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Original Article

Influence of Tree Species in some Soil Properties in an Erosion degraded Area of Southeastern Nigeria

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ABSTRACT

The effects of tree species on soil properties on an erosion-degraded area in Mbaise, Southeastern Nigeria were evaluated. Three plant species comprising Native pear (*Dacryodes edulis*), oil palm tree (*Elaeis guineensis*), oil bean tree (*Pentaclethra macrophyllum*) and a bare soil (Control) were laid out in a Randomized Complete Block Design) and 10 soil samples (replicates) per land use were collected for analysis. Soil samples were analyzed in the laboratory for some properties and generated data subjected to Analysis of variance (ANOVA) using the SPSS software (version 7.5). Least Significant Difference was used to estimate degree of variability after ANOVA. Results showed significant ($p \leq 0.05$) difference in bulk density(BD), water holding capacity (WHC), Field capacity (FC) and particle size distribution (PSD) among land use types. Similar findings were recorded in soil chemical properties. Highest value of BD (1.63 Mg/m^3) was reported on bare soil while soils under *Pentaclethra macrophyllum* 1.19 Mg/m^3) improved BD. The WHC was least in bare soil (4.6 g/kg) and highest in *Pentaclethra macrophyllum* (15.2 g/ kg) and same trend was followed in FC. Soil organic carbon was 0.6 g/kg in bare soil and 2.5 g/kg in soils under *Pentaclethra macrophyllum*. Soil pH values were moderately to slightly acidic in soils under tree species but strongly acidic in bare soils (pH = 4.4). Soil Permeability (SP) and infiltration rates (IR) were higher in soils under tree species. Values of SP were $0.95 \pm 0.29\times10^{-1}cm^2$ (Pentaclethra macrophyllum), $0.85 \pm 0.16\times 10^{-1}cm^2$ (*Elaeis guineensis*), $0.83 \pm 0.08\times10^{-1}cm^2$ (*Dacryodes edulis*) and $0.25 \pm 0.02\times 10^{-1}cm^2$ (Bare soil). The IR follows the same trend with initial IR being 9.2 ± 0.19 cm/hr (*Pentaclethra macrophyllum*), 8.7 ± 0.31 cm/hr (*Elaeis guineensis*), 8.1± 0.28cm/hr (*Dacryodes edulis*) and 4.9 ±0.32 cm/hr(Bare soil). The SP and IR are significantly (P= 0.01) related to soil organic carbon in the erosion-degraded area of southeastern Nigeria.

KEYWORDS: Degradation, Vegetation, Soil organic matter, Soil properties, humid tropics.

INTRODUCTION

Decline in soil fertility is one of the factors limiting food production in southeastern Nigeria (1). Land degradation occurs mostly in areas where lands had been exposed to a number of deteriorating factors including water erosion (2). Land use types has a tremendous effect on the soil quality and general sustenance of soil resource on the ecosystem. Lister, Burger & Patterson (3) reported that increasing herbaceous vegetation has positive influence on soil quality including changes in average bulk densities.

Powlson, Whitmore & Goulding (4) observed changes in soil properties especially soil organic carbon when land use was changed from arable to forest, grassland and perennial cropland. Plant species richness and carbon recycling could be contributing to soil quality and its ecosystem functioning (5) due to varying transfer rates of litter fall carbon (6).

Significant differences in soil texture, soil pH, soil moisture content, total nitrogen, ammonium-nitrogen, nitrate-nitrogen, soil organic carbon and available phosphorus among vegetal forms (7).

Land use affects soil properties (8) and in southeastern Nigeria, increasing population and conflictive land use types has accelerated soil erosion such that cultivated farmlands are grossly inadequate. Patches of herbs, shrubs and trees are commonly found on erosion –degraded lands with gullies, rills and inter-rills common on the landscape. Yet, some eroded parts of the landscape are characterized by species dominance, and sustain some forms of arable agriculture. Based on the above, the major objective of this study was to evaluate soil properties of the eroded lands as affected by three common tree species, namely pear (*Dacryodes edulis*), oil palm trees (*Elaeis guineensis*) and oil bean tree (*Pentaclethra macrophyllum*).

