Evaluation of soil properties as influenced by land use system in Obio Akpa community of Akwa Ibom State, Nigeria

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Abstract

Physical and chemical properties of soils derived from coastal plain sands under three land-use system (arable land, rubber and oil palm plantation) in Obio Akpa community, Akwa Ibom State were evaluated to determine the fertility status of the soils. Composite soil samples were collected from 0-15cm depth in triplicate and analyzed for some physical and chemical properties. Results obtained indicated that texture of the soils were sandy in nature with high percentage of sands which varies from 93.5 – 95.5%. The bulk density varies significantly in this order: 1.68 gcm^{-3} (Arable land) >1.65 gcm^{-3} (rubber plantation)> 1.51 gcm^{-3} (oil palm plantation). The soils were acidic with pH value in the order of 5.16 (rubber) > 4.98 (oil palm) > 4.98 (arable land). Low organic matter contents were noticed in all the soils and they vary from 2.03% (rubber) to 2.2% (oil palm). Available phosphorous varies significantly across the three land- use types with a mean value of 19.3 kg^{-1} rated moderate. The order of abundance of CEC with means values were: Ca (5.9)> Mg (1.9) > K (0.14) > Na (0.08) cmolkg^{-1}. Physical properties of the soils correlated significantly with the chemical properties except organic matter (R^2=0.866) and available phosphorous (R^2=0.0977) with a weak relationship. The soils require nutrient supplementation especially through organic manure application for sustained crop production but the soils are mostly suitable for oil palm plantation.*

Keywords: Arable land, nutrient status, oil palm plantation, rubber plantation, soil properties

Introduction

Land use can be referred to as the use to which a piece of land is put and this centers on the human activities that relate to a particular parcel of land and this varies from locations. Land use change shows a profound impact on the soil and environment as a result of the progressive growth of population and improvement of living standards which has lead the world to the increased demand for food and water. The past management of agriculture and terrestrial ecosystems has imposed so much pressure on the soil capacity and the environmental performance in order to meet the needs of the growing human population so as to maintain the global balance of matter and energy. Land use change affects the global climate via the carbon cycle and the water cycle through changing evapo-transpiration and hydrological regimes as well as biotic diversity, soil degradation, and the ability of biological systems to support human needs (Lambin *et al.*, 2003; Adam *et al.*, 2019). Although, there is a bi-modal rainfall pattern in most South Eastern derived savannah ecology, the predictability of two planting seasons is becoming unreliable in the face of current reality in weather variability.

Majority of land use changes are related to agricultural use of the land in form of arable lands, plantations, cultivated lands and pastures. Agricultural activities change the soils chemical, physical and biological properties. Such activities include tillage (mechanized or manually), weeding, terracing, sub-soiling, deep ploughing, manure application, composting and fertilizer applications, liming, draining and irrigation and all these activities have positive or negative effects on soil fertility. Soil fertility is commonly defined as the inherent capacity of a soil to supply plant nutrients in adequate amounts, forms, and in suitable proportions required for maximum plant growth through sustainable management practices (Iren, 2013; Adam *et al.,* 2019; Umoh *et al.*, 2021).

Land use affects soil fertility and productivity and this manifest as changes in soil properties such as nutrient contents (N, P, K, Ca, Mg, S), pH, organic matter, ECEC and structure (Dikko *et al.*, 2010; Denton *et al.*, 2017) observed high nutrient levels at the surface soil and its decreases with depth . Peter *et al.* (2019) observed a significant increase in organic matter, available P, ECEC, exchangeable Ca, Mg and K levels on a 20 year oil palm plantation grown on coastal plain sand and better fertility status were observed and there were no changes in texture. Akpan *et al.* (2020) reported low availability of nutrients under arable land due to continuous cropping while adequate nutrients were observed on fallowed land due to accumulations of litter on the surface of the soil which recycles nutrients and make them available in the soil system. Soil physical properties deteriorate with change in land use especially from forest to arable. Intensive cropping may lead to erosion and leaching of soil nutrients (Umoh *et al.*, 2018; Umoh *et al.*, 2019). They observed a higher leaching of phosphorous and potassium on coastal plain sand with time which in turn adversely affects yield of crops.

These changes in the soil properties are usually influenced by the type of land use to which a land is put which will either increase its fertility status or reduce it status. Therefore, this study is aimed at evaluating the soil physical and chemical properties as well as compares the changes in the nutrient status of arable land, oil palm and rubber plantations in Obio Akpa Community.

Materials and methods

Description of the study area

The study was carried out in selected locations around Obio Akpa community (Rubber Plantation, Oil Palm Plantation and Arable Land) in Akwa Ibom State, Nigeria. The area lies between latitude $4^{0}31^{1}$ and 5^{0} $33N^{1}$ and longitude 7^{1} 25^{1} and 8^{0} 25 E. The soil is derived from Coastal Plain Sand (CPS), dominated by Kaolinite and Oxides of Fe and Al with high nutrient leaching potentials (Umoh *et al.*, 2019). This area has a hot, humid tropical climate with two distinct seasons; the rainy season which lasts from April to October and dry season which spans from November to March. It is characterized by heavy annual rainfall of about 2500 3000 mm. It is characterized by high temperature with a mean monthly temperature of 28^{0}c. The highest temperature is experienced between Januarys through March, the period described by Enwezor *et al.* (1990) as overhead passage of the sun. Relative humidity is high between 75% and 95% while solar radiation ranges from 6-15 hours per day.

