

ASSESSMENT OF LITTERFALL NUTRIENT FLUX IN ISOLATED STANDS OF *MANGIFERA INDICA* IN OROGUN RAINFOREST REGION, SOUTHERN NIGERIA

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ABSTRACT

This research examined the relationships between plants and soil with respect to nutrients return via litter fall by Mangifera indica trees within the moist rainforest cover in southern Nigeria. This is with a view to identify exotic tree species that can be adopted for a sustainable management of the degraded rainforest ecosystem in this region. The study assessed the nutrients concentrated in litterfall, nutrient flux by litterfall, soil nutrient characteristics undertrees, relationship between litter nutrients and nutrients in soil, and ascertained the seasonal characteristics of litterfall nutrient flux. Litterfall samples were collected daily for a year using 1m² litter traps under tree crown areas; while samples of soil were collected by the use of core sampler from the (0-15cm) and (15-30cm) depth of the soil profiles under M. indica and rainforest trees. The samples of litterfall and soils collected were analysed in the laboratory using standard methods. Data were statistically analysed using the mean, graphs, student t-test statistics and Pearson's bivariate correlation techniques. Results revealed that both litterfall nutrients returned and nutrient properties of soils under trees differ between M. indica trees and the rainforest; Relationships between litterfall nutrient flux and soil nutrient properties are positively significant; nutrients returned by both M. indica and rainforest trees (Milicia excelsa, Musanga cecropioides, Piptadeniastrum africanum, Pentaklepta macrophylla, Albizia adianthifolia, Ricinodendron heudelotii, Ceiba pentandra, Terminalia superba, Alstonia boonei and Antiaris toxicaria) varied within the seasons of the year. Since M. indica trees are capable of returning nutrients to the rainforest soil, its production should be encouraged, and can be adopted in the quest for a sustainable management of the degraded rainforest cover.

Keywords: Isolated exotic stands; litterfall; *Mangifera indica*; nutrient flux; rainforest; soil and plant relationship.

Introduction

Nutrient cycling by the stands of exotic tree species is now becoming increasingly important to the sustenance and management of the rainforest environment. Apart from providing shade and fruits to rural farmers, the planting of these exotic trees in farmland helps to improve soil nutrient status. Within the rainforest ecosystem, tree plants and the soil are closely related, and they influence one another in the form of interaction and interrelationship (Ekanade, 2007). Plants get their nutrient elements and moisture from soil where they grow on, through their root system, while phonological changes such as shedding of leaves, branches and fruits also occur. The litterfall decays within the soil and helps to improve its nutrient contents and fertility status characteristics. These nutrient elements are used up by the plants again in a process called nutrient cycling (Wood *et al.*, 2006). The nutrient elements which are returned back to soil from litterfall help to improve and maintain the nutrient status characteristics of soil by increasing the quantities and concentration levels of the soil chemical properties (Perez *et al.*, 2003). There is therefore, a link between trees and the soils under their stands as they interact within the rainforest ecosystem, with respect to nutrients exchange.

The plants and soils within the rainforest environment are said to be in equilibrium involving an almost closed cycling of nutrients that is achieved through an increased rate of litter production, rapid mineralization and a rapid attainment of equilibrium with respect to organic matter relationships (Muoghalu *et al.*, 1993; Hermansah *et al.*, 2002). However, this equilibrium relationship is often disrupted whenever the rainforest trees are being cleared for cultivation. Even, after the trees which may have been planted in plantations are matured, the equilibrium relationship between plants and soil is not achieved such

that can be used to manage the degraded rainforest. Therefore, cultivating plantations of non-indigenous trees to replace the degraded rainforest environment will not maintain the expected equilibrium condition which the native rainforest does. In this regards, it becomes pertinent to assess nutrient flux by variant isolated species of trees to aid in accounting for the contributions of the nutrient elements returned by trees to the rainforest soils.