MATERIALS AND METHODS

Study Area: The study was carried out in an eroded area of Amuzu, Mbaise Southeastern Nigeria (Latitudes 5^0 10^1 to 5^0 26^1 N; and longitudes 6^0 45^1 to 7^0 07^1E). The eroded area covers about 5 km^2 of farmland and on an elevation of about 110 m above sea levels. Soils are derived from coastal plain sands (Benin formation). Mbaise situates in the humid tropics with a total mean annual rainfall of about 2500 mm and annual temperature range of 26 ^{0}C to 29 ^{0}C.The original vegetation is rainforest which has been depleted by human activities, primarily agriculture and deforestation. Multiple plant species are found but dominated by trees such as native pear *(Dacryodes edulis*), oil palm trees (*Elaeis guineensis*) and oil bean tree (*Pentaclethra macrophyllum*), Mango (*Mangifera indica*), Avocado pear (*Persea americana*) and cashew(*Anarcadium occidentale*). The location lies at the bank of Imo River in Imo state Nigeria. Subsistence agriculture in fragmented portions of farmland is popular. Land clearing is by slash-and-burn while soil fertility regeneration is by bush fallowing whose fallow length has drastically reduced due to scarcity of farmland.

SOIL SAMPLING

Four sites in the degraded soils of Mbaise in Southeastern Nigeria were chosen for the study. The sites are geographically –associated, and include native pea dominated site (*Dacryodes edulis*), Oil palm dominated site (*Elaeis guineensis*) and Oil- bean tree dominated site (*Pentaclethra macrophyllum*) and bare soil (Control). In each site, a 100×100m land area was delineated for soil examination and sampling. Ten composite soil samples was aided using soil auger. The samples were air-dried, passed through 2-mm sieve and stored in polythene bags for laboratory analysis.

LABORATORY ANALYSES

Particle size distribution was determined by hydrometer method (9). Bulk density was estimated by weighing a known volume of core of 5cm internal diameter, after drying at 105^0C for 48 hours (10). Water holding capacity was determined by gravimetric method after saturating the soil with water (11). Field capacity determined with a pressure plate membrane at 1/3 bar (12).

Double concentric infiltrometer cylinders with 0.6m outer diameter and 0.3m inner diameter were used according to the procedure of Yadav & Vasistha (13). Initial fall of head was recorded after 5mins and subsequent readings were taken after 5, 10, 20,30,40,50,60,70,80 and 90 mins. Infiltration rate (IR) was calculated for each internal and constant IR was measured after 455 mins. Soil permeability was estimated in the laboratory using constant head permeameter (11).

Soil pH was analyzed in soil: distilled water suspension (1:2.5) using a digital pH meter-CP 901. Organic carbon was determined by wet digestion (14). Available phosphorus was estimated by Bray (II) method (15). Cation exchange capacity was estimated. Exchangeable cations were by 1N Ammonium acetate at pH 7 method. Exchangeable cations were extracted using ammonium acetated solution and the concentration of Na^+ and K^+ were determined by flame photometer and Ca^{2+} and Mg^{2+} by inductively coupled plasma Analyzer (Perkin Elmer). Total nitrogen was determined using the Kjeldhal method (16).

Data Analysis: Soil data were statistically analyzed using PRO MIX-MODEL of SAS (17). Analysis was made according to randomized complete block design having land uses (tree Species) as treatments and a number of soil samples collected per land use as replicates. Least significant difference was computed at $P \leq 0.05$ to estimate degree of variability of soil properties among land use types.

RESULTS AND DISCUSSION

Physical properties of studied soils are shown on Table 1, indicating significant ($P \leq 0.05$) differences in BD, WHC,FC and particle size distribution. The bare soil had the highest value of BD (1.63 mg/m^3), implying reduced porosity when compared with 1.19 mg/m^3 (*Pentaclethra macrophyllum*), 1.24 mg/m^3 (*Dacryodes edulis*) and 1.29 mg/m^3 (*Elaeis guineensis*). These changes in BD over land use influenced WHC in bare soil (4.6g/kg), *Elaeis guineensis* (8.1g/kg), *Dacryodes edulis* (8.4 g/kg) and *Pentaclethra macrophyllum* (15.2 g/kg). Marked changes were observed in FC ranging from 2.6 g/kg (bare soil), 5.8 g/kg (*Elaeis guineensis*) 6.2 g/kg (*Dacryodes edulis*) and 9.6 g/kg (*Pentaclethra macrophyllum*).Particle size distribution varied significantly ($P \leq 0.05$) in all land use types with highest value of sand recorded on bare soil (880 g/kg), followed by soil under *Elaeis guineensis* (850 g/kg), *Dacryodes edulis* (800g/kg) and *Pentaclethra macrophyllum*(790 g/kg). It suggests that bare soil surfaces are sandier than other land use types. Sand sized particles are heavier than silt- and clay-sized particles such that the former are less readily moved away from site of formation.

