Journal of Bioresource Management

Volume 7 | Issue 3 Article 6

9-30-2020

Assessment of Soil Properties Under Different Land Use Types in Olokemeji Forest Reserves in Ogun State Southwestern Nigeria

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Recommended Citation
Akintola, O. O., Bodede, A. I., Smart, M., Adebayo, A. G., & Sulaiman, O. N. (2020). Assessment of Soil Properties Under Different Land Use Types in Olokemeji Forest Reserves in Ogun State Southwestern Nigeria, *Journal of Bioresource Management, 7* (3).
DOI: https://doi.org/10.35691/JBM.0202.0141

ASSESSMENT OF SOIL PROPERTIES UNDER DIFFERENT LAND USE TYPES IN OLOKEMEJI FOREST RESERVES IN OGUN STATE SOUTHWESTERN NIGERIA

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ABSTRACT

Knowledge of soil properties is essential for environmental sustainability for any forest reserve or plantation. The physical and chemical properties of soil under three different land uses was investigated to assess the nutrient and fertility status of the soils. Fifteen soil samples, each collected from different locations within the natural forest, plantation and farm land were analyzed for soil texture, bulk density, porosity, pH, organic carbon, organic matter content, total nitrogen, available phosphorus, Na, K, Ca, Mg, Zn, Cu, Fe and Mn. Texturally, the soils were loamy, loamy sand and sandy loamy in the natural forest, plantation and farmland respectively. There was a significant difference between the three different soils in composition and texture.

Keywords: Soil, organic matter, natural forest, plantation, nutrient deterioration

INTRODUCTION

Soil fertility is a relatively complex concept that can be defined as the potential of a soil to generate or produce a substantial yield. The concept of soil fertility can be linked to physical, biological, chemical, climatic and geological characteristics of the site locations (Augusto et al., 2002) as well as anthropogenic activities such as construction, farming, erosion, deforestation, over exploitation etc. The impact of trees on formation of soils and nutrient cycling such as weathering, fall litter and nutrient uptake, leaching, infiltration and erosion etc has been well reported (Binkley et al., 1992). Likewise, these processes influence the vigorous nature of trees, spatial and temporal (earthy) dynamics in a forest ecosystem. The theoretical importance of the forest ecosystems is their potential to continuously retain soil organic matter and to encourage nutrient recycling which in turn depends on various tree species in the area and a change in the forest ecosystem may affect the properties of the soil.

The change of forest land to tree plantations and farming has been shown to negatively affect soil nutrients. Studies have also shown that a change in forest cover land to farm land may encumber toting up of forest litters that increases soil nutrients, enhances soil erosion rates as well as loss of soil organic matter and nutrients and land degradation (Ozgoz et al., 2013; Barua and Hague, 2013). These in turn can result into reduction of soil fertility and biodiversity loss. Since, forest cover plays an important role in controlling soil erosion and land degradation, changes in the land cover may significantly affect the quantity and biomass multiplicity in the soil which in turn disturbs the nutrient profile of the soil.

The use of forest reserves for other land usage has recently resulted into diverse and complex ecological problems (Henrik et al., 2010). Soil physical and chemical properties have been used by many researchers for assessing the influence of land-use on changes and management of the ecosystem (Avarez and Alvarez, 2000; Faboya, 2010; Mitchel et al., 2010; Agboola et al., 2017). Thus, knowledge of soil properties will provide baseline information for environmental sustainability for any forest reserve or plantation. The study area includes a forest reserve in Nigeria where residues of tropical rain forest is still exists. Although human activities such as tree plantation establishment, bush burning, farming and other developmental activities in the reserve have led to loss of biodiversity in the area. This study investigated the impact of different land usage (natural forest, tree plantation and forest land) on the soil properties in the study area.

MATERIALS AND METHOD

Study Location

Olokemeji forest reserve, bounded to about 32km west of Ibadan and 35km north-east of Abeokuta is located between Latitude 7º 25´N to 7º 39´N and Longitude 3º32´E and 3º44´E in Ogun State southwestern Nigeria (Figure 1). The reserve which was established in 1899 is the second forest reserve in Nigeria and occupies a total land area of 58.88km^2 (Ogunleye et al., 2004). The topography of the area is generally undulating with the elevation values ranging between 90m and140m (asl) except a quartzite ridge near the western side of the reserves which precipitously rises above 240m (Agbo-Adediran et al., 2016).