Within the Nigerian moist rainforest environment, exotic trees such as *M. indica* are planted to produce fruits and serve as shade for resting within farmland areas, settlements and surrounding environment. The *M. indica* trees feature in isolation and their canopies are far apart from canopies of other trees. Although the economic relevance of the *M. indica* tree plant is known, no research effort in time past has been directed to the consideration of its ecological importance in the drive for a sustainable and effective management of the rainforest environment (Ndakara, 2014).

Essentially, several studies on litterfall have been conducted within Nigeria rainforest ecosystem. Studies conducted by Muoghalu *et al.* (1993) and Muoghalu *et al.* (1994) focused on the drier rainforest belt; while the studies carried out by Nwoboshi (1985), Oladoye *et al.* (2007) and Adedeji (2008) focused on plantation ecosystems. Owing to the influence of close canopy which characterises natural rainforest and plantation ecosystem, the studies as conducted could not ascertain the contributions of nutrients by individual tree species to soil in the nutrient cycling process. Thus, results from such studies cannot serve as rational basis when accounting for litterfall nutrient flux by isolated trees in the process of nutrient cycling. Therefore, this study is essentially necessary. Perhaps, this is the first

research on litterfall nutrient flux in *M. indica* trees within this study area.

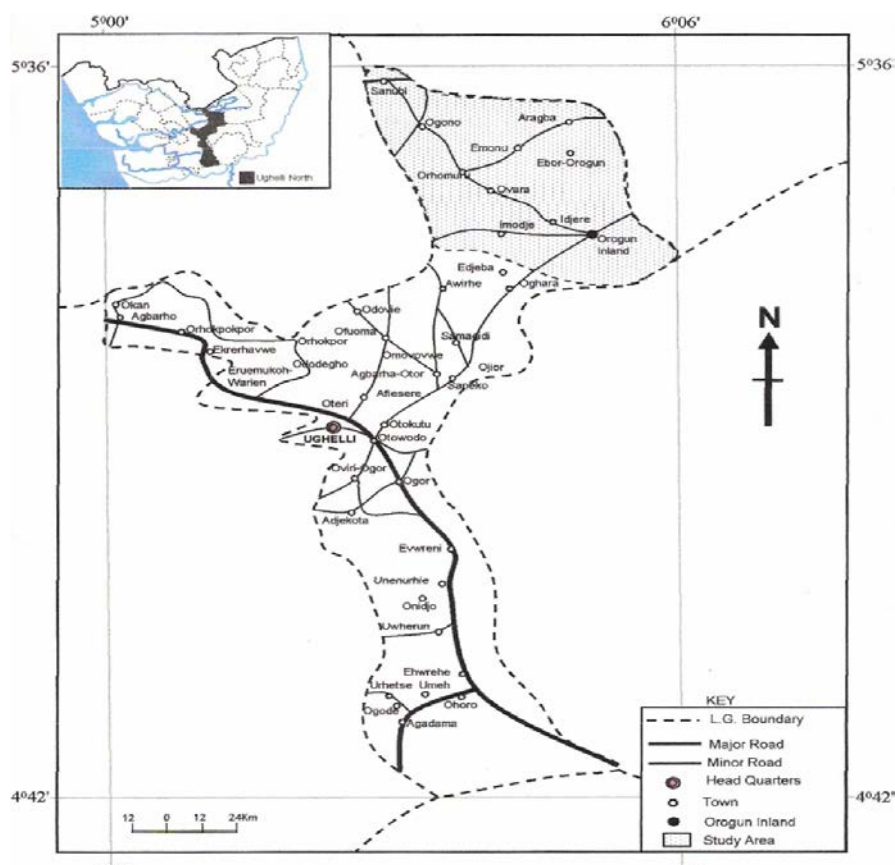
This study is aimed at examining litterfall nutrient flux by *M. indica* in order to ascertain the contributions of nutrients by individual tree of the exotic origin to the rainforest soil. This is with a view to achieve a sustainable and effective management of the rainforest ecosystem.

