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# Moisture characteristics of soils of different land use systems in Ubakala Umuahia, Abia State, Nigeria.

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**Abstract:** Information about effects of different land use systems on soil moisture characteristics is crucial for efficient land management practices. This study was, therefore, conducted to evaluate the variations of soil moisture characteristics under different land use systems in Ubakala, Umuahia South Local Government Area, Abia State, Nigeria. The land use systems studied included cassava-cultivated land (CC), 4-year bush fallow land (4-BF) and forest land (FL). The research was superimposed on land use systems that were located nearby on soil with similar parent material. Undisturbed core and disturbed auger soil samples were randomly collected from three sampling points with three replications for each land use system at two varying depths (0-20 cm and 20-40 cm). The undisturbed core samples were analysed for soil moisture characteristics in the laboratory except infiltration rate which was determined in the field with the use of double ring infiltrometer. The auger samples were analyzed for particle size distribution. Data generated were subjected to analysis of variance (ANOVA) for randomized complete block design (RCBD). Results indicated that the CC was sandy clay loam in texture while the 4-BF and FL were sandy loam textured. At both depths, CC retained the lowest amount of moisture at field capacity (0.188 and 0.199 $m^3/m^3$), permanent wilting point (0.100$m^3/m^3$) and available moisture content (0.088 and 0.099 $m^3/m^3$). In contrast, the highest amount of moisture retained at field capacity (0.214 and 0.217 $m^3/m^3$) and permanent wilting point (0.109 and 0.103 $m^3/m^3$) was found under the FL at both depths. However, the 4-BF recorded the highest available moisture content at 0 ï 20 cm depth (0.106$m^3/m^3$) while FL had the highest at 20 ï 40 cm depth (0.114$m^3/m^3$). The slowest saturated hydraulic conductivity ($K_{sat}$) (0.71 and 0.62 cm $min^{-1}$) at both depths and infiltration rate (Ir) at 0 ï 20 cm (0.63 cm $min^{-1}$) were recorded under CC whereas the fastest $K_{sat}$ (0.80 and 0.77 cm $min^{-1}$) was found under 4-BF. Forest land had the fastest Ir (0.73 cm $min^{-1}$). In all land use systems, field capacity and available moisture content increased with soil depth while permanent wilting point decreased. Conversion of bush fallow and forest lands to arable farm lands will affect the soil moisture retention and transmission characteristics. It is therefore recommended that appropriate and integrated land management options for different land use systems are undertaken to sustain agricultural productivity while protecting the environment.

**Keywords:** land use, moisture retention, moisture conduction, ANOVA, Ubakala
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## Introduction

Land use system is a complex process shaped by human activity, affected by ecological, economic, and social drivers, and capable of influencing a wide range of environmental and economic conditions (MacDonald *et al.,* 2000). Changes in land use affect physical, chemical and biological characteristics of the soil (Shukla *et al.,* 2003). Soil moisture characteristics, which are important soil hydrological properties, are affected by soil structure, aggregate stability, particle size distribution, land use system (Fu *et al.,* 2000), vegetation (including plant and litter cover and type, and soil organic content), topography and climate (Jimenez *et al.,*2006). Increase in ground cover often results in increase in soil inýltration rate and saturated hydraulic conductivity (Shukla *et al.,* 2003). Land use change from natural or semi-natural vegetation to continual tillage and grazing has a marked effect on soil bulk density, porosity, aeration, inýltration, water storage, water transport and runoff (Broersma *et al.,* 1995).

Land use and soil management practices influence the soil organic matter and related soil processes, such as moisture transmission (Liu *et al.,* 2010). As a result, it can modify the processes of soil water transport and re-distribution of nutrients. Some land use systems include continuous cropping, forestland and bush fallowing (Agoume and Birang, 2009). Forest land use system has caused positive modifications in the soil physical properties (Shepherd *et al*., 2000) and resulted to the development of tree biomass (Versterdal *et al.,* 2002). The conversion of forest and pasture lands into crop land is known to deteriorate soil properties, reduce the soil water transmission, change the distribution and stability of soil aggregates (Singh and Singh, 1996) and soils may become more susceptible to erosion since macro aggregates are disrupted (Six *et al.,* 2000). Continuous cropping decreases moisture conducting characteristics of soils while increasing the depletion of organic matter (Celik, 2005). Bush fallowing can alter soil moisture characteristics through the amounts of organic residues that are returned (Neris *et al.,* 2012). Usually, the larger the amount of residues returned over a period of several years, the higher the level of organic matter which increases the volume of water transmitted in the soil (Malgwi and Abu, 2011).

