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CORRELATION ANALYSES OF MEASURES OF PLANT BIOMASS AND SOIL ATTRIBUTES UNDER BUSH MANGO AND LOWLAND RAINFOREST TREES IN NIGERIA.

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ABSTRACT

Investigating the relationship between plants and soils is important for environmental management. This study looked at how measures of plant biomass correlated with soils under bush mango and lowland rainforest. The study adopted quasi experimental design, and applied stratified random sampling to subdivide the study area into 10 strata. Two sampling sites each was chosen from each strata (being bush mango stand and adjacent rainforest) thus, made up 20 sampling sites. Data collected were tree heights, tree diameters, and soil samples. Abney level was used to determine tree heights, girthing tape for tree diameters, and core sampler for soil samples collected from 0-15cm and 15cm-30cm soil depths. Laboratory analyses of the soil samples maintained standard procedures to obtain the concentrations of soil elements. Data generated were analysed with Pearson's bivariate correlation statistics. Findings showed that biomass of the standing bush mango and adjacent rainforest trees correlated positively with soil elements under their stands. From the stands of bush mango, tree heights correlated positively with soil bulk density (0.135), porosity (0.151), water holding capacity (0.256) and sand (0.438); while tree diameters correlated positively with total organic matter (0.20), potassium (0.457), bulk density (0.592), water holding capacity (0.473), silt (0.562) and clay (0.072). Within the rainforest, tree heights positively correlated with total organic matter (0.302), potassium (0.613), bulk density (0.064), porosity (0.122), silt (0.755*), and clay (0.183); while tree diameters positively correlated with total nitrogen (0.325), porosity (0.036), water holding capacity (416), sand (0.548) and clay (0.191). Since measures of plant biomass of the stands of bush mangoes positively correlated with soil properties, their conservation as rainforest species is encouraged for proper ecosystem functioning and management.

KEYWORDS: Bush mango, plant biomass, plant-soil relationship, rainforest management, species conservation.

1: INTRODUCTION

Different species of trees immobilize nutrients selectively; hence they impact on the soil nutrients in varied ways (Ndakara & Osokpor, 2023). The capacity and ability of given trees in any environment to maintain the soils within is determined by the level of soil fertility underneath their stands, as well as the closed cycling of nutrient elements within the ecosystems they inhabit.
However, decline in the nutrient elements of the soil usually occurs once the natural forests are converted into monocultural plantations of different tree species, leading to biodiversity loss (Kazumichi, Makoto, Kaoru, Tomoaki, Kanehiro, Benjamin, 2018), as a result of destabilization in the cycling of nutrient elements within the ecosystem (Aweto, 2001).
Indeed, the ecological impact of indigenous species of rainforest trees with respect to ecosystem functioning are known,

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but their contributions of nutrient elements to the soil as individual species of rainforest trees, together with the levels of relationships which they maintain between their biomass parameters and the soil properties under their stands have not been clearly defined because of the close canopy maintained within typical rainforest (Muoghalu & Oakhumen, 2000; Ndakara, 2014). The aboveground biomass attributes of rainforest trees have been said to be interrelated with the soil properties under their stands, and they influence one another (Ndakara, 2011; Kharel et al., 2019). The correlations between plants measures of biomass attributes and the soil properties under them indicate that soil nutrient status is directly proportional to the size of plants biomass parameters (Kharel et al., 2019).

Although many researches have been carried out with respect to uptake and returns of nutrient elements within rainforest (Liu, Luo, Li, Wang, Lu, Liu. 2015), and in different succession fallows (Saimo, Maria, Mario, Jhonathan, Arturo, Betania & Geraldo, 2019), not much has been known regarding changes in the processes, when succession fallows are replaced with agro-forestry plantations (Ndakara, & Ohwo, 2022a). This makes it necessary to assess the salient changes that take place in the rainforest soil qualities when being replaced with agro-forestry plantations. A study by Ndakara and Ofuoku (2020) reported observed build-up of organic matter and other nutrient elements under trees, which could be as a result of litterfall and rainwash directly under the tree canopies. Gruba and Mulder (2015) reported that relatively minute changes in bulk density could affect root development in plants; while total porosity was found to determine the levels of soil aeration and correlated positively with plants' nutrients. A study by Barrios et al., (2012) reported that soil chemical parameters are lower under cocoa trees than under forest; and that soil nutrients reduced increasingly with age of land cultivation within rainforest zone. However, the study by Ndakara and Ofuoku (2020), reported observed correlations which were positive between biomass and soil attributes.