The reserve which lies on the margin of lowland rainforest and derived savanna zones of southwestern Nigeria (Keay, 1952) has annual rainfall ranging from 1200mm to 1300mm over the period of eight months (March to November). The drainage of the study area is dendritic and is within the middle course of River Ogun which drains almost half of Basement Complex area of Southwestern Nigeria (Ogundele and Odewunmi, 2012).

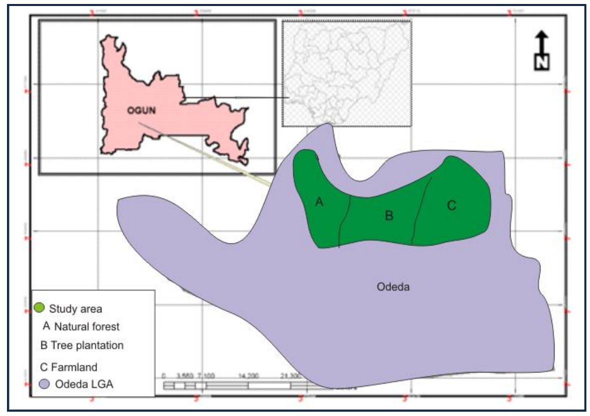

Figure 1: Location map of the study area.

Geologically, the study area falls within the Precambrian basement complex rocks of southwestern Nigeria (Figure 2). It consists of banded biotite gneisses with granitoid intrusions (Wilson, 1922). The soils are derivative of those rocks that are buried beneath alluvial sands.

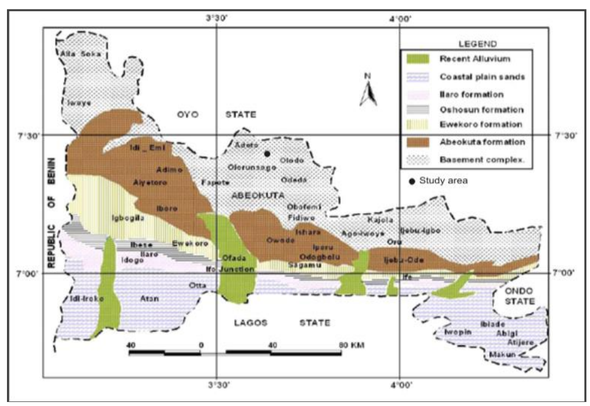

Figure 2. Geological map of Ogun State showing the study area (Modified after Olurin et al, 2016)

The tree species found in the natural forest are *Manilkara multinervis, Diospyros mespiliformis, Isoberlinadoka, Manilkara obovata, Cassia siame, Erythrophleumsuaveleon, Afzelia Africana, Vitellaria paradoxa, Gmelina arborea, Tectonia grandis* and *albizzia lebbeck* among others while *Tectonia grandis, Gmelina arborea* and*sennsiamea* are found in the plantation area of the study area.

Collection and Preparation of Soil Samples

Fifteen composite soil samples were randomly collected from each of the location sites i.e. natural forest, plantation and farming land area (Figure 1) at the depth of 0-20cm using an auger. The samples were immediately put into the polythene bags and labeled accordingly. The undisturbed soil samples were also collected using core cutters and sealed immediately on both edges with melted candle wax on the field to prevent moisture loss. The collected composite soil samples were air dried, gently crushed and sieved through 2 mm mesh for laboratory analysis.