Changes in soil properties attributed to changes in land use systems are difficult to estimate due to the time scale of the changes (Garcia-Estringana *et al*., 2012). It is also difficult to distinguish land use induced changes from changes caused by other effects such as changes in climate (Hu *et al.,* 2009). However, the effect of climate manifests on a much longer time scale compared to that of land use change (Novak *et al.,* 2009). Soil moisture characteristics are influenced by the type of the cultivated plants, the seasonal impact, and land use systems such as altered agricultural systems (Zhou *et al.,* 2008).

The evolution of different soil hydrological properties in natural ecosystems, such as forests, can be a relatively slow process. However, in agricultural land use systems, mechanical disturbances, like tillage systems, can rapidly change the soil moisture characteristics (Lipiec *et al.,* 2006). Water and nutrients are essential for plant growth and soil health. Therefore, it is important to know the effects of various land use systems on soil moisture characteristics and nutrient transport within the soil matrix. The objective of this study was to determine the effects of land use systems on soil moisture characteristics.

**Materials and method**

**Study area.**

The study was carried out in Ubakala in Umuahia South Local Government Area of Abia State, South eastern Nigeria. The area is located within latitude $5^0 30^1$N and longitude $7^0 28^1$E (NRCRI, 2007). It is highly populated, with an average population density of 2600 inhabitants per square kilometre (Ukandu *et al.,* 2011). The location has a mean annual rainfall of 2201.92m (NRCRI, 2007). The rainfall is bimodal, starting in April and ending in October with peaks in June and September.

Within the location, cassava-cultivated land, forest land and 4-year bush fallow land were investigated. These sites are within Ubakala metropolis. The forest land had existed for over 60 years with tress such as Milica excels (iroko), Swieteria mahgani and Gamelina arborea (gmelina) while the 4-year bush fallow land had trees such as Dialium guineese, Chromolaena odorata (siam weed), Anthronotha macrophylla and Parinari congensis. The cassava-cultivated land had been under continuous cultivation of cassava crop.

**Soil Sampling**

Under each land use system, 3 sampling points were located randomly. Around each of the 3 sampling points within a land use, soil samples were collected at 2 depths (0 ï 20 and 20 ï 40 cm) using soil auger. This constituted a total of 6 samples for each land use and a grand total of 18 bulk samples for the 3 land use systems. Two core samples were collected, one at 0 ï 20 cm and the other at 20 ï 40cm from each of the 3 sampling points making a total of 6 core samples in each land use system. Also, a total of 18 core samples were collected for analysis.

**Sample Preparation**

The soil samples collected with the soil anger were air-dried and sieved through 2mm sieve size for particle size analysis. The base of each core sample was covered with a cheese cloth and saturated in water for determination of soil physical properties.

**Laboratory Analysis**

**Particle size distribution analysis** was by the Bouyoucos hydrometer method as outlined by Kettler *et al.,* (2001).

**Field capacity and permanent wilting point** were determined using the estimation method described by Mbagwu (1991).

**Available water content (AWC)** was deduced from field capacity (FC) and permanent wilting point (PWP) thus:

AWC = FC ï PWP ------------------------------------ (1)

**Saturated hydraulic conductivity ($K_{sat}$)** was determined by the constant head method (Stolte, 1997).

**Infiltration rate (Ir)** was determined at the sites using double ring infiltrometer as described by Ayu (2013),

**Statistical Analysis**

Analysis of variance (ANOVA) for randomized complete block design (RCBD) was used to compare the influence of land use system and depth on soil physical properties. Significantly different means were separated using least significant difference at 5% level of probability (PÒ0.05).

## Results and Discussion

**Particle size distribution:** The particle size distribution of the soils studied is shown in Table 1. At both depths of 0 ï 20 and 20 ï 40 cm, the texture of soil under cassava-cultivated land (CC) was sandy clay loam while 4- year bush fallow and forest lands were sandy loam at both depths.

At the depths of 0 ï 20 and 20 ï 40 cm, respectively, the highest sand contents of 724.0 and 708.0 g/kg were observed under the 4-year bush fallow land (4-BF). Cassava-cultivated land (CC) recorded the lowest at both depths (705.0 and 685.2 g/kg). With regard to silt contents, the 4-year bush fallow land (4-BF) recorded the highest at the two depths (119.0 and 112.0 g/kg). The lowest silt and highest clay contents were observed under cassava-cultivated land at both depths. The values ranged from 61.0 to 67.8 g/kg for silt and 234.0 to 247.0 g/kg for clay. The lowest clay contents at both depths were observed in the 4-year bush fallow land (64.0 and 83.0 g/kg).

