



## Land Use Influence on Some Soil Physical and Chemical Properties of an Alfisol at Forestry Research Institute of Nigeria

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Authors JJO, VAO and FOA designed the study. Author FOA performed the statistical analysis. Authors JJO, VAO and FOA wrote the protocol and wrote the first draft of the manuscript. Authors JJO and FOA managed the analyses of the study. Authors VAO, FBM and RSI managed the literature searches. All authors read and approved the final manuscript.*

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### **ABSTRACT**

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it. Changes in land use cover also have a drastic effect on chemical and biological properties of soil and hence change the quality of the soil. A study was conducted to examine the effect of land use types on soil physical and chemical properties within an Alfisol in the arboretum of Forestry Research Institute of Nigeria (FRIN). Soil samples were collected at two soil depths (0-15cm and 15-30 cm soil depths) under these plantations: *Nauclea diderrichii* (NP), *Gmelina arborea* (GP), *Terminalia superba* (TP), Arable crop land (AC) and a Fallowed Land (FL) and were analysed for some selected soil physical and chemical properties. The experiment was a completely randomized design (CRD) with six replications. Data collected was subjected to Analysis of Variance (ANOVA) and means were separated using Duncan Multiple Range Test (DMRT). Results revealed that higher content of clay was recorded in

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0 to 15 cm depth of both GP (15.00%) and FL (15.00%) plantation lands whereas higher clay content was recorded at 15 to 30 cm depth in Arable crop land (23.00%) and *Nauclea* plantation land (21.00%). Higher total nitrogen (TN) was observed in FL (1.44%) while TN availability decreases in the order AC>GP>NP>TP. Higher values of soil Organic Carbon (16.74%), Available phosphorus (2.15 Cmol/kg) and Organic matter (28.86%) were obtained under FL as compared to the other land use fields at 0 to 15 cm depth. Bulk density and porosity were highly variable among different land use types and ranged from (1.039 - 1.415) g cm<sup>-3</sup> and (17.99 - 48.87)%. The information generated from the present study suggested fallowed land use as the best land use system because of its higher soil organic matter management, as it improves the soil structure and this will assist in developing sustainable and ecologically stable land use management strategies for the study area.

**Keywords:** Land use; alfisol; soil physical; chemical properties.

## 1. INTRODUCTION

Soil fertility maintenance is the major concern in tropical Africa but with the rapid population increase in the past few decades, the need for different uses to which land is being subjected to sprang up. Diminution in food production in Nigeria as a result of poor soil fertility and management has been a major problem influencing the Country [1]. These problems have resulted into the adoption of many schemes focused at ameliorating soil productivity. One of such schemes was the continual evaluation of properties of soils in lands subjected to different management practices [2]. Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it [3]. Land use concerns the products and/or benefits obtained from the use of land as well as land management actions carried out by humans to produce those products and benefits [3]. Changes in land use types and soil management can have a marked effect on soil organic matter stock and soil physical properties. Several studies in the past have shown that deforestation and cultivation of virgin tropical soil often lead to depletion of nutrients (N, P and S) present as part of complex organic polymers. Successful land management requires the sustainable use of the soil's resources, because soils easily lose their quality within a short period of time depending on their uses. Forests and agricultural activities have great impact on soil physical properties [4]. Forestry activities change the top soil surface structure [5]. Changes in land use cover also have a drastic effect on chemical and biological properties of soil and hence change the quality of soil [6,7]. Therefore, adequate knowledge of the effect of different forest plantations of similar age on soil physical and chemical properties at different soil depth is

necessary to promote a sustainable soil management practice. This study examined the effect of land use types namely; the plantations of *Nauclea diderrichii*, *Gmelina arborea*, *Terminalia superba* Arable crop land and a fallowed land all located within the arboretum of the Forestry Research Institute of Nigeria on soil physical and chemical properties.

## 2. MATERIALS AND METHODS

### 2.1 Description of Study Area

The research was conducted during 2019 planting season in parts of forest reserves of Forestry research institute of Nigeria (FRIN), Ibadan. FRIN Ibadan is located in Oyo State in the south-western-agro-ecological zone of Nigeria. The area lies at latitude 07<sup>o</sup>23'N and Longitude 03<sup>o</sup>51'E. The sites coordinates were taken with a Geographical Positioning System (GPS) as shown in Table 1. The vegetation of the area can be described as southern guinea savanna. The study is within the sub-humid tropical climate and has an annual mean rainfall of 1548 mm. The rainfall pattern is bimodal and fall between April and October at times falling at least for approximately 90 days while the dry season is between November and March. The area is characterized with mean annual maximum (day) and minimum (night) temperatures of 31.9°C and 24.2°C and the relative humidity is 71.9% [8].

