse of genetic material that can be used to selectively breed plants and animals, its contribution to natural pest and disease control, and its ability to provide valuable pharmaceutical products. Forests also purify water by stabilizing soils and filtering contaminants. The quantity and quality of water flowing from forested watersheds are important for agriculture, hydropower, municipal water supplies, recreation, and habitat for fish and other wildlife species [4].

The deep and spreading roots of trees enhance their capacity in exploiting more soil volume and taking up nutrients and water from deeper layer not usually contacted by herbaceous crops. This process of taking up nutrients from deeper soil profiles and eventually depositing at least in some portion of them on the surface layers through litter-fall and other mechanisms is referred to as 'nutrient pumping' by trees [5]. [6] reported that the development of plants depends on site characters and environmental factors. Many woody species have the largest number of roots and the majority of the fine roots are located in the uppermost fertile portion of the soil profile. Some tree species are shallow rooted for example, *Prosopis chilensis*(Molina) Stuntz has a shallow and spreading root system whereas *Prosopis juliflora* (Sw.) DC.*,* is known to have a very deep root system [7].

Trees are often the most conspicuous plant life forms in a tropical rain forest. Upon the framework of these trees and within the microclimate of the canopy of the trees, grow a wide range of other kinds of plant such as epiphytes, strangling plants, climber, parasitic and saprophytes. Trees are perennial woody-plants with usually stem or self-supporting trunks or at most two or three trunks growing from the base, and the branches and leaves are anchored by the trunk [8]. The benefits of trees to mankind and some living organism cannot be over-emphasized. The bottom-line is humans derive not a single user value from trees, but a multi-product or multi-value benefit. Some of these benefits stem from components and attributes of a single tree, while other benefits are derived from groups of tree functioning together.

Decline in nutrient availability, changes in soil properties and the degradation of forest ecosystem stability is attributed to several threats of both natural and anthropogenic activities which include deforestation, industrialization, climatic change and invasive species. Litter fall are known to contribute to nutrient availability in a forest ecosystem. However, information on influences of tree species on soil nutrient availability in the forest ecosystem is scanty, hence the necessity to provide information on the soil nutrient availability in forest ecosystem over time that would enable proper management and conservation of the forest ecosystem through this study where the influence of tree species on nutrient availability of soils in a forest ecosystem will be evaluated.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in Ikot Efre Itak in Ikono Local Government Area of Akwa Ibom State. Ikot Efre Itak forest is located between latitudes 4°30ˈ and 5°30ˈ N and longitudes 7°31ˈ and 8°20ˈ E. It covers an area of approximately 29.57 hectare [9]. The mean annual rainfall of the state is between 2400 mm and 3000 mm. The mean minimum and maximum temperature are 26ºC and 30.5ºC, respectively; while the mean relative humidity of the area is about 83%. The forest is only accessed through the consent of the village council who gives such permission. The forest is rich with a good number of plant species. However, several anthropogenic disturbances such as incessant logging, unregulated species exploitation and infrastructural encroachments are common features evidenced in and around the forest.

2.2 Vegetation Sampling and Soil Collection

Three plots were used in this study and in each plot, three belt transects were laid. In each transect, woody species were sampled purposively using a quadrat size of 10m x 10m spaced at regular intervals of 20m. The woody species were identified to species levels. A total of 7 woody species were selected for this study. In each quadrat where the woody species grew, two soil samples were obtained closer to the base of the species using a soil auger at a depth of 0 – 30 cm. The soil samples were pooled into one composite sample, stored in labeled Ziploc bags and taken to the laboratory for their nutrient analyses.

2.3 Soil Nutrient Analyses

2.3.1 Determination of organic carbon/ organic matter

The Walkey-Black method [10] was used. One gram (1.0 g) of air-dry soil (passed through 1 mm sieve) was weighed out and transferred to 500 ml Erlenmeyer flask. By means of pipette 10 ml of $K_2Cr_2O_7$ was added to the flask and swirled to disperse the soil. 20ml of concentrated H_2SO_4 was added by means of graduated cylinder to the mixture, swirled gently to mix and then swirled vigorously for one minute, and allowed to stand for 30 minutes. The suspension was diluted with 100 ml distilled water and left to stand for 30 minutes. 10 ml of 85% H_3P0_4 was added and about 0.2 g NaF was also added. 1 ml diphenylamine indicator was added from a burette to the flask and swirled. The excess dichromate was back titrated against 0.5N ferrous ammonium sulphate to a green end-point. Two blank titrations were made using the same procedure but without soil. The percentage organic carbon was calculated below.

