HYDROLOGICAL NUTRIENT FLUX IN ISOLATED EXOTIC STANDS OF *MANGIFERA INDICA* LINN: IMPLICATIONS FOR SUSTAINABLE RAINFOREST ECOSYSTEM MANAGEMENT IN SOUTH-SOUTHERN NIGERIA

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ABSTRACT
Nutrient flux by exotic tree species is becoming very relevant to the sustenance and productivity of rainforest environment. Apart from being a source of shade and fruits, the growing of exotic trees within rainforest environment helps to return nutrient elements back to the soil. This study applied scientific approach to investigate rainwash nutrient flux in isolated exotic stands of *Mangifera indica* in south-southern Nigeria. This is with a view to managing the degraded rainforest environment owing to the high relevance of trees to man. Through fall and stemflow, water samples were taken from 15 stands of *M. indica* and rainforest (control) for one year. Throughfall and water samples from open space (incident rainfall) were taken with funnel-type collectors; while samples from stemflow were collected by tying ¾ mm hose round the tree trunks. Samples collected were analysed in the laboratory using standard methods. From the stands of *M. indica* and control sites, annual throughfall volumes (%) were 88.6 and 84.2; while stemflow volumes (%) were 6.2 and 7.3 of the water samples from open space (4325mm). Nutrient elements released back to the soil via the rainwash sources varied. N, P, K, Ca., Mg. and Na. returned via throughfall from stands of *M. indica* were 3.43, 0.78, 9.5, 5.77, 2.17 and 0.81 kg/ha per year; the corresponding values for the control were 6.04, 0.58, 8.5, 4.46, 2.13 and 0.65 kg/ha/yr. While N, P, K, Ca., Mg. and Na. released to the soil via stemflow from stands of *M. indica* were 0.25, 0.04, 0.3, 0.42, 0.26 and 0.04 kg/ha per year; the corresponding values for the control were 0.47, 0.08, 0.7, 0.28, 0.55 and 0.14 kg/ha per year. Exotic trees release nutrients back to the soil under their stands. The nutrient elements released to the soil by exotic trees help to improve soil qualities within the rainforest ecosystem.

Key words: Hydrological, isolated-exotics, *Mangifera indica*, nutrient-flux, rainforest ecosystem.

INTRODUCTION

The relevance of tree stands within the rainforest environment is high. Apart from the resource base of the rainforest, the trees maintain a direct mutual relationship with man in the environment with respect to exchange of gases. However, owing to centuries of anthropogenic disturbances, the originally contiguous and luxuriant rainforest ecosystem is highly degraded; relics of which are now found only in sacred places as island habitats (Ndakara, 2011). Once species of trees of the rainforest origin are cut down for any purpose, their regeneration is difficult while reforestation takes several years to attain maturity. This makes it necessary to incorporate some exotic trees which have high limit of environmental tolerance and viability into the ecosystem.

Indeed, nutrient flux by exotic tree species is now becoming highly relevant to the sustenance and productivity of rainforest environment. Aside the provision of shade and fruits to rural farmers, growing of exotic trees in farmland helps to return nutrient elements back to soil. Through nutrient cycling, trees return nutrient elements to soil via hydrological processes because nutrient cycles in rainforest ecosystem and hydrological cycle are linked. In this process, water acts as a major solvent and agent of transportation for nutrient elements from the tree stands to the soil (Bruijnzeel, 2001).

Although the economic relevance of non-indigenous trees within rainforest in South-southern Nigeria are known, efforts have not been directed to consider their ecological benefits with respect to their viability to protect the environment after the natural plant covers have been removed in the rainforest ecosystem of South-southern

Nigeria.