### 2.2 Experimental Design

The study was set in a completely randomize design (CRD) where 5 Land use types: T1 (*Nauclea diderrichii* Plantation), T2 (*Gmelina arborea* Plantation), T3 (*Terminalia superba* Plantation), T4 (Arable crop land) and T5 (Fallowed land) were considered while samples

were collected at 2 soil depths (0-15 cm and 15-30 cm soil depths). These were replicate 6 times to make a total of 60 experimental units. Six random soil samples were collected with the aid of core samplers and soil auger from the various land use type at two depths each and taken to the laboratory for soil bulk density and porosity determination. The auger samples were analyzed for some selected chemical properties.

### 2.3 Laboratory Studies

**Physical properties:** Bulk density was determined by Core method and the oven-dried soil samples still in the core samplers (unturnd) were re-saturated with water by capillarity after covering one of the ends of the core samplers each with a piece of cloth to determine the soil porosity. The particle size distribution was determined by hydrometer method [9] and the textural class of the soil was determined using the textural triangle.

**Chemical properties:** The soil organic carbon was determined by the walkley-Black method [10], Total Nitrogen was determined by Kjeldahl method [11]. Soil pH was measured using a glass electrode testronic digital pH meter with a soil: water ratio of 1:2. Available phosphorus extracted by Bray-1 extractant [12]. Organic carbon was determined using dichromate wet digestion method [10]. The value obtained for organic carbon was then multiplied by a constant 1.724 to obtain the value of the organic matter content of the samples. Exchangeable bases (Ca, Mg, K and Na) were extracted in  $\text{NH}_4\text{-OAC}$  buffered at PH 7.0 [13]. The Ca and Mg were determined using Atomic Absorption Spectrophotometer and K and Na were estimated using flame photometer. Exchangeable acidity ( $\text{Al}^{3+}, \text{H}^+$ ) were extracted with concentrated KCl [13] and determined by titration with 0.05M NaOH using phenolphthalein as an indicator.

### 2.4 Statistical Analysis

Analysis of variance was performed to ascertain whether the land uses differed in soil properties. Differences between individual means were assessed using the Least Significant Difference (LSD) test at 5% level of probability

## 3. RESULTS AND DISCUSSION

The location coordinates within the Institute are shown in Table 1. The closeness further

emphasized that the soil type (Alfisol) under these plantations are the same in terms of Pedological classification.

### 3.1 A Brief Description of the Five Land use Types

**Nauclea forest land (NP):** A large number of *Nauclea diderrichii* trees species were planted in this area. The heights of the trees were 10-12 meters and underneath the trees were covered with ferns vegetation.

**Gmelina forest land (GP):** The institute planted this area of land to *Gmelina arborea*, the average height of trees was over 10 meters. There was little vegetation under the trees and the ground was covered by some leaves.

**Terminalia forest land (TP):** *Terminalia superba* trees species were planted on this land and there was obviously no vegetation undergrowth as at when this research was conducted.

**Arable crop land (AC):** A large number of arable crops mainly maize were planted in these areas using conventional farming method.

**Fallowed land (FL):** Here was an area of land that had been previously cultivated but presently undergoing fallow.

### 3.2 Physico-Chemical Properties of the Soil as Influenced by Different Land use Systems

Particle-size distribution is usually employed in soil classification as well as for estimating various related soil properties (Hillel 1980). Relatively higher sand content was recorded in Terminalia Plantation land (TP) soils followed by Arable crop land (AC), Nauclea Plantation land (NP), Fallowed land (FL) and Gmelina Plantation (GP) in the upper 0 to 15 cm depth (Table 3), whereas at 15 to 30 cm depth sand content was found to be higher in Terminalia Plantation (TP) soils followed by Gmelina Plantation soils (GP), Fallowed land (FL), Nauclea Plantation soils (NP) and Arable crop (AC) fields (Table 2). On the other hand, higher content of clay was recorded in 0 to 15 cm depth of both Gmelina Plantation land (GP) and Fallowed land (FL) whereas higher clay content was recorded at 15 to 30 cm depth in Arable crop land and Nauclea plantation land. For silt content on the other hand, the highest silt content was obtained in

fallowed land soils at both depth (Table 2). Although texture is an inherent property, this variation might be attributed to accelerated weathering resulting from the disturbance effect of continuous cultivation, as was also concluded by [14] from the result obtained from the nearby site. The particle size distribution of the soils experimental sites showed sandy loam, loamy sand and sandy clay loam in texture (Table 2). This suggests that the different land use types did not have so much effect on the soil texture of the study area, since texture is an inherent soil property that is not influenced within short period of time.