Table 1. Physical properties of Soils (0-20cm depth)

Land Use	BD Mg/M³	WHC g/kg	FC g/kg	TS g/kg	Si g/kg	Cl g/kg	Texture
Control (Bare soil)	1.63	4.6	2.6	880	50	70	Loamy sand
Dacryodes edulis	1.24	8.4	6.2	800	100	100	Sandy Loam
Elaeis guineensis	1.29	8.1	5.8	850	60	90	Sandy Loam
Pentaclethra macrophyllum	1.19	15.2	9.6	790	70	140	Sandy Loam
P-value	0.05	0.001	0.001	0.03	0.05	0.05	
$LSD_{0.05}$	0.04	1.8	1.5	2.2	1.8	1.6	

BD = bulk density WHC = water holding capacity, FC = field capacity, TS= total sand Si = silt Cl = clay.

Exchangeable basic cations: Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} differed significantly (P≤ 0.05) among land use types. The *Pentaclethra macrophyllum* was more efficient in raising Ca^{2+} (2.4 cmol/ kg) and Mg^{2+} (1.2 cmol/ kg) while *Elaeis guineensis* raised K^{+} (0.8cmol/ kg) more efficiently than other land use types (Table 2). Least values of these basic cations were recorded in bare soils suggesting loss of these elements through leaching during runoff and rainfall events. There was a significant (P≤ 0.05) increase in CEC from 5.5 cmol/ kg (Bare soil) to highest value of 14.4 cmol/ kg *(Pentaclethra macrophyllum*) (Table 2). Available phosphorus distribution was influenced by land use (Table 2) with bare soil showing least value of 6.9 mg/ kg while soils dominated by *Pentaclethra macrophyllum* raised available P to 15.2 m/ kg. Values of organic carbon (OC) and total nitrogen (TN) indicated significant (P≤ 0.05) variation among land use types (Table 2). The OC values were 2.5 g/kg, 2.0 g/kg, 1.8 g/kg and 0.6 g/kg for soils under *Pentaclethra macrophyllum, Elaeis guineensis, Dacryodes edulis* and Bare land, respectively. Similarly, TN distribution was as follows: 0.1 g/kg (Bare soil), 0.3 g/kg (*Dacryodes edulis*), 0.4g/kg (*Elaeis guineensis*) and 0.6 g/ kg (*Pentaclethra macrophyllum*). Soil pH was raised by the tree species from 4.4(Bare Soil), to 5.8 *(Dacryodes edulis*), 6.1 (*Elaeis guineensis*) and 6.5 (*Pentaclethra macrophyllum*).

Table 2. Chemical properties of Soils (0-20cm depth)

Land Use	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CEC	OC	TN	Avail.P	pH water
	Cmol/kg					g/kg		mg/kg	
Control (Bare soil)	0.5	0.3	0.03	0.1	5.5	0.6	0.1	6.9	4.4
Dacryodes edulis	2.1	0.9	0.08	0.2	11.6	1.8	0.3	13.1	5.8
Elaeis guineensis	2.0	1.0	0.10	0.8	12.9	2.0	0.4	13.6	6.1
Pentaclethra macrophyllum	2.4	1.2	0.13	0.3	14.4	2.5	0.6	15.2	6.5
P-value	0.0001	0.001	0.01	0.01	0.001	0.001	0.01	0.001	0.01
$LSD_{0.05}$	0.8	0.1	0.02	0.06	1.7	0.8	0.09	3.1	0.2

CEC = cation exchange capacity, OC = organic matter, TN = total nitrogen, Avail .P= available phosphorus.

