

ORIGINAL ARTICLE

INFLUENCE OF LAND USE TYPES ON THE INFILTRATION CAPACITY OF ULTISOL SOILS IN UNIVERSITY OF PORT HARCOURT, NIGERIA

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ABSTRACT

The study aimed to determine the influence of different land-use types on the Ultisol soils in the University of Port Harcourt Teaching and Research Farm, Port Harcourt. Three land use types were considered namely cultivated, forested and uncultivated plots. Soil samples were collected randomly at 0 – 30 cm depth from three locations in the different land-use types. The samples were bulked and used for determination of soil separates, core sampling was collected for determination of bulk density, total porosity and saturated hydraulic conductivity. A double ring infiltrometer was used to determine infiltration rate of the various land use types. The research revealed that the infiltration rates of the different land use types was generally slow and followed the order uncultivated (35 mm/hr^{-1}) > cassava (5.1 mm/hr^{-1}) and > forested (3.4 mm/hr^{-1}) plots. The sand fraction dominated the various land use, having sandy loam in cassava and forested plots while uncultivated plot was dominated by loamy sand. Bulk density across the various land use did not exceed the critical threshold value of 1.63 g/cm^3 . The porosity percentage recorded in the various land use types were within the satisfactory soils (40-45%), good soils (45-50%), and optimum porosity (>50) values required for crop production. Hydraulic conductivity (provide the value) for the various land use types was generally slow. Water holding capacity (provide the value) was also very poor. Aggregate stability measured by mean wet diameter was significant in the different land use types (provide the value) and was found to be more stable in forested plot (provide the value) compared to cassava (provide the value) and uncultivated plots (provide the value).

KEYWORDS: *Cassava plot, Forested plot, Infiltration capacity, Land use, Ultisol,*

INTRODUCTION

Infiltration rate is one of the most important factors controlling agricultural production in terms of irrigation efficiency and amount of water entering the soil during irrigation or rainfall and the advance rate of water down the furrow. Infiltration capacity is the maximum rate at which a soil is capable of absorbing water in a given condition (Udom and Adesodun, 2016). It is an important soil hydrological property which is influenced by soil structure, aggregate stability, particle size distribution, vegetation, plant and litter cover (Smith, 2014; Kirkham, 2014).

Other factors include soil organic matter content, topography, climatic and land use type. Soil water is one of the principal factors limiting the growth of plants not only in arid or semi-arid regions where total crop water requirements usually exceed water supply, but also in the humid environment where poor rainfall distribution and water management results in occasional water stress (Musa and

Adeoye, 2010). An important soil ecosystem function is the enhancement of soil water storage and minimization of runoff and erosion (Lal and Shukla, 2005). However, soil that is continually disturbed by tillage and other anthropogenic activities, often loses its resilience and develops poor structural characteristics, including surface sealing and crusting, and consequently reduced infiltration and high runoff and erosion. This is because intensified land use primarily affects soils intrinsic and dynamic properties including soil structure and moderated soil properties (Ogban, 2017).

Soils under the same geology and environmental conditions can differ in their infiltration capacity as a results of differences in land use (Smith, 2014). Kirkham (2014) found that infiltration capacity of soil decreased as moisture content of the surface soil layers increased and that the surface soil cover play significant role in the modifications of infiltration rate. Quantification of infiltration is important to determine the availability of water to crops, calculate the amount of additional water needed for irrigation, predicts flooding and pollutant transport (Ogban, 2017). Land use changes either by natural or artificial means have been reported to have a marked effect on soil bulk density, porosity, aeration, infiltration, water storage, water transport characteristics and runoff (Kirkham, 2014). Land use changes are often considered to be the main factors influencing soil infiltration.

Thus, this study was aimed to examine the effects of different land used type on infiltration capacity of Ultisol soils so as to suggest improved water management strategies for improve crop production in the area.

MATERIALS AND METHODS

Study Area

The study was conducted in the Research and Demonstration Farm of the University of Port Harcourt with Latitude $4^{\circ} 45^1$ and Longitude $6^{\circ} 50^1$. Rivers state is characterized by high rainfall, which decreases from south to north. Total annual rainfall decreases from about 4,700 mm on the coast to about 1,700 mm in extreme north of the state (Isa, 2020). The climate of the area is typical of a tropical rainy type. The mean annual temperature is 26°C . Based on the rainfall pattern, the climate of the area is divided into rainy season (March to October) and a very short dry season (November to February). The geology of the area is coastal plain sand consisting of grey sandy clay.