The tree species type occupying an ecosystem has the capacity to modify the soil properties (Phil-Eze, 2010; Pawlik, Burkepile & Thurber, 2016; Ndakara & Osokpor, 2023). Several researches have reported observed variations in soil chemical properties within different ecosystems, resulting from differences in tree species contained (Fabio & Reinaldo, 2012; Kharel et al., 2019). Tree species impact on soil exchangeable cations, CEC, soil pH values and base saturation percentage (Mueller, Gerber, Johnston, Ray, Ramankutty & Foley, 2012; Gruba, Mulder & Brozek, 2013; Gruba & Mulder, 2015). As several tree species are capable of improving soil exchangeable cations thus, boosting the soil cation exchange capacity, some other tree species contribute little to soil exchangeable cations thus, low CEC observed under their stands (Crouse, 2015; Ndakara & Ohwo 2022b). Several studies have been conducted in the rainforest ecosystem, with respect to soil-plant relationships (Phil-Eze, 2010; Ndakara, 2011; Fabio & Reinaldo, 2012; Ndakara, 2012; Crouse, 2015; Kazumichi et al., 2018). From these studies, information regarding the interrelationship between biomass parameters of standing bush mango trees and soil properties underneath them were not reported because studies within this study area were focused on communities, where the influence of a particular tree species could not be isolated. Therefore, the results from such studies would not be appropriate as generalised findings that can explain soil-plant relationships since different species of trees exert varying impact on soil (Ndakara, 2011; Hunter, 2013). Different trees within the tropical environments have been reported to exert varying degrees of impact on the soil underneath their stands (Ndakara, 2016; Kazumichi et al., 2018; Fabricio et al., 2018). Therefore, stands of bush mango in the rainforest ecosystem should have exerted impacts on the soil physical and chemical properties. In the same vain, measures of plant biomass of the stands of bush mango should either be capable of deteriorating the soil properties or assist in improving the soil characteristics.

Therefore, this study aimed at ascertaining the extent to which measures of plant biomass of the standing bush mango and rainforest trees are related with the soil under their stands. This is with a view to determining the extent to which stands of bush mango influence the rainforest soil physical and nutrient elements.

1.2: Conceptual Applications

The concept of "plant-soil relationship" was adopted as the framework for this research. This concept is based on the interactions and interrelationships that exist between the plants and soils on which they grow in any given ecosystem; with major focus on the exchange of soil chemical elements and water, between the plants and the soil. Plants within an ecosystem are closely related to the soil, and they interact with each other. The levels of interactions take from the growth of the plants through their life-time to death, and in a circularly causal direction (Aweto, 2001; Ndakara, 2014). Plants are established on the soils, and through their roots, they absorb water and nutrient elements from the soil. The nutrient elements are transported through the parts of the standing plants for their use (Hunter, 2013; Osokpor & Ndakara, 2023). Through the different stages of the plants growth and development, the plants utilise the nutrients got from the soil. However, as the plants develop to climax, they shed their leaves, flowers and branches as litterfall, which in turn add nutrients to the soil when they decay. When the plants die, they decay to enhance the soil nutrient elements again. Therefore, plants interactions with soils are directly linked to nutrient cycling (Kharel, *et al.*, 2019; Ndakara & Ohwo, 2022a).

Different researches have investigated aspects of interrelationships between the biomass parameters of standing plants in different ecosystems. Some of such studies by (Muoghalu & Oakhumen, 2000; Phil-Eze, 2010; Feldpausch, *et al*., 2012; Londe, De Sousa, Kozovits, 2016; Kazumichi, Makoto, Kaoru, Tomoaki, Kanehiro, Benjamin, 2018) were conducted in communities to examine the relationship between plants and the soils within different ecosystems. While the studies carried out by (Aweto & Molelee, 2005; Barrios, Sileshi, Shepherd, Sinclair, 2012; Ndakara & Ohwo, 2022) investigated plant-soil relationships in plantations within different environments; other studies looked at how alien plants and the soils within the environment are interrelated (Ndakara & Ofuoku, 2020; Suzuki, *et al*., 2021).