### 3.3 pH

The pH value under Gmelina Plantation soils (GP) at 15 to 30 cm depth (Table 2.) was found to be the highest whereas lowest in Nauclea Plantation soils (NP) at 0 to 15 cm sampling depth. The soil pH could be categorized as strongly acidic under Nauclea Plantation land (TP) at 0 to 15 cm sampling depth whereas that of Gmelina Plantation land (GP) at 15 to 30 cm depth was moderately acidic, following the classification described by [15]. The higher value of pH under Gmelina Plantation land (GP) at 15 to 30 cm depth could be due to higher values of exchangeable bases which result from leaves

and other plant parts additions to soil. This is evident from the positively correlation between pH and the exchangeable bases.

### 3.4 Organic Carbon

The organic carbon of the soils varied from 14.41 to 16.74% for 0 to 15 cm depth (Table 3) and ranged from 14.40 to 15.64% (Table 3) at 15 to 30 cm depth.

It was observed that the soil organic carbon decreased with depth in the different land use types except Terminalia plantation land use soil which behaved otherwise. This probable might have resulted from accumulation of organic carbon in the subsurface layer as a result of leaching of nutrients by precipitations. At surface layer the average soil organic carbon were higher in fallowed land soils and Arable crop soils compared to the soils of other land use systems. This could be attributed to continuous addition of organic residues either from the plants (leaves) or household waste which reduces organic carbon oxidation. At both depths Arable crop soils had higher organic carbon content compared to the other land uses soils. This could be due to the application of refuse, which also increased to total Nitrogen content of Arable crop soil. [16] reported an increase in organic carbon

**Table 1. Coordinates of the study locations**

Land use	Longitude	Latitude
Nauclea forest land (NF)	07 <sup>o</sup> 23.413 N	003 <sup>o</sup> 51.532'E
Gmelina forest land (GF)	07 <sup>o</sup> 23.390 N	003 <sup>o</sup> 51.550'E
Terminalia forest land (TF)	07 <sup>o</sup> 23.366 N	003 <sup>o</sup> 51.544'E
Arable crop land (AC)	07 <sup>o</sup> 23.387 N	003 <sup>o</sup> 51.645'E
Fallowed land (FL)	07 <sup>o</sup> 23.726 N	003 <sup>o</sup> 51.314'E

**Table 2.PH, Textural properties of the soil at 0 -15 and 15 - 20 cm depth under different land use types**

Land use	PH	Sand (%)	Silt (%)	Clay (%)	Soil Texture
Nauclea Plantation (NP)	5.04	82.50	4.50	13.00	Sandy Loam
Gmelina Plantation land (GP)	5.43	77.50	7.50	15.00	Sandy Loam
Terminalia Plantation land (TP)	5.46	86.50	4.50	11.00	Loamy Sand
Arable crop land (AC)	5.31	84.50	4.50	11.00	Loamy Sand
Fallowed land (FL)	5.29	78.50	6.50	15.00	Sandy Loam
15 – 30cm					
Nauclea Plantation land (NP)	4.95	74.50	4.50	21.00	Sandy clay Loam
Gmelina Plantation land (GP)	5.76	82.50	4.50	13.00	Loamy Sand
Terminalia Plantation land (TP)	5.23	84.50	2.50	13.00	Loamy Sand
Arable crop land (AC)	5.12	72.50	4.50	23.00	Sandy clay Loam
Fallowed land (FL)	5.21	76.50	8.50	15.00	Sandy Loam

by 11 and 67% to incorporation of crop residues in Humbo and Alaba.

### 3.5 Total Nitrogen

Higher total nitrogen was observed in fallowed land while its concentration decreases in the order AC>GP>NP>TP at 0 to 15 cm depth (Table 3). This could be related to the higher organic matter content in the soil of fallowed land whereas at 15 to 30 cm depth higher total nitrogen was observed in Arable crop land and its availability decreases from GP>FL>TP>NP (Table 3).