Laboratory Analysis

Both physical (particle size distribution, soil moisture content, bulk density and soil porosity tests) and chemical analyses (pH, organic matter content, total nitrogen, available phosphorus, Na, K, Ca, Mg. Zn, Cu, Fe and Mn) were carried out on the collected soil samples. Particle size distribution test was carried out using hydrometer (152H, Gilson, USA) method of Brown (2003), bulk density of the soils was determined by drying the undisturbed core samples to a constant weight at 105°C and dividing the oven dried weight of the samples by its volume (Blake and Hartge, 1986) and the porosity of the soil was determined by assuming that the particle density of the soil is 2.65 g/cm3 (Hao et al., 2008). The pH of the soil samples was determined using electrode pH meter (PCE-228) in water-soil solution (1:1), while the organic carbon contents of the soils were determined using Walkley and Black (1934) method and then multiplied by 1.724 to calculate soil organic matter content. Total nitrogen and available phosphorus were determined by micro-kjeldhal digestion-distillation methods (Bramner, 1965) and electrophotometer method (Bray and Kurtz, 1945). The exchangeable cation was extracted using 1M ammonium acetate solution; Ca and Mg were analyzed from the extract by EDTA titration method while K and Na were done by flame photometer. Analysis of Zn, Cu, Fe and Mn were analyzed using atomic absorption spectrophotometer (AAS, MEDTECH).

Data Analysis

One-way Analysis of Variance (ANOVA) was used for determination of variability among the study locations while the Duncan Multiple Range Tests was used for the separation of means (SPSS 20.0). Deterioration index (DI) (Equation 1) as proposed by Ekanade (1991) and adopted by Oyedeji (2006) and Agboola et al. (2017) was used to assess the deterioration or improvement of soil nutrients among the land uses.

$$Deterioration\ Index\ (DI) = \mathrm{X} - \mathrm{Xi}/\mathrm{X}$$ ....Equation 1

Where X is the mean value of soil nutrients in forest soil (natural site) and Xi is the mean value of soil nutrients in the other sites. A positive value indicates deterioration while negative values indicates improvement. Pearson correlation was used to determine the relationship among the determined parameters.

RESULTS AND DISCUSSION

Physical Properties of Soils

The physical property of soils is predominantly determined by texture, structure, moisture content, porosity, water holding capacity and bulk density among others. Plants need support, nutrients and food from soil but the supply and uptake of these nutrients requires a considerable amount and combination of these properties.

Table 1: Particle size distribution of the soils

Land use types	**Particle size (%)**			**Textural class**
	Sand	silt	Clay	
Natural forest	48.00[c]	34.50[a]	17.5[a]	Loam
Tree plantation	82.11[a]	9.12[b]	8.77[c]	Loamy sand
Farmland	78.11[b]	7.67[c]	14.22[b]	Sandy loam

Particle size distribution test showed that soils from the natural forest had mean values of sand (48%), silt (34.50%) and clay (17.5%), tree plantation had sand (82.11%), silt (9.12%) and clay (8.77%), while the percentage of sand was 78.11%. Silt (7.67%) and clay (14.22%) were recorded from farmland soils (Table 1). Texturally, the soils from natural forest, plantation and farmland were loam, loamy sand and sandy loam.

There was a significant difference in the values of the particle sizes of soils under different land uses studied. This could be attributed to the long-time effect of the forest on the soils as trees are known to affect vegetation, micro climates and fauna among others in the environment through biological recycling of minerals, thermal and moisture regime and changes in fauna and flora characteristics (Shukla, 2009). Thus, improving soil nutrient composition by reducing the leaching and erosion effects on soil as well as increase in the productivity inputs through nitrogen fixation and biological activities (Schroth and Sinclair, 2003).

It has been reported that soils with loose particles such as sand, results into single grain structure while those that are rich in clay content with fine grained size usually become firm, water resistant and subsequently slow down the root penetration of plants (Akintola et al., 2020; Tet-mensah, 1993). The appreciable presence of different particle sizes in the soil affect the water holding capacity of the soil, organic matter, cation exchange and biological characteristics of the soil. The loamy nature of the studied soils indicated the influence of forest on the soils through the littering of leaves, roots and animals remains that decomposed with time and glues the soil particle together to become stable aggregates for plants while the sandy nature of the soils is attributed to the nature of the underlying rocks through which the soils are formed.