Methodology

Study Area

This research was conducted in the moist rainforest of Orogun, Ughelli North Local Government Area of Delta State, Southern Nigeria (Fig. 1). The study area is located between latitude $5^{\circ} 20'N$ and $5^{\circ} 36'N$, and also between longitude $5^{\circ} 30'E$ and $6^{\circ} 06'E$. It falls within the moist tropical climate with mean

annual temperature of about $30^{\circ}C$ and annual rainfall distribution between 2000mm and 4000mm. The distribution of rainfall pattern during the year is characterized by the double maxima regime; the two periods of maximum rainfall being in July and September (Ndakara, 2012). The natural vegetation is lowland rainforest of the moist evergreen forest type. The originally contiguous rainforest cover within this area has been degraded owing to age-long human activities such as agricultural practice of shifting cultivation. Most of the original forest has been destroyed and the landscape is now dominated by a mosaic of different stages of farms and succession communities. Relics of the original rainforest cover now feature as island habitats, and confined to restricted sacred places as sacred groves (Ndakara, 2011; 2012).



Design of the Study and Samples

Collection

The study area was stratified into 5 zones in line with the existing quarters of the clan, for effective and evenness in samples collection. In each quarter, 3 *M. indica* trees were selected by maintaining the conditions that sampled trees were far apart from canopies of other trees thereby eliminating relationships with it; and have not been subjected to burning and sweeping which possibly could have impacted on the soil chemical properties under the tree stands. In each quarter, a sample plot of 30 x 30 m sub-divided into 3 quadrats of 10 x 30 m was chosen from the adjoining rainforest and served as control for this study (making 15 sample sites established within the rainforest control area). The adjoining rainforest sites are native and matured forest covers that are within sacred places where human activities have been restricted.

Samples collected were litterfall and soil. Samples of litterfall were collected daily for a year using 1m² litter traps by considering litterfall and tree crown area; while samples of soil were collected by the use of core sampler from the (0-15cm) and (15-30cm) depth of the soil profiles under *M. indica* and rainforest trees. The samples of soil were analysed in the laboratory for the concentrations of total nitrogen, available phosphorus and exchangeable Ca, Mg, Na and K.

Laboratory Analysis of Samples

The samples of litterfall collected were sorted into fruit, leaf, flower and small wood litters. Apart from the flower and leaf litter, only the litter within diameter size of ≤ 2.5 cm was included in this study. The litter samples were oven-dried to constant mass, then ground into powder form and analyzed for the concentrations of N, P, Ca, K, Mg and Na. In determining total nitrogen and available phosphorus, the Kjeldahl digestion on a

Tecator 2000 Digestion System was adopted. Nutrient cations (Ca, K, Mg and Na) were determined by first digesting the ground litter samples in HNO₃ / H₂O₂ on a block at 105°C, and then re-dissolved in nitric acid for analysis by the use of Spectro CIROS CCDE Inductively Coupled Argon Emission Plasma Spectrometry (Ndakara, 2011).

Organic matter content determination was achieved by first determining the organic carbon contents of the soil using Walkley-Black wet oxidation approach before multiplying with 1.724 to get organic matter content. The Walkley-Black method was so adopted because it is more accurate than other methods used to determine organic matter content of soil such as the ignition method (Ekanade, 1985). Total nitrogen was determined by first digesting the soil with (H₂SO₄) and then the nitrogen content of the digest was determined with an auto-analyzer. Available phosphorus extracts were obtained by leaching the soil with Bray P – 1 extracting solution of Hydrochloric acid and Ammonium fluoride (0.025N HCl + 0.03N NH₄F). The concentration of available phosphorus was determined colorimetrically with a “spectronic 20” spectrophotometer after the colour had been developed with Murphey and Riley reagent. Soil nutrient cations were determined by leaching the soil with 1N neutral ammonium acetate. The concentrations of calcium, sodium and potassium were determined with a flame photometer while magnesium was determined with an atomic absorption spectrophotometer.