Milliequivalent of oxidizable material per gramme of soil (me ox/g) = ml of Fe $(NH_4)_2(SO_4)_2 .6H_20$ for blank – ml for sample × normality of Fe $(NH_4)(S0_4)_2.6H_20$ divided by weight of soil (g).

% C = me ox/g × 12/4000 × 1/0.77 × 100
= me ox/g × 0.39

Where 12/4000 = milliequivalent weight of carbon in grammes; 1/0.77 = factor of converting the carbon actually oxidized to total carbon and 100 = factor to change from decimal to percentage.

Organic matter amount was estimated using the equation below:

Organic Matter (%) = 1.724 × percent organic carbon (Black et al., 1965).

2.3.2 Determination of total nitrogen

Micro-Kjeldahl method outlined in [11] was adopted. Five grams (5 g) of soil was weighed out and transferred to 500ml Kjeldahl flask. Through a funnel one heap teaspoon (about 11 g) of digestion mixture was added to the flask. 25 ml of concentrated H_2SO_4 was added and swirled gently until the content was thoroughly mixed. The flask was placed on Kjeldahl digestion apparatus and heated at low heat for four (4) hours until frothing ceased or organic matter destroyed as evidenced by the light grey colour. It was further heated for 30 minutes. The heat was turned off, flask removed, capped immediately with beaker and left to cool. After cooling, 250 ml of distilled water was added to the flask and the contents mixed thoroughly. The flask was tilted to an angle of 45º and 75 ml of 40 % NaOH was added so that it ran down the side to the bottom of the flask without mixing. Two to three pieces of zinc metal were added and the flask was immediately attached to the distillation apparatus. The heat was turned on to low and the contents of the flask swirled to mix. Distillation commenced and about 200 ml of the distillate was obtained in the receiving flask. The receiving flask was then lowered such that the receiving tube was above the level of the solution in the flask and detached from the apparatus. The distillate was titrated against standard acid until the blue colour disappeared. A blank titration was carried through the procedure but with no soil sample. The percentage nitrogen in the soil sample was calculated as

$$\% N = \frac{(T-B) \times N_A}{S}$$

Where

T = sample titration (ml),
B = blank titration (ml),
N_A = normality of acid used (to 4 decimal places) and
S = sample weight (g)

2.3.3 Determination of available phosphorus

Bray No.1 method was used. Here, 1 g of air-dried soil (passed through 2 mm sieve) was weighed out and transferred to 50 ml conical flask. 10 ml of extracting solution was added to the flask and the mixture shaken on a mechanical shaker for five (5) minutes and filtered through Whatman No.2 filter paper. 2ml of aliquot filtrate was transferred into a colorimetric tube and 5ml of distilled water and 2ml of ammonium molybdate solution added. The content of the tube was mixed properly and 1ml of dilute $SnCl_2.H_2O$ solution added and mixed again. After ten minutes, the percentage transmittance of the mixture was measured on electro photometer at 660 ppm wavelength. Phosphorus standard stock solution (100 ppm) was prepared by dissolving 0.4393 g dry anhydrous KH_2PO_4 in distilled water and diluted to 1 litre. Colour was allowed to develop for 30 minutes and the percentage transmittance read at the same wavelength. The values were used to plot a standard curve (optical) density against concentration (in ppm) and the curve used to read off the concentration (ppm) in the soil samples.