Essentially, different studies have been conducted in different parts of the world on stemflow and throughfall as aspects of nutrient cycling. Nye (1960) examined the concentrations of organic matter and cycling of nutrients under the wet tropical forests in Ghana; Parker (1983) studied nutrient cycling via stemflow and throughfall in forest; Goller (2005) studied the biogeochemical implications of water conditions in the rainforest of Ecuador; none of these studies examined the aspect of stemflow and throughfall in isolated tree stands. Furthermore, in the Nigerian rainforest ecosystems, the study conducted by Muoghalu and Oakhumen (2000) was carried out in a drier natural rainforest ecosystem; while Adedeji (2008) carried out his study on plantation ecosystems. From these studies, it was difficult to ascertain the amount of nutrient elements returned to the soil by individual tree stands, due to close canopy effects. Therefore, the results of the studies above cannot form a rational basis for understanding the cycling of nutrient elements under isolated trees.

The primary aim of this study is to investigate hydrological nutrients fluxes as potentials of non-indigenous tree stands for sustainable rainforest ecosystem management in south-southern Nigeria. This is with a view to maintaining the expected direct mutual relationship with man who lives within the rainforest environment with respect to exchange of gases and other vital relevance of trees to man. Perhaps this study is the first research on the cycling of nutrient elements by isolated exotic trees in the rainforest ecosystem within south-southern Nigeria.

MATERIALS AND METHODS

Study Area

This research was carried out on the isolated exotic stands of *Mangifera indica* (Mango) in the moist tropical rainforest of Orogun within south-southern Nigeria. Orogun region falls within the humid sub-equatorial climate of Af Koppen's classification, with annual rainfall above 2000mm, and average temperature of about 26ºC (Ndakara, 2014). The natural vegetation is the moist evergreen tropical rainforest with tree forms ranging in strata from shrubs to exceedingly tall members.

Experimental Design and Samples Collection

A detailed reconnaissance survey revealed that the isolated stands of exotic trees contained in this study area have no specific pattern of distribution. Hence, *M. indica* which is a commonly found cultivated tree species was selected for this study due to its immense importance.

This study was conducted in the existing five quarters of Orogun clan (Umusu, Unukpo, Imodje, Emonu and Ogwa), These quarters were so used to ensure that every unit of the study area was evenly covered. From each of the quarters, 3 stands of *M. indica* were selected, making a total of 15 tree stands sampled. In selecting the isolated tree stands, considerations were given to those trees which were not exposed to sweeping and burning which can affect soil properties. Also, the trees were carefully selected such that their canopies were well separated from those of other trees. In each of the quarters, a control site was established for incident rain water collection from the open spaces. In quantitative characterisation of vegetation, sample areas known as quadrats are delimited for investigation (Chapman, 1976). Thus, in each of the quarters, a plot measuring 30 by 30 m sub-divided into 3 quadrats measuring 30 by 10 m was selected from the adjoining rainforest to serve as control for this research (this makes 15 sample sites established within the control).

Water samples from the rainwash and incident rainfall were collected twice in a month for a period of 12 months (February 2010 to January 2011), except in December and January where rainfall was observed once respectively. However, data collected for stemflow, throughfall, litterfall as well as that from open space water were reported as mean monthly data for a given sample site so as to give the monthly data set for the 12 months data collection exercise.

Samples from stemflow were collected using interception method by tying rubber hose of ¾ mm in diameter round the tree trunks, sealed with bitumastic paste and channelled into 5 litter clean gallons; while samples of throughfall and rain water from open space were collected using improvised funnel-type collector with (10 litre content) buckets placed on stools 3 feet above the ground. The buckets were sealed with polythene sheets, and funnels fixed at the top to intercept the water before it gets to the ground. Samples of rainwash collected for all rainfall events were put into labelled sampling bottles and taken to the laboratory for analysis on the concentrations of nitrogen, phosphorus; potassium, calcium, magnesium and sodium respectively, Figure 1 to 12, and therefore, ascertain the amount of nutrient elements returned to the soil by the trees in the process of nutrient cycling. Three rain gauges (one placed under each *M. indica*, control plot and open space respectively) were used to confirm the effectiveness of the funnel-type collector, to ensure integrity of samples collected.