Table 2: Mean Values of Physiochemical Parameters of the Studied soils

Land use Types	Bulk density (%)	Porosity (%)	pH	Organic carbon (%)	Organic matter content (%)
Natural forest	2.31^{a}	42.56^{c}	6.61^{a}	2.96^{a}	5.11^{a}
Tree plantation	1.83^{b}	49.11^{b}	5.58^{b}	1.68^{b}	3.11^{b}
Farmland	1.51^{c}	54.56^{a}	5.34^{c}	0.88^{c}	1.52^{c}

Table 3: Mean values of chemical properties of the studied soils

Land use types	TN %	AP %	Na mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	Fe mg/kg	Zn mg/kg	Cu mg/kg	Mn mg/kg
Natural forest	0.89^{a}	0.70^{a}	0.73^{a}	0.42^{a}	4.68^{a}	1.23^{a}	134.56^{a}	35.88^{a}	25.11^{a}	101.28^{a}
Tree plantation	0.67^{b}	0.56^{b}	0.31^{b}	0.20^{b}	2.31^{b}	0.78^{b}	105.22^{b}	21.89^{b}	19.11^{b}	65.67^{b}
Farmland	0.35^{c}	0.29^{c}	0.11^{c}	0.07^{ϵ}	0.99^{c}	0.25^{c}	58.22^{c}	12.56^{c}	9.01^{c}	35.01^{c}

TN- Total Nitrogen; AP-Available Phosphorus; Na- Sodium; K- Potassium; Ca- Calcium; Mg-Magnesium; Fe-Iron; Zn-Zinc; Cu-Copper and Mn- Manganese

The mean values of bulk density of the soils in percentage (Table 4) showed that soils from the natural forest (2.31%) had a significantly higher bulk density than those from plantation (1.83 %) and farmland (1.51 %). The mean values of porosity in the soils from natural, plantation and farmland were 44.56%, 49.11% and 54.56% respectively. The significantly high values of moisture content, bulk density and lower porosity obtained from natural forest soils may be attributed to retention of nutrients in the soil as the forest provides greater protection to the soil from heat and erosion due to rainfall. The higher porosity and lower bulk density noticed, is in line with the relationship between the two factors as observed by Blake and Hartge (1986) and Akintola et al. (2020).

Chemical Properties of Soil

The pH of the soils ranged from slightly acidic (5.34-5.58) in the farmland and tree plantation to almost neutral (6.61) in the natural forest. The soils from the farmland were the most acidic among the three land uses in the study (Table 2). Organic carbon and organic matter content were significantly higher in the natural forest soils with respective mean values of 2.96% and 5.11%. The least mean values of OC (0.88%) and OMC (1.52%) were recorded in the soils from farmland.

The natural forest (0.89%) and tree plantation (0.67%) had higher mean values of total nitrogen in the soils than farmland soil (0.35%). The available phosphorus was significantly highest in natural forest soil

(0.70%) than tree plantation (0.56%) and farmland soils (0.29%).

Calcium had the highest mean concentrations among the exchangeable cations in the studied soils. The mean values of Ca were higher in the natural forest (4.68 mg/kg,) than tree plantation (2.31mg/kg) and farmland (0.99mg/kg) soils. The mean values of Mg in the soils from natural forest were 1.23 mg/kg, 0.78 mg/kg from tree plantation and 0.25 mg/kg from farmland. While the mean values of Na and K in soils from natural forest were 0.73 and 0.42 mg/kg, 0.31 and 0.20 mg/kg from tree plantation and 0.11 and 0.07 mg/kg from farmland (Table 3). Generally, the mean values of exchangeable cations were significantly higher in the natural forest soils than tree plantation and farmland soils.

The mean values of the micro-nutrients in the soils showed that Fe had the highest values in the studied soils (Table 3). Iron showed significantly higher mean values in the soil from natural forest (134.56 mg/kg) than tree plantation (105.22 mg/kg) and farmland (58.22 mg/kg) soils. The mean values of Zn in the soils from natural forest were 35.88 mg/kg, tree plantation (21.89 mg/kg) and farmland (12.56 mg/kg) while the mean values of Cu and Mn in soils from natural forest were 25.11 mg/kg and 101.28 mg/kg, tree plantation (19.11 and 65.67 mg/kg) and farmland (9.01 and 35.01 mg/kg) respectively (Table 3).