### 3.6 Available Potassium

Available P content in the soils of the land use types were found to be higher at the surface depth than that of the respective subsurface depth except in Terminalia plantation land soil (Table 3). This could be due to the application of manure, potassium fertilizer in the case of Arable crop land soils.

### 3.7 Micronutrient

Micronutrients were more available in the upper 15 cm soil layer than the lower layer; possibly this was associated with the higher amount of organic matter present in this layer of the soil, or the accumulation of litter fall may have led to the increase in available micronutrients in the soil. Bholra and Mishra [17] reported that release of nutrients through decomposition of litter fall increased the available micronutrient concentrations under different nitrogen fixing tree species. Besides, the formation of chelates of micronutrient cations by the organic molecules produced due to decomposition of organic matter might have enhanced the availability of micronutrients in the soil [18].

### 3.8 Iron (Fe)

The micronutrients status of the soils was influenced by different land use systems (Table 3). The highest available Fe at 0 to 15 cm depth was measured under Terminalia plantation soils (56.20 mg/Kg) followed by the trend AC>NP>GP>FL. In 15 to 30 cm depth, highest Fe was obtained in Terminalia Plantation soils (89.30 mg/Kg) followed by the trend NP>GP>AC>FL. In spite of the significant variation observed, available Fe was in a sufficient level for plant growth under all the various land uses except in fallowed land

land soil based on the rating established by [18]. At both depths, available Fe concentration was lowest in fallowed land soils.

### 3.9 Manganese (Mn)

At 0 to 15 cm depth, available Mn concentration (Table 3.) was highest in Gmelina plantation (160.00 mg/Kg) followed by the trend FL>NP>AC>TP while, in 15 to 30 cm depth the highest concentration was recorded in Terminalia plantation (85.00 mg/Kg) soil. According to the nutrient toxicity level suggested by [18] the concentration of Mn was in the toxic level in all these soils of the various land uses considered, as the concentrations of Mn in both layers were greater than 21.87 mg/kg compared to the critical level of 5 mg/Kg. This obvious content of Mn could be attributed to the pH of the soil where Mn becomes more available in acidic soils.

### 3.10 Zinc (Zn)

The highest concentration of Zn was found in subsurface soil layer (15 to 30 cm) depth of Terminalia plantation (78.00 mg/Kg) followed by the trend FL>AC>GP>NP land, whereas in the surface depth 0 to 15 cm depth, the highest available Zn concentration under Arable crop (35.00 mg/Kg).

### 3.11 Bulk Density and Porosity

The results of soil analyses on bulk density (BD) and total porosity (TP) of different land use systems at two depths are presented in Table 4. Bulk density and porosity were highly variable among different land use types and ranged from (1.039- 1.415) g cm<sup>-3</sup> and (17.99 - 48.87) %.

The bulk density of soils increased with depth while the soil porosity on the other hand decreased with depth except in Terminalia plantation land (TP), Arable crop land (AC) and Fallowed land (FL) uses which behaved otherwise. The soil bulk density of all other land use types were higher compared to that fallowed land use at the two depths. At 0 to 15 cm depth unlike the soil bulk density, the porosity values of soils of Nauclea plantation land (NP) and Gmelina plantation land (GP) were higher than the fallowed land use whereas those of Terminalia plantation land (TP) and Arable crop land (AC) were lesser. The values of soil bulk density under the various land use systems at

both depths were in the order of Arable crop land (AC)>Gmelina plantation land (GP)>Terminalia plantation land (TP)>Nauclea plantation land (NP) >Fallowed land (FL) while the soil porosity on the other hand, at 0 to 15 cm depth were in the order of Nauclea plantation land (NP)> Gmelina plantation land (GP)>Fallowed land (FL)>Terminalia plantation land (TP)>Arable crop land (AC)and Fallowed land (FL)> Terminalia plantation land (TP)>Nauclea plantation land (NP)> Arable crop land (AC)> Gmelina plantation land (GP) at 15 to 30 cm depth. However, this in agreement with [19] who reported that perennial crops system were effective in improving soil physical properties. The effect of land use types

was statistically significant on soil density, and total porosity.

The lowest ( $p<0.05$ ) bulk density as observed with Fallowed land may be attributed to the improved soil organic matter from plant residue decomposition and improved soil structure. This also may be attributed to the decomposed plant litter that may have promoted soil faunal activities and may have played a major role in the build-up and stabilization of soil structure and as a result, improved soil granulation and soil porosity as well. These findings are in agreement with [20] and [21] who reported that soil organic matter improved soil structure and its stability.