Soil Sampling and Preparation

Three areas under different land use practices were selected: Cassava plot (under five years' continuous cultivation). Uncultivated plot (under fallow for four years) and Forested plot of *Gmelina* and *Treculia*. Soil samples from these areas were collected at random, using the soil auger at 0-30 cm depth. They were air-dried, gently crushed and made to pass through 2 mm sieve with the exception of the samples used for aggregate size stability test. Sieved samples were stored in polythene bags to avoid soil moisture loss and contamination and were labelled appropriately for selected physical and chemical analysis. Core samples were also collected with core cylinders measuring 6cm long and 5cm in diameter. The core samples were securely held in the cylinder with a piece of cheese cloth and twine and were labelled properly for determination of saturated hydraulic conductivity, bulk density, and total porosity

Infiltration Measurement

A total of 18 infiltration runs was carried out using the double ring infiltrometer method (FAO, 1979). The infiltrometer has an outer ring of 30 cm diameter and an inner ring of 15cm. The infiltrometer was driven vertically into the soil to a depth of 10 cm using a driving plate and mallet. Infiltration commenced by adding water into the outer ring which acted as a buffer to discourage lateral flow of water, but rather promote one-dimensional vertical flow of water in the inner ring. Water was also immediately added to the inner ring. Measurement was taken from the inner ring at 5 minute intervals with the help of a plastic cm ruler tape to the inner ring wall. The Infiltration rates were measured for a period of two to three hours depending on the time the steady state was determined. The steady state infiltration rate (I) was calculated according to the method of Bower (1986) as:

$$I = \frac{Q}{AT} \quad (1)$$

Where, Q = is the quantity of water infiltrating (cm³), A = is area of the soil surface exposed to infiltration (cm²) and t = is time (s).

Methods of Soil Analyses

Determination of Aggregate Stability and Water Holding Capacity

The distribution of aggregates by wet sieving was measured as described by Kemper and Rosenau (1986), while aggregate stability was evaluated by the mean-weight diameter. In this procedure, air-dried soil samples were sieved to obtain 4.75 mm natural aggregates. Fifty grams of 4.75 mm dry sieved aggregates were placed on the top most of sieves of different openings sizes 2.0, 1.0, 0.5, and 0.25 mm, presoaked by capillary in distilled water for 5 mins before oscillated vertically in water 20 times, using 4 cm amplitude in a mechanical agitator.

The stable aggregates remaining on each sieve were oven-dried at 50°C for 24hrs and weighed. The mass of aggregates <0.25 mm was obtained by the difference between mass of sample and the sum of sample weights collected on the 2.0, 1.0, 0.5, and 0.25 mm nest of sieves. The percentages of the stable aggregates on each sieve representing the water stable aggregates and were calculated as:

$$\%WSA = \frac{MR}{MT} \times 100 \quad (2)$$

Where MR = mass of resistant aggregates (g) and MT = total mass of wet-sieved soil (g). The mean weight diameter (MWD) of the water stable aggregates was calculated by the following equation (Hillel, 2004):

$$MWD = \sum_{i=1}^n x_i w_i \quad (3)$$

Where, Xi = mean diameter of each size fraction, and Wi = weight of aggregates in that size range as a fraction of the dry weight of the sample analysed. Water holding capacity of the soil was calculated as:

$$\text{WHC} = \frac{MW - MD}{MD} \times 100 \quad (4)$$

Where MW = mass of weight soil, MD = mass of dry soil

Determination of Bulk Density, Porosity, and Saturated Hydraulic Conductivity

Bulk density was measured with oven-dried soil core samples by the method of Grossman and Reinsch (2002) as:

$$\text{Bulk density} = \frac{\text{Mass of oven-dried soil (g)}}{\text{Volume of bulk soil (cm}^3\text{)}} \quad (5)$$

Where, B.D = Bulk density, Ms = Mass of oven dry soil (g)

Vt = Volume total of soil (cm⁻³) = πr^2h (r = radius of the core cylinder, h= height of the core cylinder).