In summary therefore, the circularly causal interrelationship between soil elements and biomass characteristics of the standing bush mango plants within the lowland rainforest indicates that a more realistic approach to research on the relationships between plant and soil has to be within the conceptual framework of "Plant-Soil Relationship" (Ndakara, 2012; Ndakara, 2016; Kazumichi *et al*., 2018). Hence, this study applied the "Plant-Soil Relationship" concept to explain how biomass attributes of plants correlate with chemical elements of the soils on which they grow.

3. Study Area

This research was conducted in Isoko, within the southern Nigeria lowland rainforest. Geographically, the latitudinal location situates between 5⁰33'N and 5⁰14'N, while the longitudinal location situates between 6⁰04'E and 6⁰24'E (Fig. 1).

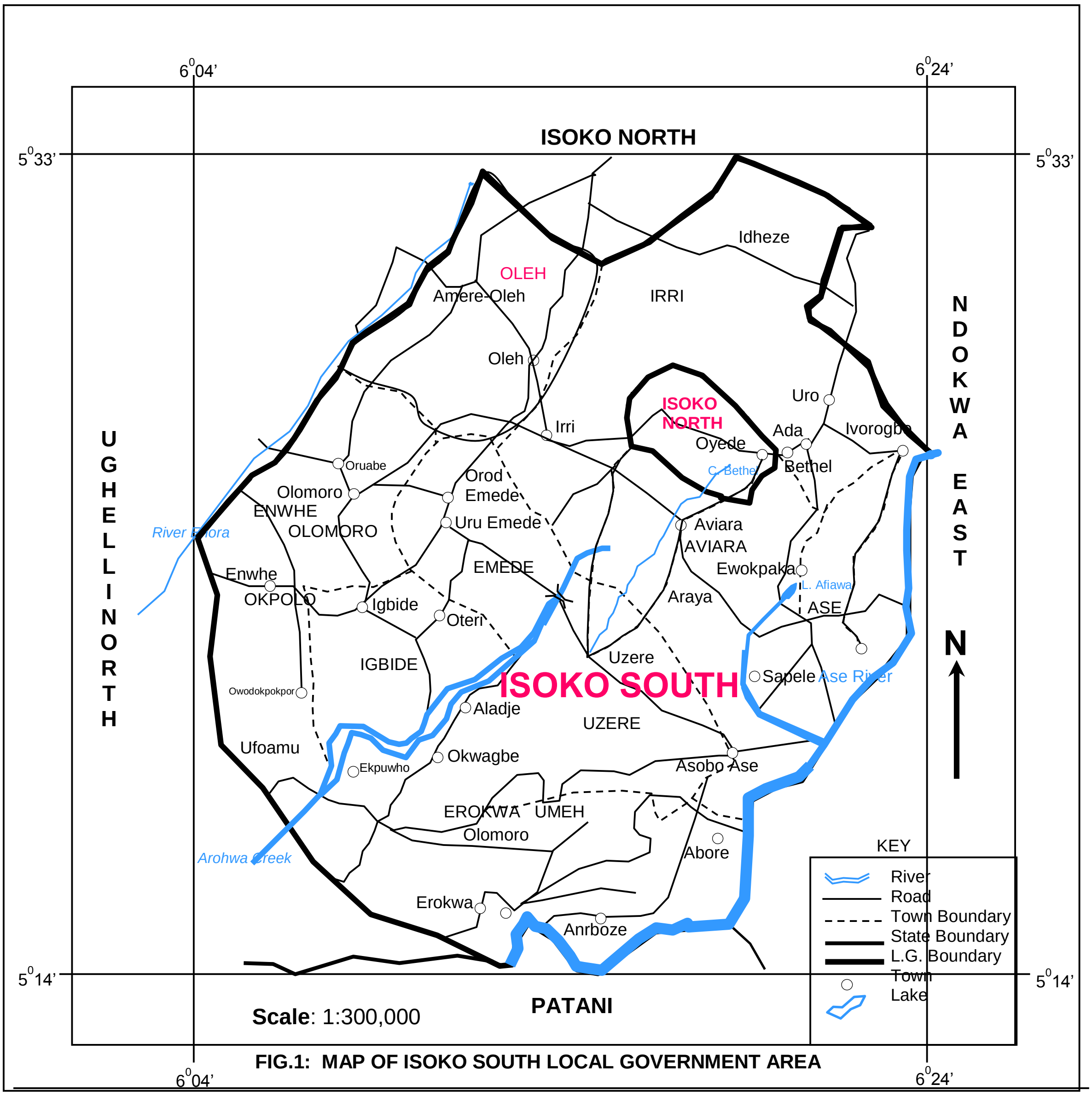

FIG.1: MAP OF ISOKO SOUTH LOCAL GOVERNMENT AREA

***Source**: Ministry of Lands, Survey & Urban Development, Asaba, (2022)* The land area covered by this region approximates 668km^2. The topography is low lying, with some parts of the region flooded and submerged seasonally. The climatic characteristics are defined by the regional location as humid tropical with two distinct prevailing tropical air-masses as tropical continental (cT) and tropical maritime (mT). These two air-masses prevail throughout the year and define the seasons as dry and rainy seasons respectively (Ndakara & Eyefia, 2021). The annual mean rainfall is between 2000mm and 4000mm, while that of temperature falls between 26^{0}C and 28^{0}C. The prevailing plant communities are the tropical rainforest and the freshwater swamp forest, with derived savannah which interspersed the environment within both the well-drained and waterlogged areas. The vegetal physiognomy of the rainforest is characterized with evergreen and three-tier stratifications. The soils are typical of mesomorphic and hydromorphic, which explains the well-drained and water-logged soils respectively. The soil size fraction comprises sand, silt and clay which dominate the environment. The soils within the environment support the growth and production of arable crops and agro-forestry (Ndakara & Osokpor, 2023). Some species of trees contained in the rainforest are *Piptadenastrium africanum, Terminalia superba, Antiaris toxicaria, Ricinodendron heudelotii, Pentaklepta macrophylla and Irvingia gabonensis* (bush mango). Many of the tree species have become so scanty such that in many areas, their stands are not seen (Zhang, Devers, Desch, Justice & Townshend, 2005; Obi & Ndakara, 2020; Suzuki, Kobayashi, Seidl, Senf, Tatsumi, Koide, Azuma, Higa, Koyanagi, Qian, Kusano, Matsubayashi & Mori, 2021; Ohwo & Ndakara, 2022).

4: METHODOLOGY