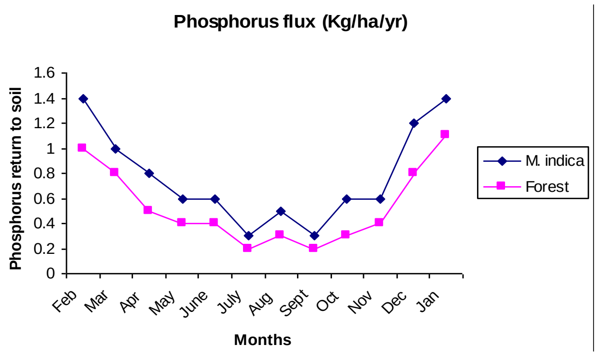

Figure 2. Phosphorus flux

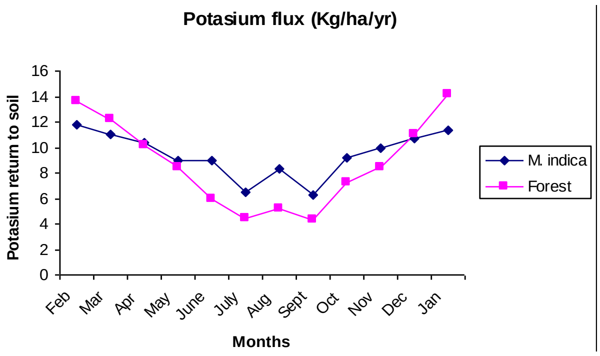

Figure 3. Potassium flux

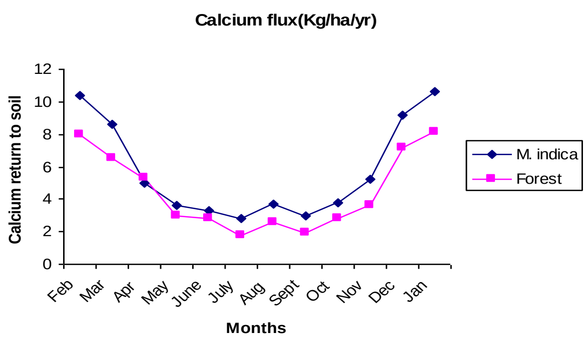

Figure 4. Calcium flux

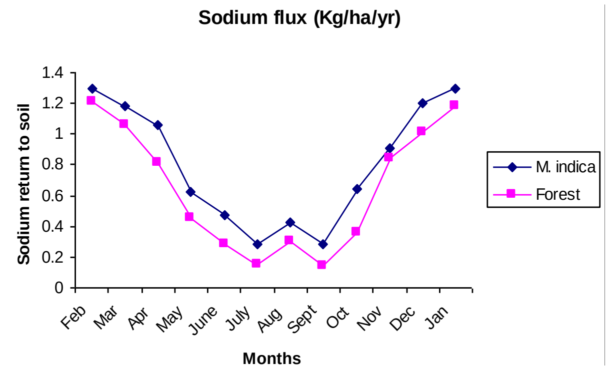

Figure 5. Sodium flux

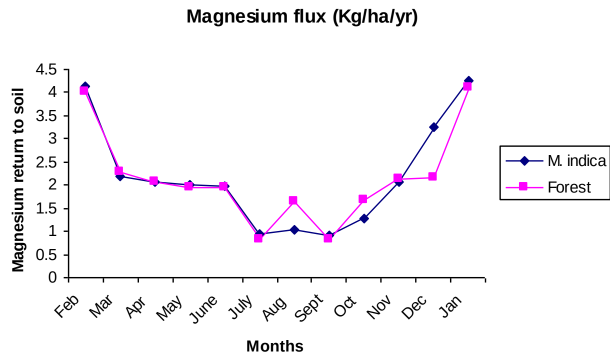

Figure 6. Magnesium flux

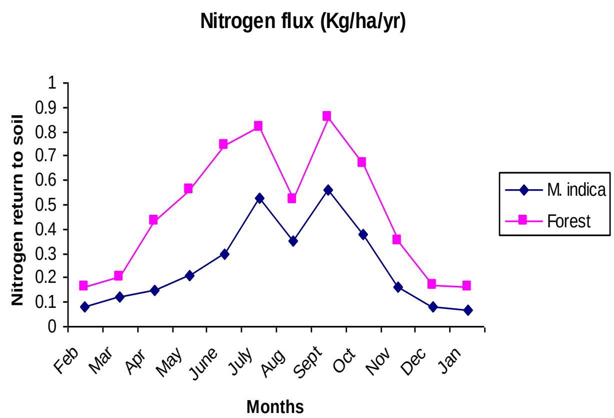

Figure 7. Nitrogen flux

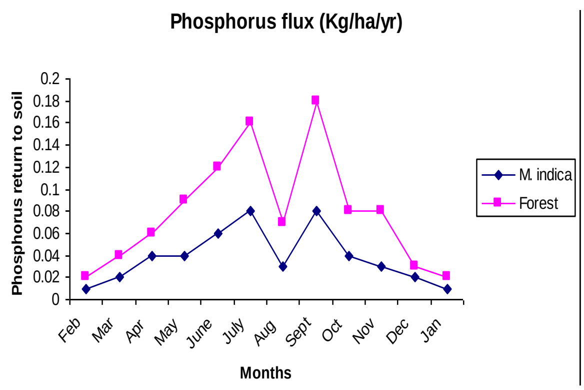

Figure 8. Phosphorus flux

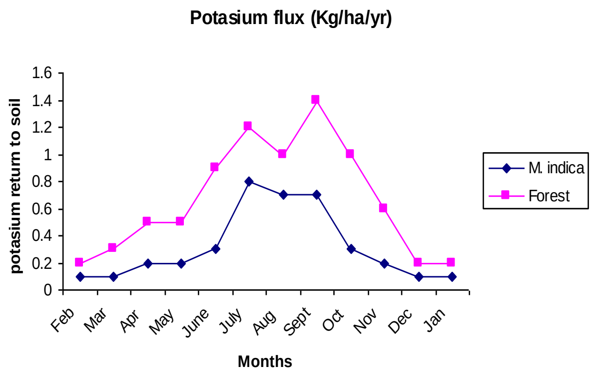

Figure 9. Potasium flux

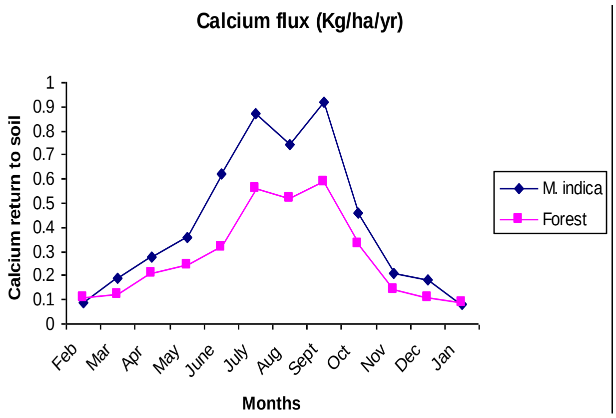

Figure 10. Calcium flux

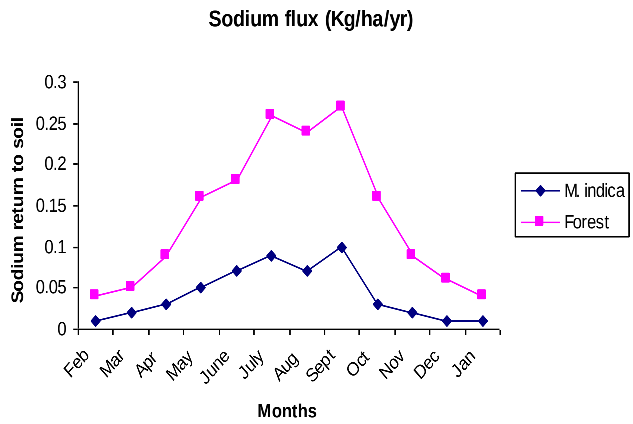

Figure 11. sodium flux

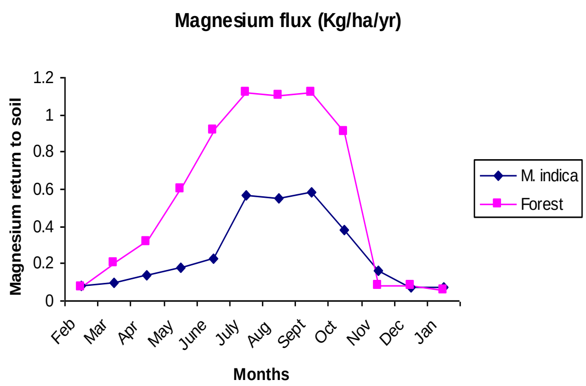

Figure 12. Magnesium flux

Laboratory Analyses of Samples

The samples of water were filtered using ash-free filter papers before analysis commenced (Schleicher and Schuell, blue band 589³), except for the measurement of pH which did not involve the use of filtered water samples. Thus measured nitrogen and phosphorus concentrations could not be termed dissolved; instead the term "total organic" (TO) was used. In the determination of total N and P, a segmented Flow Analyser (SANplus, SA 2000/4000, Skalar Analytical BV, The Netherlands) was used. Detection limits were (0.04 mg / l for P and 0.05 mg / l for PO_4-P) in rainfall, stemflow and throughfall. The TON and TOP were derived from the difference between the total amounts and the inorganic forms (i.e TON = N_{tot} - NH_4 – N - (NO_3 – N + NO_2 – N), TOP = $P_{tot,}$ - PO_4P).