Data Analysis

Data from laboratory analyses were tested with the descriptive and inferential statistics. The concentrations and nutrient fluxes were determined using the technique of mean; graphs were adopted to present the variability in litterfall nutrient flux in response to season (the drier and wetter seasons

experienced within this study area); the independent samples t-test statistics was used to test the differences in the concentrations and nutrients returned between *M. indica* and rainforest; while Pearson's bivariate correlation was employed to correlate the relationships between nutrients in the soil and litterfall nutrient fluxes.

Results and Discussion

Nutrient Concentrations and Returns in Litterfall

Litterfall nutrient concentrations and returns vary between the stands of *M. indica* and the rainforest (table 1). The observed mean variation in nutrient concentrations and returns in litterfall between *M. indica* trees

and the rainforest could be attributed to the variation in tree species contained in the rainforest. This is because the cycling of nutrients varies with variations in tree species composition (Proctor, 1983; Muoghalu *et al*, 1993; Pragasan and Parthasarathy, 2005).

Apart from potassium, the concentrations and returns of nutrient elements were higher in rainforest than in the stands of *M. indica* trees. Generally, the concentrations of Ca, N and K in litterfall were higher than the concentrations of Mg, P and Na in both the stands of *M. indica* trees and the rainforest control sites. The higher concentrations and returns of Ca, N and K than those of Mg, P and Na can presumably be attributed to their higher availability in the soils.

Table 1: Mean Nutrient Concentrations and Returns in Litterfall

Nutrient elements	Nutrient Concentrations (mg/g)		Nutrient Fluxes (kg/ha/yr)	
	Sites		Sites	
	<i>M. indica</i>	Rainforest	<i>M. indica</i>	Rainforest
Nitrogen	4.78	10.69	3.43	9.08
Phosphorus	0.60	0.72	0.45	0.60
Potassium	3.74	3.69	2.64	3.39
Calcium	7.14	9.53	5.22	7.81
Sodium	0.34	0.53	0.25	0.49
Magnesium	1.64	3.18	1.17	2.57

Source: Field work

Table 2: Independent-Samples T-Test results for the differences in litterfall nutrient contents between *M. indica* and the rainforest

Samples	Mean	Standard deviation	Standard error Mean	Observed Mean difference	Standard error Mean (Expected difference)	t-value	Sig. (2-tailed)
M. indica	3.0400	2.6658	1.0883	-1.6833	0.9321	-1.806	0.13
Rainforest	4.7233	4.3764	1.7867				

Source: SPSS Output, 2018

Results of the independent-samples t-test (table 2) show that with standard error mean (expected difference) of 0.93, mean (observed difference) of -1.68 and significant 2-tailed of 0.13, there is no significant difference in litterfall nutrient contents between *M. indica* and the rainforest at the 0.05 confidence level. Although the mean values of nutrient concentrations in litterfall varied between the stands of *M. indica* and the rainforest, the

differences were not significant thus, showed a marked similarity in the amount of nutrient elements contained in litterfall for both the exotic tree and the rainforest. The observed higher concentrations of Ca, N and K than the concentrations of Mg, P and Na in rainforest corroborates with the report of findings in the studies by Nye and Greenland (1960) where N, P, K, Ca and Mg concentrations are 19, 0.7, 6.5, 19.6 and 4.3 respectively.