Generally, the sand and silt contents decreased with depth while the clay contents increased. However, the silt content under cassava-cultivated land increased with depth. As shown in Table 1, and with regards to depth, sand and clay particles were significantly (PÒ0.05) different, whereas silt was statistically similar. With regards to the land use systems and depths, the sand, silt and clay particles of cassava-cultivated land (CC) were significantly (PÒ0.05) different from 4-BF and FL. The land use systems differed significantly in their particle size distribution. However, sand fraction of the 4-BF was statistically similar to that of FL at both depths.

**Table 1**: **Particle size distribution of soils studied**

| Land use | Soil Properties | | | |
|---|---|---|---|---|
| | Sand | Silt | Clay | Texture |
| | → | (g/kg) | ← | |
| | | **0 – 20 cm** | | |
| CC | 705.0 | 61.0 | 234.0 | sandy clay loam |
| 4-BF | 724.0 | 119.0 | 157.0 | sandy loam |
| FL | 713.3 | 106.7 | 180.0 | sandy loam |
| Mean | 714.1 | 95.6 | 190.3 | |
| | | **20 – 40 cm** | | |
| CC | 685.2 | 67.8 | 247.0 | sandy clay loam |
| 4-BF | 708.0 | 112.0 | 180.0 | sandy loam |
| FL | 703.2 | 101.3 | 195.5 | sandy loam |
| Mean | 698.8 | 93.7 | 207.5 | |
| **$LSD_{0.05}$** | | | | |
| Land use | 10.0 | 19.3 | 11.0 | |
| Depth | 2.1 | 17.9 | 10.2 | |
| L × D | 10.4 | 15.9 | 8.1 | |

CC = cassava cultivated land, 4-BF = 4-year bush fallow land, FL= forest land
L × D = Interaction of land use × depth.

The high sand contents of the soils could be attributed to their being derived from unconsolidated sand deposits formed over coastal plain sand (Asawalam *et al*., 2009; Chukwu, 2013). The removal of vegetative cover and top soil as a result of intensive cultivation exposed the soil thereby contributing to the high sand and clay contents giving rise to its sandy clay loam texture (Jaiyeoba, 2003). The sandy loam texture observed in the 4-year bush fallow and forest lands corroborated the report of Ufot *et al*. (2016), who reported sandy loam texture for bush fallow and forest lands in Akokwa, Imo State. The higher clay contents observed at the subsoil under cassava-cultivated land could be attributed to increased cultivation (Oguike and Onwuka, 2017). This may be as a result of either increase of clay translocation from the surface to subsurface horizons or removal of clay from the surface by runoff (Jaiyeoba, 2003). On the contrary, Shepherd *et al.* (2000) observed that changes due to land use do not show easily for particle size. The increase in clay with soil depth may be due to dissolution and leaching of clay materials as a result of intense torrential rainfall (Oguike and Onwuka, 2017), argillation of clay, lessivage and sorting of soil materials (Ojanuga, 2003).

**Moisture retention characteristics.**

Soil moisture characteristics such as field capacity (FC), permanent wilting point (PWP) and available water content (AWC) of soil studied are shown in Table 2. Among the parameters measured at the two depths (0 ï 20 and 20 ï 40cm), forest land (FL) contained the most moisture at field capacity with values 0.214 and 0.217 $m^3/m^3$. The cassava-cultivated land (CC) was observed to contain the lowest (0.188 and 0.199 $m^3/m^3$) at both depths. With regard to permanent wilting point (PWP), forest land (FL) contained the most at both depths with values of 0.109 and 0.103 $m^3/m^3$, while cassava-cultivated land contained the lowest (0.100 $m^3/m^3$) at both depths. 4-year bush fallow land (4-BF) had the highest available water content (0.106 $m^3/m^3$) at 0 ï 20 cm depth while forest land recorded the highest (0.114 $m^3/m^3$) at 20 ï 40 cm. However, cassava-cultivated land had the lowest with values 0.088 and 0.099 $m^3/m^3$at 0 ï 20 and 20 ï 40 cm depths, respectively.