Nutrient cations (such as Sodium, Calcium, Magnesium and Potasium) concentrations were gotten by atomic absorption spectrometry. However, the pH of water was measured electro-chemically. The determination of throughfall and the nutrients returned was based on the tree projected crown area; while determination by chemical enrichment was the basis for the determination of stemflow nutrients returned, which was based on the enrichment ratio. The enrichment ratio depends on the total amount of nutrients from stemflow in relation to each nutrient element concentration from incident rainfall, provided that the rain gauge occupies equal area with the tree trunks' basal area. The enrichment ratio becomes valid if leaching occurs (i.e. chemical concentration of rainwash is greater than the mean chemical concentration of the incident gross precipitation for a nutrient element).

Data Analysis

Data from laboratory analyses were tested by both descriptive and inferential statistical techniques using SPSS 15.0 version. The technique of mean was used to compute the mean values for nutrient elements returned. Graphs were used to show the monthly volume of rain-wash. Paired-Samples t-test technique was used to compute the differences in nutrient elements returned via rainwash between the stands of *M. indica* and the rainforest trees.

RESULTS

Volume of Rainwash

The volume of rainwash varied within the months of the year. Rainfall events were observed in all the months within which samples were collected. Rainwash volumes varied amongst the stemflow, throughfall and the incident rainfall.

The total measured annual volume of water from throughfall in *M. indica* and rainforest trees are 3831.95 and 3641.65 mm. These values accounted for 88.6 and 84.2% of the measured incident rainfall volume of 4325 mm. These values of water volume are about the same range of throughfall values reported for Amazon basin rainforest area with 78-91% (Elsenbeer et al., 1994; Filoso et al., 1999); tropical rainforests of south western Amazonia with 89.9% by Germer *et al*. (2006); tropical rainforest of Cameroun with 92.4 – 96.6% by Chunyong *et al.* (2004); and in Nigerian rainforest with 78.8% by Muoghalu and Oakhumen (2000). The corresponding values of stemflow volume in the stands of *M. indica* and adjoining rainforest are 268.2 mm and 315.7 mm which accounted for 6.2 and 7.3% of the measured incident rainfall volume of 4325 mm. These values are similar in range with stemflow values reported for Nigerian rainforest with 5.2% (Muoghalu and Oakhumen, 2000). The volumes of throughfall water and that of stemflow varied with the seasons of the year.