Table 3: Paired Samples T-Test Results for the Differences in Litterfall Nutrient Fluxes between *M. indica* and the Rainforest

Samples	Mean	Standard deviation	Standard error Mean	Observed Mean difference	Standard error Mean (Expected difference)	t-value	Sig. (2-tailed)
M. indica	2.1933	1.9366	0.7906	-1.80	0.85	-2.105	0.089
Rainforest	3.9900	3.6502	1.4902				

Source: SPSS Output, 2018

Results of the independent-samples t-test (table 3) show that the standard error mean (expected difference) is 0.85, mean (observed difference) is -1.80, while significant 2-tailed is 0.09. Therefore is no significant difference in litterfall nutrient fluxes between *M. indica* and the rainforest at the 0.05 confidence level.

The higher returns of Ca, N and K than the returns of Mg, P and Na in the rainforest corroborates the findings reported in the studies by Muoghalu *et al* (1993) where N, P, K, Ca and Mg fluxes are 6.6, 4.0, 4.5, 9.7 and 1.5 respectively. The order of nutrient concentrations and returns in litterfall is Ca > N > K > Mg > P > Na for *M. indica*; and N > Ca > K > Mg > P > Na for the rainforest respectively. The observed order for the *M. indica* trees is in line with the findings which were reported by Mueller-Dombois *et. al* (1984) and

Muoghalu *et. al.* (1993); while the observed order for the rainforest corroborates with the findings in studies by Bernhard-Reversat (1993) and Perez *et al* (2003).

Seasonal Patterns in Litterfall Nutrient Flux

The trend in litterfall nutrient returns between *M. indica* trees and the rainforest varies with differences in the seasons (figs 1 – 6). The returns and trend in the seasonal patterns of nutrient fluxes is quite similar for N and P respectively in both *M. indica* trees and the rainforest. From fig 1 and 2, both *M. indicatrees* and rainforest returned the highest amount of total nitrogen and available phosphorus in March, which marks the onset of rainy season in southern Nigeria.