Field studies and laboratory procedures

The soil samples were collected from 0 - 15 cm depth, transported to laboratory, air dried, crushed and sieved to pass through 2mm diameter mesh, and then used to determine some physicochemical characteristics of the soils as described by Udo et al. (2009). Particle size distribution was determined by Bouyoucos hydrometer method. Bulk density was determined by the method described by Udo et al. (2009) and calculated using the formulae $Pb = \frac{Ms}{Vs}$ where Pb = bulk density, Ms = mass of oven dry soil, Vs = volume of core sampler obtained using the relation V= $\pi r^2 h$, where r and h are radius and height of the core sampler. Soil pH was determined in 1:2.5 soils: water ratio with a pH meter. Organic carbon was determined by Walkley Black Dichromate Oxidation Method. Total nitrogen (N) was determined by the microkjeldahl method. Available phosphorous (P) was extracted by the Bray 1 extraction method and the content of P was determined calorimetrically using a Technico AAll auto analyzer (Technico, Oakland, Calif). Exchangeable bases (K, Na, Ca, and Mg) were extracted with 0.1 N ammonium acetate; K and Na were read with a flame photometer while Ca and Mg were determined through the EDTA titration method. Exchangeable acidity was determined by leaching the soils with 1N KCl and titrating aliquots with 0.01 NaOH. Effective Cation Exchange Capacity (ECEC) was calculated as the sum of exchangeable bases (Ca, Mg, K and

Na) and exchangeable acidity. Base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying by 100**.**

Statistical analysis

Analysis of Variance (ANOVA) was used to evaluate the differences among the three land uses, means were compared using standard error at 0.01 and 0.05 probability levels. Relationships between the soil properties were determined by correlation analysis.

Results and discussion

Soil physical properties of the three Land use

The results of the particle size analysis and bulk density of the three land use are shown in Table 1. The textural classes of these soils were sandy and were not significantly different from the land use types. The sand content varies from 93.5 to 95.5% with a mean of 94.8%. The clay contents were observed to be highest in oil palm plantation but lowest in rubber plantation. The trend was: Oil palm > Arable land >Rubber. The silt content varies from 2.5 to 3.5%, indicating the homogeneity of soil forming processes and similarity of parent materials (Enwezor *et al.,* 1990). Similar finding was observed by Denton *et al.* (2017) who had no significant difference in the soil texture. The results obtained may encourage leaching of basic cations. The bulk density of the soil varies significantly with the land use, values ranged from 1.51 gcm^3 in oil palm plantation to 1.68 gcm^3 in arable land. The lowest values obtained in oil palm plantation could be attributed to high organic matter content (Table 1), while the highest value in arable land could be attributed to continuous disturbance by tillage practice and cropping.

Chemical properties of soils in the three land use

The results of the chemical properties of the soils used for the study are shown in Table 2. The pH of soils was not significantly different at 5% probability levels in all the soils. The values varies from 4.98 to 5.16 (mean 5.04), considered slightly acidic condition which is satisfactory for most crops production (Enwezor *et al.,* 1990). The soils were non-saline with low electrical conductivity value which ranges from 0.03 dsm^{-1} (Rubber Plantation) to 0.05 dsm^{-1} (Arable land). The organic matter contents were moderate; the values were above the critical level of 2% proposed by Aduayi *et al.* (2002) for these soils. The trend was: Rubber (2.03) < Arable land (2.10) < oil palm (2.2%). Oil palm plantation had the highest organic matter content, which may have been due to the accumulation of organic matter over the years on the soil surface, the results is similar with the work done by Akinmutimi and Onyetorochukwu (2019) who carried out fertility status of selected soils for the crop production in five ecological area of Nigeria and observed high organic matter on fallowed land. There was no significant difference among the different land use in total N content. Available P varies significantly, values ranged from 12.28 mgkg^{-1}in rubber plantation to 31.83 mgkg^{-1}in oil palm plantation. Oil palm plantation had the highest P and N in the soils, this could be attributed to litter accumulation on the surface soil, which on decomposition liberates the nutrients.

Cation exchange capacity (CEC) values in the study area were low, values fall below the critical limit expected in soils as proposed by Federal Fertilizer Department (2012). The low values observed could be attributed to leaching losses by high tropical rainfall. Umoh *et al.* (2018) and (2019) reported high leaching of nutrients (K and P) on sandy soil due to it light texture.

Effective cation exchange capacity (ECEC) and base saturation were significantly different across the land use types. The trend for ECEC was: Rubber (10.74) > Arable land (9.86) > (9.53 cmolkg^{-1}) oil palm while base saturation was 82.15% (Arable land) > 79.4% (oil palm) > 78.3% (rubber plantation).