These changes in physical and chemical properties point to the significant contribution of vegetation to soil formation since these soils are derived from the same parent materials (Coastal plain sands), and lies on a gentle slope and in the same humid climate.Significant (P= 0.05) changes in physical and chemical properties of forest and derived savannah soils of Edo State, Nigeria were earlier reported(18). In another study conducted at Enugu State, Nigeria, significant (P <0.05) differences in bulk density, hydraulic conductivity, total porosity, ammonium-nitrogen and nitrate-nitrogen were observed among soils under Maize, velvet bean, pigeon pea and African yam bean. In addition, significant differences in soil water depletion patterns by crop species had been reported (19).

Soils under Pentaclethra macrophyllum recorded highest soil permeability and infiltration rates (Table 3), possibly due to least value of bulk density and highest value of soil organic carbon. The results suggest rapid recycling and return of above ground biomass of Pentaclethra macrophyllum when compared with other tree species (20). Increased organic matter suggests greater macro aggregation which reduces bulk density while increasing soil permeability and infiltration rates at least in a short run. Soils with more macro pore spaces conduct soil water more easily than soils with micro pores (21) and less prone to runoff water accumulation and movement down slope when compared with bare soils. However, micro aggregates (22), requiring their protection by incorporation of organic matter into readily erodible soils.

Field capacity water increased as clay content of soils increased, with bare soil (70g/kg clay) having least value of 2.6 g/kg and *Pentaclethra macrophyllum* (140g/kg clay) recording 9.6 g/kg

FC. The clay-sized particles are associated with higher retention of soil moisture, although other factors such as organic matter content influence FC of soils at epipedal horizons.

Root characteristics of trees could be contributing to the variability in soil moisture content and behavior as already reported (19). Roots contribute to infiltration into deeper horizons of soils.

Table 3. Soil permeability and infiltration rate of soils

Land Use	Soil permeability (cm^2)	Accumulated infiltration (cm)		Infiltartion Rate (cm\hr)	
		Initial	Final	Initial	Final
Control (Bare soil)	0.25±0.02×10^{-1}	6.1 ±0.03	6.8 ±0.04	4.9 ±0.32	1.03 ±0.003
Dacryodes edulis	0.83 ±0.08 ×10^{-1}	7.6 ±0.01	7.9 ±0.01	8.1 ± 0.28	1.16 ± 0.06
Elaeis guineensis	0.85±0.16 ×10^{-1}	8.2 ± 0.06	8.5 ± 0.08	8.7 ±0.31	1.28 ± 0.03
Pentaclethra macrophyllum	0.95 ± 0.29 ×10^{-1}	8.5 ± 0.09	8.8 ± 0.09	9.2 ± 0.19	1.29 ± 0.02

Table 4 shows the relationship existing between Soil organic carbon, soil permeability and infiltration rates. Results show that soil organic carbon contributed 50% to soil permeability with high coefficient of alienation ($1-\times^2=0.50$).On the other hand soil organic carbon had a greater influence on infiltration rate. In both cases, they increased as soil organic carbon increased in the soil system. With a lower coefficient of alienation, soil organic carbon should be considered one of the major factors influencing infiltration at surficial layers of soils, implying that such influence may decrease deeper horizons.

Table 4. Relationship between soil permeability, infiltration rate and soil organic carbon(N=40)

Model Statistics	r	r^2	$1-r^2$	P
$Y_{sp} = 0.56\times + 0.181$	0.71	0.50	0.50	0.01
$Y_{IR} = 0.36\times - 0.216$	0.76	0.58	0.42	0.01

Ysp = Soil Permeability as dependent variable
Y_{IR} = Infiltration Rate as dependent variable
$1-R^2$ = Coefficient of alienation
× = independent variable (organic carbon)

CONCLUSION

The study revealed significant (P≤ 0.05) differences under *Dacryodes edulis, Elaeis guineensis* and *Pentaclethra macrophyllum* when compared with bare soils. Of the tree species, *Pentaclethra macrophyllum* had more profound effect in influencing the physicochemical properties of studied soils including soil permeability accumulated infiltration and infiltration rate. Soil organic carbon had a significant effect (P= 0.01) on both soil water infiltration rate and soil permeability. Further studies should involve trials on arable crops on eroded soils of Southeastern Nigeria as well as use of soil profile pits in the examination of the effect of studied trees in deeper horizons of soils.

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