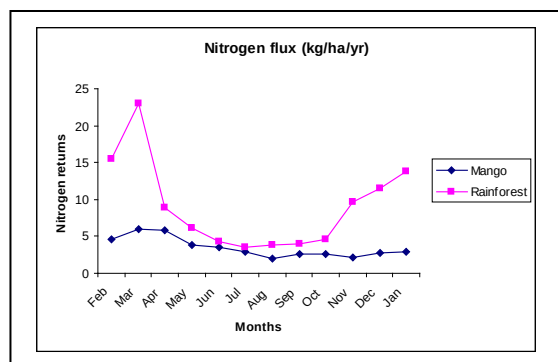


Fig 1: Seasonal variations in Nitrogen Flux

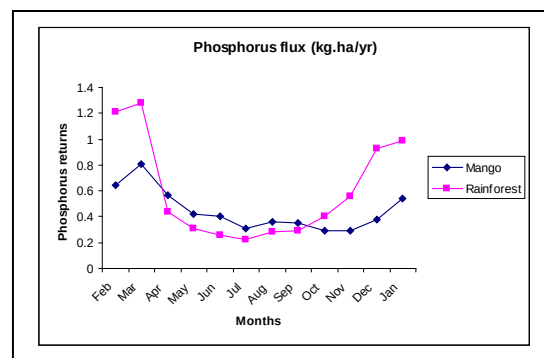


Fig 2: Seasonal variations in Phosphorus Flux

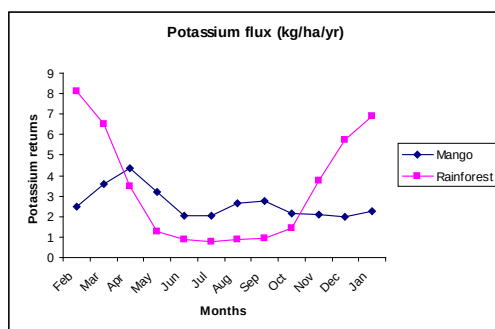


Fig 3: Seasonal variations in Potassium Flux

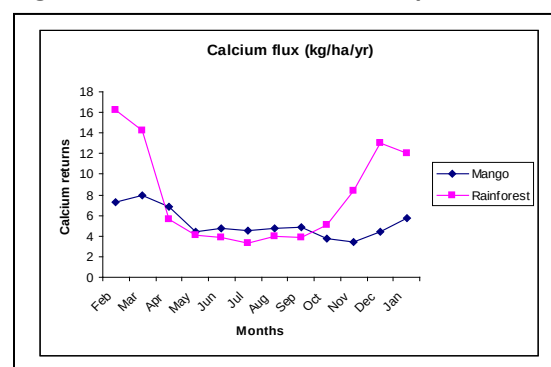


Fig 4: Seasonal variations in Calcium Flux

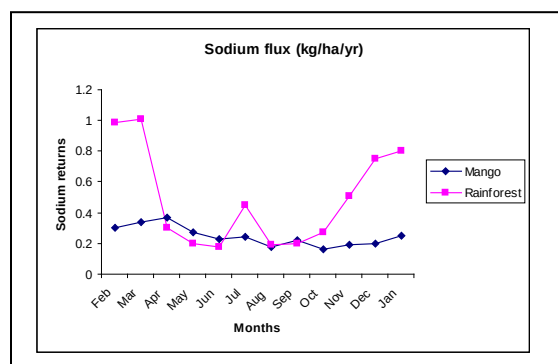


Fig 5: Seasonal variations in Sodium Flux

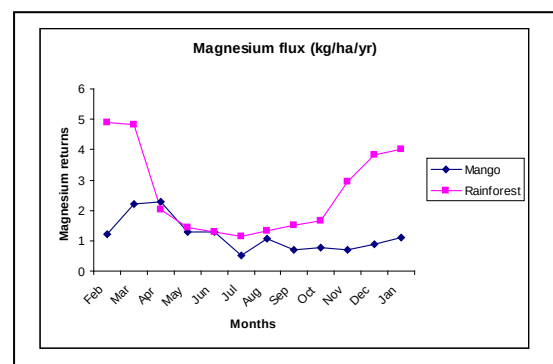


Fig 6: Seasonal variations in Magnesium Flux

From the stands of *M. indica* trees, the highest return of K, Mg and Na was recorded in April, while the highest return of Ca was observed in March. However, in the adjoining rainforest, the highest return of K, Mg and Ca was recorded in February, while that of Na was recorded in March. The seasonal pattern therefore reveals that *M. indica* trees returned the highest amount of nutrients to the soil during the beginning of rainy season. Although the rainforest returned the highest amount of Na in March as with N and P, the highest amount of K, Mg and Ca returned was recorded in the dry season. The seasonal pattern of nutrient flux in the rainforest is

similar to the pattern reported in studies carried out by Muoghalu *et al* (1993). This therefore confirms that in nutrient cycling processes, nutrient flux by litterfall varies with variation in seasons of the year.

Nutrient Elements in Soils under *M. indica* and Rainforest

Nutrient elements varied between the soil under *M. indica* and the soil under rainforest. Apart from the observed lower concentration of exchangeable Ca, the mean nutrient properties of the topsoil are higher under the rainforest than under *M. indica*.

Table 4: Mean Soil Nutrient Properties under *M. indica* and Rainforest

Nutrient elements	Sites	
	<i>Mangifera indica</i>	Rainforest
Organic matter (%)	5.20	6.33
Total nitrogen (%)	0.48	0.59
Available phosphorus (mg/kg)	12.09	14.86
Exchangeable calcium (mg/kg)	769.40	709.67
Exchangeable Magnesium (mg/kg)	253.47	476.93
Exchangeable Potassium (mg/kg)	60.73	116.47
Exchangeable Sodium (mg/kg)	54.87	88.47

Source: Field work

This reveals that the concentrations of nutrient elements are higher under native rainforest than under *M. indica* trees. Improvement in the growth and productivity of trees depend on the availability of these important nutrient elements in the soil. Soil organic matter is an important source of plant nutrients. The build-up of organic matter in soil is one of the essential changes that take place in soils under the rainforest ecosystem. The composition of total nitrogen is higher under the rainforest than under the *M. indica* trees thus, similar to the observed soil organic matter content. This is as should be expected because organic matter is the major store of

soil nitrogen (Ekanade, 1985; Vitousek and Sanford, 1986).