This research used the quasi experimental approach as the research design, while the study area was stratified into 10 using the stratified random sampling technique. Two sampling sites each were established in each strata; one being bush mango stand in isolation, and the other being adjacent rainforest that was used as the control for the study. Therefore, 20 sampling sites were investigated in all. The plant biomass data collected were the tree heights and their diameters, while samples of soil were taken from 0-15cm and 15cm-30cm of soil profiles under the tree stands. Abney level was utilized to determine the tree heights, girthing tape was utilized for the tree diameters, and core sampler for soil samples collection. Laboratory analyses of the soil samples followed standard procedures to obtain the concentrations of total nitrogen (N), available phosphorus (P), total organic carbon which was converted into total organic matter (TOM), exchangeable potassium (K), bulk density (Bdensity), total porosity, water-holding capacity (WHC), particle size distributions. The Pearson's bivariate correlation statistics was employed to analyse the data, and the results are presented in tables 1 and 2.

5. RESULTS AND DISCUSSION

5.1: Correlations between measures of Plant Biomass and Soil under bush mango

The level of relationship between measures of biomass features of standing trees with the soil properties under their stands varied. This is as to be expected because earlier studies by Hunter (2013), Ndakara (2016), Kazumichi, et al. (2018) revealed that different species of trees impact on the soil under their stands differently. In other to ascertain the relationship that exist between the soil and standing biomass features of bush mango, test of hypothesis was carried out. The hypothesis states that 'there is no positive correlation between the measures of plant biomass and soil under stands of bush mango. Pearson's bivariate correlation statistical technique was used to test the correlation level to show the level of relationships which exist between the plant biomass parameters of stands of bush mango and the soil parameters under their stands.