2.3.4 Determination of exchangeable cations

The method outlined in [11] was used. Approximately 10 g of air-dry soil (passed through 2mm sieve) was weighed out and transferred to a 250 ml conical flask and 100 ml of NH_40A_c was added, by means of a measuring cylinder, to the flask. The flask was corked and shaken mechanically for 30 minutes. The suspension was filtered using Whatman filter and stored in McCartney bottles for the determination of exchangeable bases (calcium, magnesium, potassium and sodium). Na and K were determined by flame photometry using flame photometer Jenway PFP7 and Ca, and Mg by EDTA (Ethylenediaminetetraacetic acid) method.

2.4 Statistical Data Analysis

Means and standard errors of triplicates as well as Two-way Analysis of Variance (ANOVA) were computed using Graph Pad Prism 6.0.

3. RESULTS

3.1 Nutrient Composition in Soils of Selected Woody Species in the Forest

The nutrient composition in soils of selected woody species in the forest is presented in Table 1.

From the result, organic matter (3.13±0.001 %) and total nitrogen (0.08±0.001 %) were higher in soils of *Musanga cecropioides* R.Br.apud Tedlie while available phosphorus (14.14±1.15 mg/kg) and Ca (14.20±0.01 cmol/kg) were higher in soils of *Cola argentea* Mast. *Pentaclethra macrophylla* Benth., *Cola argentea*, *Piptadeniastrum africanum* (Hook.f.) Brenan and *Musanga cecropioides* had the least values for organic matter (1.43±0.001 %), total nitrogen (0.03±0.001%), available phosphorus (11.40±0.58 mg/kg) and Ca (10.30±0.06 cmol/kg), respectively. Mg (9.48±0.01 cmol/kg) was higher in soils of *Piptadeniastrum africanum*, Na was higher in soils of *Mansonia altissima* A. Chev. (0.10±0.01 cmol/kg) and *Musanga cecropioides* (0.10±0.01 cmol/kg) while K was higher in soils of *Coelocaryon preussii* Warb*.* (0.16±0.01 cmol/kg). *Pentaclethra macrophylla* had the least values for Mg (5.01±1.15 mg/kg), *Coelocaryon preusii* (0.07±0.01 cmol/kg) and *Synsepalum dulcificum* (Schumach & Thonn.) Baill. (0.07±0.02 cmol/kg) had the least values for Na while *Pentaclethra macrophylla* (0.12±0.01 cmol/kg) and *Synsepalum dulcificum* (0.12±0.01 cmol/kg) had the least amount of K. The nutrient composition across the soils of the selected woody species in the forest was significantly different ($p < 0.05$).

Table 1. Nutrient composition in soils of selected woody species in the forest

Nutrients	***Piptadeniastrum africanum* (Hook.f.) Brenan**	***Coelocaryon preussii* Warb**	***Mansonia altissima* A. Chev.**	***Cola argentea* Mast.**	***Pentaclethra macrophylla* Benth.**	***Musanga cecropioides* R.Br.apud Tedlie**	***Synsepalum dulcificum* (Schumach & Thonn.) Baill.**
Organic matter (%)	1.73±0.01[a]	1.66±0.01[a]	1.64±0.02[a]	1.50±0.12[a]	1.43±0.001[a]	3.13±0.001[b]	1.73±0.002[a]
Total nitrogen (%)	0.05±0.02[a]	0.04±0.001[a]	0.04±0.001[a]	0.03±0.001[a]	0.04±0.001[a]	0.08±0.001[a]	0.04±0.002[a]
Available phosphorus (mg/kg)	11.40±0.58[a]	12.80±0.23[b]	13.08±0.01[b]	14.14±1.15[b]	14.02±0.01[b]	13.06±0.001[b]	12.22±0.01[b]
Ca (cmol/kg)	12.00±1.15[a]	13.40±0.01[b]	13.80±0.01[b]	14.20±0.01[b]	11.00±1.15[a]	10.30±0.06[b]	12.04±0.02[a]
Mg (cmol/kg)	9.48±0.01[a]	9.00±1.73[a]	6.11±0.01[b]	7.14±0.01[b]	5.01±1.15[c]	5.31±0.001[c]	6.62±0.01[b]
Na (cmol/kg)	0.08±0.02[a]	0.07±0.01[a]	0.10±0.01[a]	0.10±0.03[a]	0.09±0.01[a]	0.10±0.01[a]	0.07±0.02[a]
K (cmol/kg)	0.13±0.02[a]	0.16±0.01[a]	0.14±0.01[a]	0.13±0.02[a]	0.12±0.01[a]	0.13±0.002[a]	0.12±0.01[a]