Relationship between Litterfall Nutrient Flux and Soil Nutrient Elements

There are observed relationships between litterfall nutrients returned and the nutrient elements of the soils under *M. indica* trees and the rainforest. The correlation values between the nutrients returned by litterfall and the soil nutrient elements under *M. indica* trees and the rainforest are positive (table 5). This shows that there is a positive relationship between nutrients returned to the soil by litterfall and soil nutrient elements underneath tree stands.

Table 5: Pearson's Bivariate Correlations between Soil Nutrient Elements and Litterfall Nutrient Flux.

Litter nutrient elements	Sites	Soil Nutrient Elements					
		Nitrogen	Phosphorus	Potassium	Calcium	Sodium	Magnesium
Nitrogen	<i>M. indica</i>	.882	.473	-.043	.731	.615	.367
	Rainforest	.921	.595	-.004	.692	.566	.547
Phosphorus	<i>M. indica</i>	.300	.808	-.690	.535	.289	.326
	Rainforest	.421	.925	-.991	.607	.782	.327
Potassium	<i>M. indica</i>	-.981	-.906	.902	.682	-.952	.305
	Rainforest	-.811	-.910	.894	.478	-.276	.666
Calcium	<i>M. indica</i>	.595	.086	.682	.882	.500	.366
	Rainforest	.325	.505	.508	.914	.329	.419
Sodium	<i>M. indica</i>	.500	.784	-.997	.705	.897	.121
	Rainforest	.642	.047	-.999	.680	.940	.143
Magnesium	<i>M. indica</i>	.500	.349	.564	.261	.596	.803
	Rainforest	.216	.488	.546	.575	.626	.929

Source: SPSS Output, 2017

Generally, the observed levels of correlation between litterfall nutrients returned and soil nutrient elements show that litterfall contributes to the soil nutrient status. Therefore, there is an interrelationship between litterfall nutrients returned and the soil nutrient elements underneath tree stands.

Findings about the interrelationships between the nutrient properties of soil under the trees and litterfall nutrients returned reveal that the greater the amount of litterfall nutrient elements returned to the soil, the higher the nutrient status of the soil under the isolated exotic trees. This relationship is to be expected because in nutrient cycling process, tree plants depend on soil nutrients for their growth and development while the reciprocal effects give back nutrient elements to the soil through litterfall. Litterfall nutrient flux correlated positively with the soil nutrient properties. This implies that litterfall enhances the capacity of trees to regenerate soil fertility underneath their stands.

Conclusions

This study assessed litterfall nutrient returns and soil characteristics under *M. indica* trees in southern Nigerian moist rainforest ecosystem.

The study examined litterfall nutrient concentrations, litterfall nutrient returns, soil nutrient properties, the level of relationship between soil nutrient properties and litterfall nutrient flux, and determined the variability in litterfall nutrient flux with respect to season.

However, the findings revealed that litterfall returns nutrient elements to the soil, and is therefore an essential source of nutrients return by trees to the soil underneath their stands in the process of nutrient cycling. Litterfall nutrients returned varied with the seasons of the year, as well as between the isolated *M. indica* trees and the rainforest control trees. Significant positive correlations were observed between litterfall nutrients returned and soil nutrient elements under the tree stands.

Therefore, from the results of this study, it can be concluded that *M. indica* trees return nutrient elements to the soil underneath their stands and are capable of improving the soil nutrient status characteristics underneath their stands. It is therefore suggested that, growing of *M. indica* trees should be encouraged so as to ensure sustainable management of the deforested rainforest ecosystem

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