**Table 3. Some chemical properties of the soil at 0 – 15 and 15 – 30 cm depth under different land use types**

Land use	T.N (%)	O.C (%)	O.M (%)	Avail. P (mg/kg)	Ca	K	Na	Mg	Fe	Cu	Zn	Mn
<b>0 – 15 cm</b>												
NP	1.32	15.34	26.45	1.75	1.248	0.023	0.478	0.905	35.60	4.20	5.30	51.30
GP	1.38	15.96	27.52	2.10	5.489	0.054	0.457	3.741	35.30	3.60	32.00	160.00
TP	1.24	14.41	24.84	1.33	2.745	0.054	0.435	1.645	56.20	3.40	9.40	8.50
AC	1.41	16.40	28.27	1.78	3.244	0.054	0.804	1.768	40.50	2.80	35.00	30.60
FL	1.44	16.74	28.86	2.15	4.990	0.100	0.804	2.056	02.00	2.40	6.70	130.00
<b>15– 30 cm</b>												
NP	1.24	14.43	24.88	1.71	0.749	0.031	0.435	1.069	61.70	5.00	4.30	24.20
GP	1.32	15.34	26.45	1.37	6.986	0.061	0.500	4.564	39.80	3.90	7.40	11.70
TP	1.28	14.87	25.64	2.63	1.747	0.054	0.848	1.151	89.30	2.80	78.00	85.00
AC	1.35	15.64	26.96	0.73	1.248	0.061	0.783	0.905	22.60	2.50	21.00	27.90
FL	1.29	14.93	25.74	1.78	2.246	0.054	0.804	1.398	03.00	1.30	30.00	46.30

**Table 4. Some physical properties (Bulk density and Porosity) of the soil at 0 – 15 and 15 – 30 cm depth under different land use type**

Land use	Soil bulk density	Soil porosity
	<b>0 – 15cm</b>	
Nauclea Plantation (NP)	1.059 <sup>b</sup>	48.87 <sup>a</sup>
Gmelina Plantation land (GP)	1.286 <sup>a</sup>	41.75 <sup>ab</sup>
Terminalia Plantation land (TP)	1.280 <sup>a</sup>	31.90 <sup>abc</sup>
Arable crop land (AC)	1.327 <sup>a</sup>	17.99 <sup>c</sup>
Fallowed land (FL)	1.039 <sup>b</sup>	41.07 <sup>ab</sup>
<b>15 – 30cm</b>		
Nauclea Plantation land (NP)	1.276 <sup>a</sup>	32.58 <sup>abc</sup>
Gmelina Plantation land (GP)	1.371 <sup>a</sup>	25.12 <sup>bc</sup>
Terminalia Plantation land (TP)	1.368 <sup>a</sup>	33.94 <sup>abc</sup>
Arable crop land (AC)	1.415 <sup>a</sup>	30.55 <sup>abc</sup>
Fallowed land (FL)	1.263 <sup>a</sup>	42.09 <sup>ab</sup>

Means value within a column followed by the same letter(s) are not significantly different at  $P = .05$

#### 4. CONCLUSION

In Nigeria, the growing population and more intensive land use have resulted in sharp falloffs of soil fertility by continuous removal of soil particles and vegetation. Describing the spatial variability of soil nutrients in relation to site properties such as climate, land use and other variables is important for understanding how the ecosystem works and evaluating the effects of further land use change on soil properties [22]. Findings of this study suggest that many soil properties are influenced by land use. At 0 – 15 cm depth, higher values of soil TN, OC, Av.p and Organic matter were obtained under Fallow land use as compared to the other land use fields whereas at subsurface layer, higher values of soil Av.p, Fe, Zn and Mn were obtained under *Terminalia superba* plantation. Under *Terminalia superba* fields the contents of TN, OC, Av.p and Organic matter at surface level were significantly lowest. These effects are attributed to the higher organic matter management in the Fallow land use. The information generated from the present study suggested fallowed land use as the best land use system because of its higher soil organic matter management, as it improves the soil structure and this will assist in developing sustainable and ecologically stable land use management strategies for the study area. Moreover, organizations, people living around the study area and others who intend to invest, transfer or introduce new agricultural technologies in the area will benefit from the study.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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