Means with different superscripts along the same row are significantly different ($p < 0.05$).
± Standard error

4. DISCUSSION

Variations were observed in nutrient contents across the soil, occupied by the woody species in the forest. This may entail that woody species vary in their soil nutrient return and also exert great influence on soil nutrient composition in forest ecosystem. This had been documented by several scholars in previous studies [12,13,14]. The research report by [6] added that, tree species are known to affect soil through the absorption of nutrients and addition of nutrients through leaf litter to different soil layers. This is evidenced in this study. Soils of some woody species has high concentration of some nutrients while some soils had low nutrient concentration. This trend may confirm the plant-soil feedbacks in this forest in terms of nutrient composition. Many studies have shown that trees are ecosystem engineers and are able to generate species-specific effects on soil properties that could potentially lead to a feedback effect [15,16]. These feedbacks as posed by the plants, may have lasting influence on the soil. This corroborates with the findings of [3]. This researcher reported that changes in soil biotic and abiotic conditions created by plants cause legacy effects in the soil that does not only affect the performance of co-occurring plants of the same and other species, but also the offspring of these species. In this way, soil conditions that were altered by a plant can affect the establishment, growth, performance or reproduction of the later arriving plants.

Soils of *Musanga cecropioides* had the highest organic matter and total nitrogen contents, soils of *Cola argentea* had the highest values for available phosphorus and calcium, soils of *Piptadeniastrum africanum* had the highest concentration of Mg, soils of *Mansonia altissima* and *Musanga cecropioides* had the highest Na content while that of *Coelocaryon preussi* had the highest K contents. The availability of these nutrients in high amounts resulting from the presence of these tree species, may confirm the positive plant-soil feedback in the ecosystem. This may be suggestive of the fact that the conspicuous presence and abundance of these woody species in the soil of the forest have great potentials for the improvement of soil fertility, nutrient cycling and productivity. The potentials of these species in enhancing the availability of soil nutrient in the forest may be linked to the quality and richness of their vegetal debris and litter, which upon decomposition, release several nutrients to the soil. This had been affirmed by [17,18]. On the other hand, *Pentaclethra macrophylla*, *Cola argentea*, *Piptadeniastrum africanum* and *Musanga cecropioides* had the least values for organic matter, total nitrogen, available phosphorus and Ca respectively. *Pentaclethra macrophylla* also had the least values for Mg, *Coelocaryon preusii* and *Synsepalum dulcificum* had the least values for Na. The low values of soil nutrients recorded in the study as a consequence of the presence of these woody species across various plots in the forest, may expound the negative plant-soil feedback in the ecosystem with regards to nutrient composition. This may further be an indication of the low nutrient richness in leaf litter components of these species. The low nutrients in soils of the aforementioned species may also be a pointer to their low potential for soil productivity, fertility and nutrient cycling. It may also be linked to the differential recycling of soil nutrients under different species. The research report by [19] puts forward that each species and ultimately each community has got its own requirement and capacity for utilizing the soil materials and also for returning to the soil.

5. CONCLUSION

This study revealed that variations in soils under different tree species were observed in nutrient contents across the plot occupied by the woody species in the forest. This may entail that woody species vary in their soil nutrient return and also exert great influences on soil nutrient composition in the forest ecosystem. This study has shown that trees are ecosystem engineers and are able to generate species-specific effects on soil properties that could potentially lead to feedback effect. These feedbacks as posed by the plants, may have lasting influences on the soil, the study also revealed changes in soil biotic and abiotic conditions created by plants cause legacy effects in the soil that does not only affect the performance of co-occurring plants of the same and other species, but also the offspring of these species. In this way soil conditions that were altered by a plant can affect the establishment, growth, performances or reproduction of the later arriving plants.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

The forest is only accessed through the consent of the village council who gives such permission.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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