Correlation matrix between the physical and chemical properties of the soil

The relationships between the physical and chemical properties of the soil are presented in Table 3.The soil pH and total nitrogen were significantly correlated positively with sand (R^2 =1.000**), followed by Ca (R^2 =0.9451*), and EA with (R^2 =0.938*). Thus shows that the sand content of the soil contributed significantly to acidic nature of the soil.

The bulk density of the soil correlated significantly with all the chemical properties except organic matter (-0.866*) and available phosphorus (R^2 =0.977) with a negative relationship, thus shows that bulk density did not contribute to the availability of phosphorus and organic matter. The effective cations exchange capacity were found to be positively correlated with sand (R^2 =0.965*) and bulk density (R^2 =0.585*). The base saturation had a strong relation with all the physical properties except and (R^2 = -0.725) with a weak relationship.

Conclusion

The physical and chemical properties vary in concentration in the land uses. The soils were generally sandy with lowest bulk density recorded in soils under oil palm plantation over other land uses. Soil pH was significantly lower under oil palm and arable land compared with rubber plantation. Organic matter contents and total nitrogen were not significantly different within the land uses while exchangeable cations differ significantly and the soils were low in nutrient levels except oil palm plantations. Cultural management practices to control erosion and the use of organic manures are recommended for sustained agricultural production.

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Table 1: Effect of three land use types on some physical properties

Land use types	Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (gcm^{-3})
Rubber	95.5	2.5	2.0	Sand	1.65
Oil palm	93.5	2.5	4.0	Sand	1.51
Arable land	93.5	3.5	3.0	Sand	1.68
SEM	NS	0.577	1.0	NS	0.907

SEM = Standard Error Mean

Table 2: Effect of land use types on chemical properties of the soil

		Land use types			
Parameters	**Units**	**Rubber**	**Oil palm**	**Arable land**	**SEM**
pH (H_2O)		5.16	4.98	4.98	NS
EC	dSm^{-1}	0.03	0.04	0.05	NS
Organic matter	%	2.03	2.2	2.10	NS
Total N	%	0.05	0.04	0.04	NS
Av. P	mg kg^{-1}	12.23	31.83	13.32	10.999
Ca	cmol/kg^{-1}	6.4	5.44	5.76	0.488
Mg	cmol/kg^{-1}	1.8	1.92	2.09	0.146
Na	cmol/kg^{-1}	0.08	0.07	0.10	0.153
K	cmol/kg^{-1}	0.13	0.14	0.15	NS
EA	cmol/kg^{-1}	2.33	1.96	1.76	0.289
ECEC		10.74	9.53	9.86	0.625
Base saturation	%	78.31	79.43	82.15	1.975

SEM – Standard Error Mean, EC – Electrical Conductivity, AV. P = Available Phosphorous, EA = Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity

Table 3: Correlation matrix between the physical and chemical properties of the studied soils

	Sand	Silt	Clay	BD	pH	EC	OM	TN	AVP	Ca	Mg	Na	K	EA	ECEC	Bs
Sand	1															
Silt	-0.5	1														
Clay	-0.866	0	1													
BD	0.35	0.636	-0.771	1												
pH	1.000**	-0.5	-0.866	0.35	1											
EC	-0.866	0.866	0.5	0.165	-0.866	1										
OM	-0.811	-0.101	0.995	-0.832	-0.811	0.41	1									
TN	1.000**	-0.5	0.866*	0.35	1.000**	-0.866	-0.811	1								
AV.P	-0.54	-0.458	0.889	-0.977	-0.54	0.047	0.931	-0.54	1							
Ca	0.945	-0.189	-0.982	0.637	0.945	-0.655	-0.958	0.945	-0.786	1						
Mg	-0.812	0.911	0.412	0.262	-0.812	0.995	0.317	-0.812	-0.052	-0.577	1					
Na	-0.189	0.945	-0.327	0.854	-0.189	0.655	-0.421	-0.189	-0.724	0.143	0.726	1				
K	-0.866	0.866	0.5	0.165	-0.866	1.000**	0.41	0.866	0.047	-0.655	0.995	0.655	1			
EA	0.938	-0.769	-0.64	0.004	0.938	-0.985	-0.559	0.938	-0.216	0.773	-0.964	-0.517	-0.985	1		
ECEC	0.965	-0.254	-0.967	0.585	0.965	-0.703	-0.937	0.965	-0.743	0.998*	-0.63	0.077	-0.703	0.814	1	
BS	-0.725	0.959	0.2884	0.391	-0.725	0.972	0.185	-0.725	-0.188	-0.46	0.991	0.813	0.972	-0.918	-0.518.	1

** Correlation is significant at the 0.01 level (2 - tailed).
*Correlation is significant at the 0.05 level (2 - tailed).
EC = Electrical Conductivity, AV.P = Available Phosphorous, ECEC = Effective Cations Exchange Capacity, EA = Exchangeable Acidity, BD=Bulk Density, OM = Organic Matter, TN = Total Nitrogen, BS = Base Saturation