Table 1: Correlation Outputs for the Relationships between Measures of Plant Biomass and Soil under Bush Mango Stands

Correlations

		Height	DBH	N	P	TOM	K	Bdensity	Porosity	WHC	Sand	Silt	Clay
Height	Pearson Correlation	1	.023	-.447	-.095	-.300	-.053	.135	.151	.256	.438	-.380	-.457
	Sig. (2-tailed)		.949	.196	.794	.399	.885	.710	.677	.475	.206	.278	.184
	N	10	10	10	10	10	10	10	10	10	10	10	10
DBH	Pearson Correlation	.023	1	-.186	-.426	.020	.457	.592	-.297	.473	-.529	.562	.072
	Sig. (2-tailed)	.949		.607	.220	.957	.184	.071	.404	.167	.116	.091	.844
	N	10	10	10	10	10	10	10	10	10	10	10	10
N	Pearson Correlation	-.447	-.186	1	.110	-.386	-.149	-.231	.728*	-.681*	.442	-.527	.137
	Sig. (2-tailed)	.196	.607		.761	.270	.681	.521	.017	.030	.201	.117	.707
	N	10	10	10	10	10	10	10	10	10	10	10	10
P	Pearson Correlation	-.095	-.426	.110	1	-.092	-.323	.031	-.132	-.505	.334	-.326	-.079
	Sig. (2-tailed)	.794	.220	.761		.801	.363	.931	.716	.136	.346	.357	.829
	N	10	10	10	10	10	10	10	10	10	10	10	10
TOM	Pearson Correlation	-.300	.020	-.386	-.092	1	.677*	-.323	-.498	.630	-.530	.557	.078
	Sig. (2-tailed)	.399	.957	.270	.801		.032	.362	.143	.051	.115	.095	.831
	N	10	10	10	10	10	10	10	10	10	10	10	10
K	Pearson Correlation	-.053	.457	-.149	-.323	.677*	1	-.195	-.220	.699*	-.343	.373	-.040
	Sig. (2-tailed)	.885	.184	.681	.363	.032		.590	.540	.025	.331	.288	.913
	N	10	10	10	10	10	10	10	10	10	10	10	10
Bdensity	Pearson Correlation	.135	.592	-.231	.031	-.323	-.195	1	-.233	.010	-.275	.242	.299
	Sig. (2-tailed)	.710	.071	.521	.931	.362	.590		.518	.979	.443	.501	.401
	N	10	10	10	10	10	10	10	10	10	10	10	10
Porosity	Pearson Correlation	.151	-.297	.728*	-.132	-.498	-.220	-.233	1	-.435	.649*	-.733*	-.004
	Sig. (2-tailed)	.677	.404	.017	.716	.143	.540	.518		.209	.043	.016	.992
	N	10	10	10	10	10	10	10	10	10	10	10	10
WHC	Pearson Correlation	.256	.473	-.681*	-.505	.630	.699*	.010	-.435	1	-.626	.654*	.089
	Sig. (2-tailed)	.475	.167	.030	.136	.051	.025	.979	.209		.053	.040	.807
	N	10	10	10	10	10	10	10	10	10	10	10	10
Sand	Pearson Correlation	.438	-.529	.442	.334	-.530	-.343	-.275	.649*	-.626	1	-.977**	-.528
	Sig. (2-tailed)	.206	.116	.201	.346	.115	.331	.443	.043	.053		.000	.117
	N	10	10	10	10	10	10	10	10	10	10	10	10
Silt	Pearson Correlation	-.380	.562	-.527	-.326	.557	.373	.242	-.733*	.654*	-.977**	1	.339
	Sig. (2-tailed)	.278	.091	.117	.357	.095	.288	.501	.016	.040	.000		.338
	N	10	10	10	10	10	10	10	10	10	10	10	10
Clay	Pearson Correlation	-.457	.072	.137	-.079	.078	-.040	.299	-.004	.089	-.528	.339	1
	Sig. (2-tailed)	.184	.844	.707	.829	.831	.913	.401	.992	.807	.117	.338	
	N	10	10	10	10	10	10	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 1 presents the correlation outputs for the relationships between measures of plant biomass and soil under stands of bush mango. The results showed that tree heights positively correlated with bulk density (0.135), total porosity (0.151), water holding capacity (0.256) and sand fraction (0.438); while tree diameters positively correlated with organic matter concentrations (0.20), exchangeable potassium concentrations (0.457), bulk density (0.592), WHC (0.473), silt fraction (0.562) and clay fraction (0.072) respectively.