**Table 2: Moisture retention characteristics of soils studied**

| Land use | Soil Properties | | |
|---|---|---|---|
| | FC | PWP | AWC |
| | ⟶ | ($m^3/m^3$) | ⟵ |
| | | **0 – 20 cm** | |
| CC | 0.188 | 0.100 | 0.088 |
| 4-BF | 0.211 | 0.105 | 0.106 |
| FL | 0.214 | 0.109 | 0.105 |
| Mean | 0.204 | 0.105 | 0.100 |
| | | **20 – 40 cm** | |
| CC | 0.199 | 0.100 | 0.099 |
| 4-BF | 0.214 | 0.101 | 0.113 |
| FL | 0.217 | 0.103 | 0.114 |
| Mean | 0.210 | 0.101 | 0.108 |
| **$LSD_{0.05}$** | | | |
| Land use | 0.012 | 0.028 | 0.046 |
| Depth | 0.069 | 0.024 | 0.040 |
| L × D | 0.010 | 0.031 | 0.037 |

CC = cassava-cultivated land, 4-BF= 4-year bush fallow land,
FL= forest land, L × D = Interaction of land use × depth.

Generally field capacity and available water content increased with depth, while permanent wilting point decreased with depth. As shown in Table 2 and with regards to land use systems, at both depths, the field capacity of CC was significantly (PÒ0.05) lower than 4-BF and FL. Also at both depths, the field capacity of 4-BF was significantly (PÒ0.05) similar to FL. Forest land was significantly (PÒ0.05) higher in permanent wilting point than the other land use systems, while CC was significantly (PÒ0.05) lower. Cassava-cultivated land had significantly (PÒ0.05) lower available water contents than 4-BF and FL at both depths

The high field capacities recorded under4-year bush fallow land and forest land may be attributed to the high organic matter which provided large surface area required for the absorption and retention of water molecules (Materechera and Mkhabela, 2001). The high water retention capacity of soils under 4-year bush fallow and forest lands was similar to the findings of Ayoubi *et al*. (2011). The low available water content of soils under cassava-cultivated land may be attributed to their low structural stability. Yihenew and Ayanna (2013) who made similar observation reported that land under continuous cultivation deteriorated soil structural aggregates, reducing their available water contents.

**Moisture transmission characteristics.**

The moisture transmission characteristics of the soils studied are shown in Table 3. At the depths of 0 ï 20 and 20 ï 40cm, 4-BF had the fastest $K_{sat}$ of 0.77 and 0.80 cm $min^{-1}$, respectively, while CC had the slowest of 0.62 and 0.71 cm $min^{-1}$, respectively. The $K_{sat}$ under CC was significantly (PÒ0.05) slower than 4-BF and FL at both depths whereas 4-BF and FL were statistically similar. For the infiltration rates (measured only at 0 ï 20cm), FL was the fastest among the three land use systems. The difference in infiltration between FL and 4-BF was not significant but they significantly (PÒ0.05) differed from CC.

**Table 3**: **Moisture transmission characteristics of soils studied**

| Land use | Soil Properties | |
|---|---|---|
| | $K_{sat}$ | Ir |
| | →(cm min$^{-1}$) ← | |
| | **0 – 20 cm** | |
| CC | 0.71 | 0.63 |
| 4-BF | 0.80 | 0.70 |
| FL | 0.78 | 0.73 |
| Mean | 0.76 | 0.69 |
| | **20 – 40 cm** | |
| CC | 0.62 | |
| 4-BF | 0.77 | |
| FL | 0.74 | |
| Mean | 0.71 | |
| **$LSD_{0.05}$** | | |
| Land use | 0.06 | 0.03 |
| Depth | 0.02 | |
| L × D | 0.42 | |

CC = cassava-cultivated land, 4-BF= 4-year bush fallow land
FL= forest land L × D = Interaction of land use × depth

The slow saturated hydraulic conductivity and infiltration rate observed under CC may be attributed to structural instability and possible compaction due to mechanical disruption of the pore arrangements resulting from frequent tillage (Celik, 2005). The fast saturated hydraulic conductivity and infiltration rate observed under 4-BF and FL may be as a result of high organic matter content expected in soils under such land use systems. This concurred with the findings of Malgwi and Abu (2011) who reported that the high level of organic matter in forest and bush fallow lands led to low bulk density, high total volume and favoured transmission of water under saturated conditions.

### Conclusion and Recommendation

The objective of this study was to compare the impact of land use systems on soil moisture characteristics. From the study, it may be concluded that soil moisture characteristics significantly vary among land use systems. It may also be apparent that change in land use systems from natural forest and bush fallow lands to continuous arable cropping will have a significant effect on soil moisture characteristics. It is recommended that various integrated land management such as replenishing either by using crop residues as mulching or applying such inputs as organic wastes/materials to enhance the organic matter status of cassava cultivated land should be practiced to overcome land degradation and achieve sustainable agricultural production in cultivated lands of the study area.

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