Nutrient Concentrations and Returns in Rainwash and water from open space

Generally, rainwash samples contained nutrient elements. However, the concentrations and return of the elements varied between the stands of *M. indica* and trees from the rainforests (Tables 1 and 2).

Table 1. **Nutrient concentrations in mg l^{1} yr^{-1}**

Nutrient elements	Throughfall		Stemflow		Incident rainfall
	M. indica	Rainforest	*M. Indica*	Rainforest	
Nitrogen	5.63	6.64	0.44	0.71	0.20
Phosphorus	5.42	4.41	0.63	0.54	0.16
Potassium	52.77	65.39	10.36	12.12	2.43
Calcium	27.83	31.27	5.42	5.80	2.09
Sodium	0.98	0.90	0.39	0.43	0.08
Magnesium	21.29	19.63	3.90	4.69	2.16

Source. Field survey (2010-2011).

Table 2. Annual nutrients returned in kg/ha/yr

Nutrient element	Throughfall		Stemflow	
	M. Indica	Rainforest	*M. Indica*	Rainforest
Nitrogen	3.43	6.04	0.25	0.47
Phosphorus	0.78	0.54	0.04	0.08
Potassium	9.47	8.76	0.32	0.67
Calcium	5.77	4.46	0.42	0.28
Sodium	0.81	0.65	0.04	0.14
Magnesium	2.17	2.13	0.26	0.55

Source. Field work.

In the throughfall and stemflow, the concentrations of N, K and Ca; and those of N, K, Ca, Na and Mg are respectively greater in rainforest than in the stands of *M. indica*. Generally, the nutrient concentrations in throughfall were greater than those in stemflow and the water from open space (Throughfall > stemflow > incident rainfall). Throughfall has the highest nutrient concentrations while that of stemflow is very low. However, nutrients enrichment in rainwash is as a result of nutrients leached out of the plant tissue, coupled with the capture of airborne (aerosols) by the tree stands.

The nutrients returned to soil underneath tree stands varied between throughfall and stemflow, and also between the seasons of the year (Table 2). Nutrient elements returned to soil underneath tree stands were higher via through fall than stemflow. Apart from nitrogen, nutrient elements returned by *M. indica* via throughfall are higher in amount than those from rainforest. In opposite trend, aside calcium, all other nutrient elements returned to soil via stemflow were higher in rainforest than in the stands of *M. indica*.

DISCUSSION

Rain-wash returns nutrient elements to the soil from the stands of *M. indica*. However, throughfall was observed to return higher amount of nutrients to the soil than stemflow (throughfall > stemflow). Nutrients returned to the soil via rainwash are readily available to plants. Higher concentrations of dissolved nutrient elements were contained in rainwash than in water from the open space. While some of the enrichment is as a result of leaching of materials out of the plant tissue, part of it result from the airborne particles (aerosols) captured by the tree plants (Bruijnzeel, 2001). Nutrients from stemflow are generally a small fraction (about 15%) of those in throughfall. The highest concentration and returns of all nutrient elements through rainwash was via throughfall, followed by stemflow and the lowest in incident rainfall. These observations are in line with studies by Muoghalu and Oakhumen (2000) in a Nigerian secondary lowland rainforest.

CONCLUSION

From the results of this study, it can be concluded that the application of science is vital to the quest for effective approaches to the management of degraded environment. Since the exotic stands of *M. indica* is capable of adding nutrient elements to soil thereby supporting their growth and production through nutrient cycling, their introduction into the environment will replace the lost mutual interrelationship which exists between plants and man with respect to exchange of gasses and other related importance of tree plants to mankind. Since the exotic stands of *M. indica* are viable in rainforest environment, they can therefore be considered in the management drive for environmental sustainability within the rainforest, especially as it takes longer years for trees of the rainforest to attain equilibrium with the regional climate.

Conflict of interest

The author did not declare any conflict of interest

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