While tree heights only correlated positively with the soil physical parameters; tree diameters correlated with both physical and chemical properties of the soil. In testing the hypothesis which states that there is no positive correlation between measures of plant biomass parameters and soil under stands of bush mango, the null hypothesis was rejected. This is because the observed correlations are positive. Therefore, there is a positive correlation between the measures of plant biomass and soil under stands of bush mango. This finding confirmed the reports of earlier studies by Hunter (2013), and Kazumichi et al. (2018) where plant biomass were reported to be interrelated with the soil under their stands. However, the general analysis of soil-plant relationship exposed the extent to which plants and the soil are interrelated in the process of cycling nutrient elements between plants and soils (Ndakara, 2014).

5.2: Correlations between Biomass and Soil Attributes under Rainforest

The extent to which the biomass of standing trees in the rainforest correlate with the rainforest soil was also investigated. This was achieved by testing the hypothesis which states that ‘there is no positive correlation between the biomass and soil attributes under the adjacent rainforest. Pearson’s bivariate correlation statistics was employed to ascertain the correlation level, so as to know the extent to which measures of plant biomass and soil are related within the rainforest trees.

Table 2: Correlation Outputs for the Relationships between Measures of Plant Biomass and Soil under Rainforest

Correlations

		Height	DBH	N	P	TOM	K	Bdensity	Porosity	WHC	Sand	Silt	Clay
Height	Pearson Correlation	1	-.352	-.515	-.077	.302	.613	.064	.122	-.072	-.441	.755*	.183
	Sig. (2-tailed)		.319	.128	.832	.397	.059	.860	.737	.844	.202	.012	.612
	N	10	10	10	10	10	10	10	10	10	10	10	10
DBH	Pearson Correlation	-.352	1	.325	-.067	-.439	-.622	-.232	.036	.416	.548	-.134	.191
	Sig. (2-tailed)	.319		.359	.853	.204	.055	.518	.921	.232	.101	.713	.597
	N	10	10	10	10	10	10	10	10	10	10	10	10
N	Pearson Correlation	-.515	.325	1	.137	-.282	-.085	-.748*	-.289	-.188	.296	-.510	-.093
	Sig. (2-tailed)	.128	.359		.706	.429	.816	.013	.419	.603	.406	.132	.799
	N	10	10	10	10	10	10	10	10	10	10	10	10
P	Pearson Correlation	-.077	-.067	.137	1	.411	-.297	.281	.563	.269	-.247	-.575	-.170
	Sig. (2-tailed)	.832	.853	.706		.238	.405	.431	.090	.452	.491	.082	.638
	N	10	10	10	10	10	10	10	10	10	10	10	10
TOM	Pearson Correlation	.302	-.439	-.282	.411	1	-.125	.412	.382	.137	-.909**	.103	.128
	Sig. (2-tailed)	.397	.204	.429	.238		.730	.237	.276	.705	.000	.777	.725
	N	10	10	10	10	10	10	10	10	10	10	10	10
K	Pearson Correlation	.613	-.622	-.085	-.297	-.125	1	-.293	-.232	-.559	-.038	.423	-.256
	Sig. (2-tailed)	.059	.055	.816	.405	.730		.412	.520	.093	.916	.223	.475
	N	10	10	10	10	10	10	10	10	10	10	10	10
Bdensity	Pearson Correlation	.064	-.232	-.748*	.281	.412	-.293	1	.628	.433	-.276	-.002	-.103
	Sig. (2-tailed)	.860	.518	.013	.431	.237	.412		.052	.211	.441	.996	.778
	N	10	10	10	10	10	10	10	10	10	10	10	10
Porosity	Pearson Correlation	.122	.036	-.289	.563	.382	-.232	.628	1	.429	-.157	-.030	-.432
	Sig. (2-tailed)	.737	.921	.419	.090	.276	.520	.052		.216	.664	.935	.212
	N	10	10	10	10	10	10	10	10	10	10	10	10
WHC	Pearson Correlation	-.072	.416	-.188	.269	.137	-.559	.433	.429	1	-.066	-.103	-.002
	Sig. (2-tailed)	.844	.232	.603	.452	.705	.093	.211	.216		.857	.776	.996
	N	10	10	10	10	10	10	10	10	10	10	10	10
Sand	Pearson Correlation	-.441	.548	.296	-.247	-.909**	-.038	-.276	-.157	-.066	1	-.317	-.357
	Sig. (2-tailed)	.202	.101	.406	.491	.000	.916	.441	.664	.857		.372	.312
	N	10	10	10	10	10	10	10	10	10	10	10	10
Silt	Pearson Correlation	.755*	-.134	-.510	-.575	.103	.423	-.002	-.030	-.103	-.317	1	.337
	Sig. (2-tailed)	.012	.713	.132	.082	.777	.223	.996	.935	.776	.372		.341
	N	10	10	10	10	10	10	10	10	10	10	10	10
Clay	Pearson Correlation	.183	.191	-.093	-.170	.128	-.256	-.103	-.432	-.002	-.357	.337	1
	Sig. (2-tailed)	.612	.597	.799	.638	.725	.475	.778	.212	.996	.312	.341	
	N	10	10	10	10	10	10	10	10	10	10	10	10