High amount of soil nutrients noted in the soils under natural forest may be attributed to less or no anthropogenic inputs such as human activities as well as soil stability due to coverage from the forest which prevents them from rain and heat effects. Since nutrients from leaves return to the soil through litters, degeneration and decomposition forming organic matter in a forest ecosystem. According to Shukla (2009) this provides shelter and serves as main route of nutrients and energy transfer to the soil. Thus, the nutrient cycling in forest ecosystem involves recycling of nutrients between soil and plants through these three processes; nutrient uptake, the ability to retain (retention) and return (Ogunkunle and Awotoye, 2011).

Generally, the high levels of determined parameters in soils from the study area may be due to the accumulation of organic matters which serves as store house and source of nutrients in the soil. Thus, the upsurge of soil nutrient in any vegetation environment may be attributed to the organic matter. Consequently, the higher concentration of organic matter and other soil nutrients in the natural forest than the tree plantation and farmland is related to the nature of organic matter such as decomposition of various and diverse remains of plants such as herbs, grasses, shrubs, trees and animals found in the them. This finding conforms with the study of Fisher (1995) where he stated that forests improve soil condition through nitrogen fixation, surface enrichment through litter of plant remains, increase in biological activity and soil organic matter among others.

Deterioration Index (DI) of Soil Nutrients of the Studied Land Use Types

The deterioration index (DI) indicates the relation in percentage of chemical parameters of the tree plantation and farmland to that of natural forest (Figure 3; 4; 5). A positive DI as adopted by Agboola et al. (2017) means deterioration, while, a negative value means improvement of soil nutrients over that of natural forest.

Deterioration index (Figure 3) showed positive DI for organic matter in the tree plantation (43.44%) and farmland (70.25%). Total nitrogen and available phosphorus deteriorated in the soils from tree plantation and farmland with farmland accounting for the highest percentage (Figure 3).

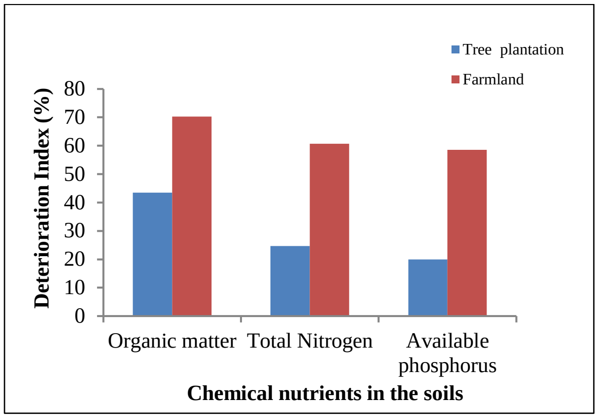

Figure 3. Deterioration Index of organic matter, total nitrogen and available phosphorous in the soils

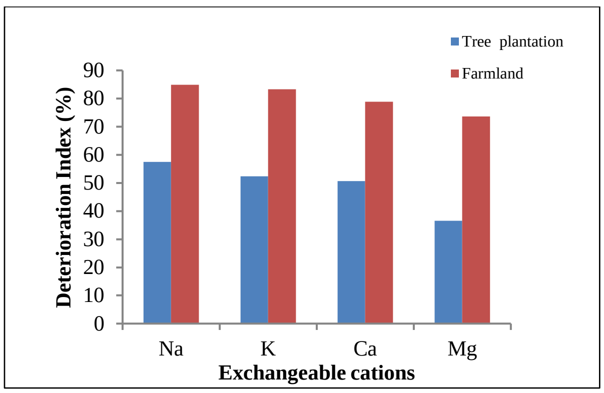

Figure 4. Deterioration Index of exchangeable cations in the soil

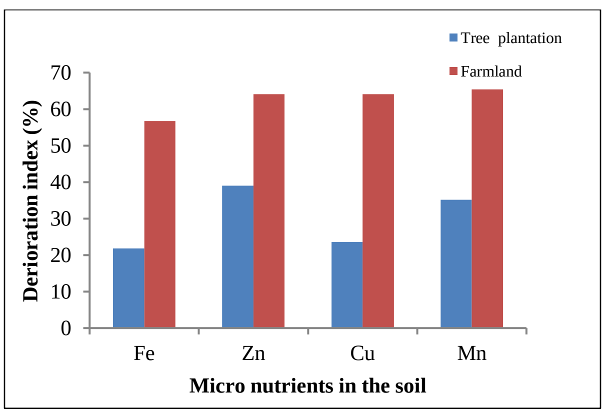

Figure 5. Deterioration Index of micronutrients in the soil

Exchangeable cations deteriorated in the soil of tree plantation [Na (57.53%), K (52.38), Ca (50.64%) and Mg (36.59)] and farm land [Na (84.93%), K (83.33%), Ca (78.84) and Mg (73.68)]. The highest percentage values were also observed in the soils from farm land area (Figure 4).