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2 presents the correlation outputs for the correlations between the measures of plant biomass and soil under the adjacent rainforest. The results showed that tree height has positive correlations with organic matter (0.302), exchangeable potassium (0.613), bulk density (0.064), total porosity (0.122), silt fraction (0.755*), and clay fraction (0.183); while tree diameter has positive correlations with total nitrogen (0.325), total porosity (0.036), water holding capacity (416), sand fraction (0.548) and clay fraction (0.191) respectively.

Both tree height and tree diameter had positive correlations with the soil physical and chemical elements. In testing the hypothesis which states that 'there is no positive correlation between the measures of plant biomass and soil elements under the rainforest', the stated null hypothesis was rejected. This is because positive correlations were observed between the biomass parameters of the stands of rainforest trees and the soil properties under their stands. Therefore, positive correlations exist between the measures of plant biomass and soil elements under the adjacent rainforest.

The findings about the correlations between the measures of plant biomass of the rainforest trees and soil characteristics under their stands are in line with findings earlier reported in the studies carried out by Hunter (2013), and Kazumichi et al. (2018) where plant biomass were reported to be interrelated with properties of soil under their stands. Plants naturally establish themselves on the soil from which they obtain nutrient elements and water, which support their effective growths and productions (Fabricio, et al., 2018). This process typically involves the plant biomass attributes which help in the movements of the nutrient elements and water for the plants' use. Also, the general account of soil-plant relationship revealed the extent which soil and plants are interrelated in the process of cycling nutrient elements (Ndakara, 2014). The study by Ndakara and Ofuoku (2020) also observed positive correlations between biomass parameters and soil under rainforest trees. The phenomena exchange and interactions between plants and soil with respect to nutrient elements are circularly causal in relationship.

6. CONCLUSION AND RECOMMENDATIONS

Plants and soil within the rainforest environment interact through the plants' absorption of nutrient elements and water from the soil, as well as the returns of the nutrient elements earlier absorbed back to the soil from which they were derived. The nutrients taken up by plants are stored in the biomass parameters of the standing plants, from where they are used up for growth and production (Hunter, 2013). Therefore, the extent to which trees are related with soil under their stands can be determined by their biomass characteristics.

This study showed that biomass of the standing bush mango and adjacent rainforest trees correlated positively with elements of the soil under their stands. However, the levels of the relationships vary between the bush mango and rainforest trees. While tree heights from stands of bush mango had positive correlations with soil physical elements only, tree heights within the rainforest had positive correlations with both physical and nutrient elements. Tree diameters correlated positively with both physical and nutrient elements under stands of both bush mangoes and the rainforest. Since measures of plant biomass of the stands of bush mango trees had positive correlations with soil elements, their conservation as rainforest tree species is encouraged for proper ecosystem's functioning and effective soil management.

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