Soil micro-nutrients also deteriorated in the two land use types (Figure 5) with farmland having the highest percentage [Fe (56.73%), Zn (64.07%), cu (64.11%) and Mn (65.43%)] while the tree plantation soil had lower values [Fe (21.80%), Zn (38.99%), Cu (23.59%) and Mn (35.16%)]. The deterioration status of the soil nutrients from tree plantation and farmland area could be related to the anthropogenic inputs such as cultivation, burning of litters during dry season, harvesting or climatic factors (Isah et al., 2014; Anderson et al., 2017; Suleiman et al., 2017). This can also be ascribed to the low returns of nutrients from trees/plants to soil.

Relationship Between Soil Chemical Properties in the Study Area

Significant correlation ($P < 0.01$) was observed among the determined chemical parameters of the studied soils (Table 4). Soil pH was strong and significantly correlated with organic matter content (0.985), total nitrogen (0.95), available phosphorus (0.873), Na (0.958), Ca (0.936), Mg (0.889), K (0.947), Fe (876), Zn (0.866), Cu (0.745), and Mn (0.895). Total nitrogen also showed strong and relationship with available phosphorus (0.952), Na (0.982), Ca (0.955), Mg (0.889), K (0.928), Fe (0.960), Zn (0.950), Cu (0.728), and Mn (0.963). Available phosphorus was strong and significantly correlated with Na (0.957), Ca (0.945), Mg (0.947), K (0.967), Fe (0.973), Zn (0.979), Cu (0.618), and Mn (0.978). The relationship that exist between the soil pH and other chemical properties indicated that soil pH sturdily affects soil processes such as nitrogen cycling which impact the soil chemical, physical and biological processes (Akintola *et al*, 2020; Anderson et al., 2018).

Generally, the relationship that exists between the soil organic matter and other chemical parameters in the soils from the three land use types showed the importance of organic matter content in soil nutrients.

Table 4: Pearson Correlation coefficients of the determined Chemical parameters in the soil samples

Parameters	PH	OC	OMC	TN	AP	Na	K	Ca	Mg	Fe	Zn	Cu	Mn
PH	1	.985**	.985**	.950**	.873**	.958**	.947**	.936**	.889**	.876**	.866**	.745**	.895**
OC		1	1.000**	.919**	.812**	.926**	.914**	.904**	.845**	.817**	.803**	.784**	.842**
OMC			1	.919**	.812**	.925**	.914**	.907**	.846**	.819**	.805**	.787**	.843**
TN				1	.952**	.982**	.980**	.955**	.928**	.960**	.950**	.728**	.963**
AP					1	.957**	.967**	.945**	.947**	.973**	.979**	.618**	.978**
Na						1	.988**	.961**	.938**	.955**	.944**	.730**	.970**
K							1	.971**	.945**	.962**	.959**	.725**	.978**
Ca								1	.959**	.955**	.954**	.709**	.964**
Mg									1	.922**	.929**	.671**	.952**
Fe										1	.992**	.615**	.981**
Zn											1	.591**	.976**
Cu												1	.678**
Mn												.	1

**. Correlation is significant at the 0.01 level

OC- Organic content, OMC- Organic matter content, TN-Total nitrogen; AP- Available Phosphours

CONCLUSION

Anthropogenic activities like deforestation, removal of vegetation cover and intensive cropping cause a decline in physical, chemical and biological properties of soil. While, the forests protect and increase the soil fertility and productivity to support a flourishing vegetation. This study has showed the deteriorative influence of land uses on soil fertility as well as importance of forest to improve soil condition through soil organic matter.

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