$$\text{Total porosity} = \frac{\text{Volume of water at saturation (0 kpa) (cm}^3\text{)}}{\text{Volume of bulk soil (cm}^3\text{)}} \quad (6)$$

Saturated hydraulic conductivity was measured using the constant head soil core method (Reynolds et al., 2002) and calculated by rearranging Darcy's equation for constant head condition as below;

$$K_{sat} = \frac{V}{AT} \times \frac{L}{\Delta H} \quad (7)$$

Where V = volume of water collected at steady state (cm³), L= is the length of the soil core (cm), A = cross-sectional area (cm²), T = time (h) and H = hydraulic head difference (cm). The test started by attaching an empty core cylinder to the top of the saturated core sample (the exposed soil part and not the base of core with the cheese cloth). The core cylinder of same diameter and length was used. They were held together firmly with the use of a masking tape and placed on a retort stand. A beaker was placed under the system to collect water infiltrating through it.

Then, water flow was released in order to fill up the entire system with water. The 6cm length core was used and hydraulic head of 5cm was maintained for a period of 5minutes. The water discharged was collected and was measured with the use of 100ml measuring cylinder. Three trials were carried out for each sample and the hydraulic conductivity was calculated by the average of the obtained values.

Data analysis:

Data was presented as means and analysed using one way ANOVA. Least significant differences (LSD) was determine at (p<0.05)

RESULTS AND DISCUSSION

Infiltration Rate

The results of the infiltration studies of the different land used types are presented graphically below

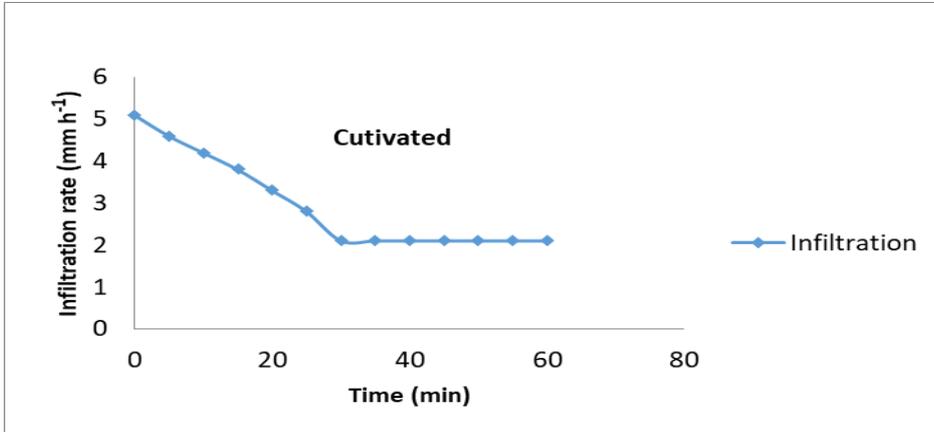


Figure 1. Infiltration rates under cultivated land use

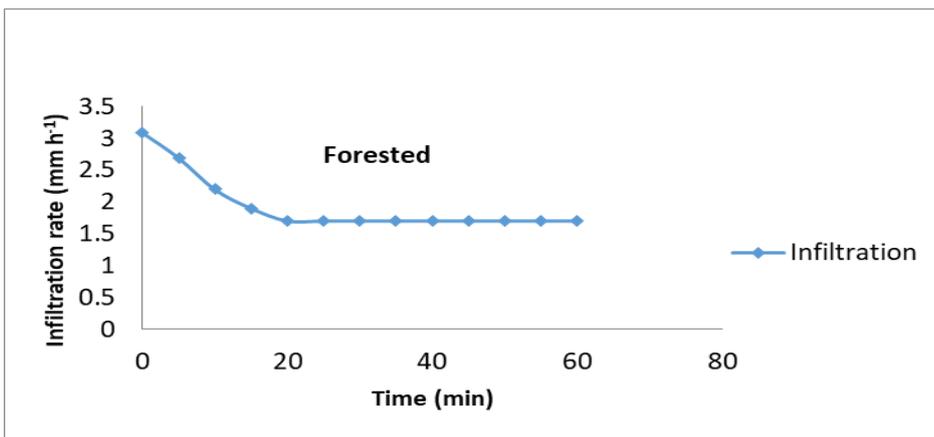


Figure 2. Infiltration rates under forested land use

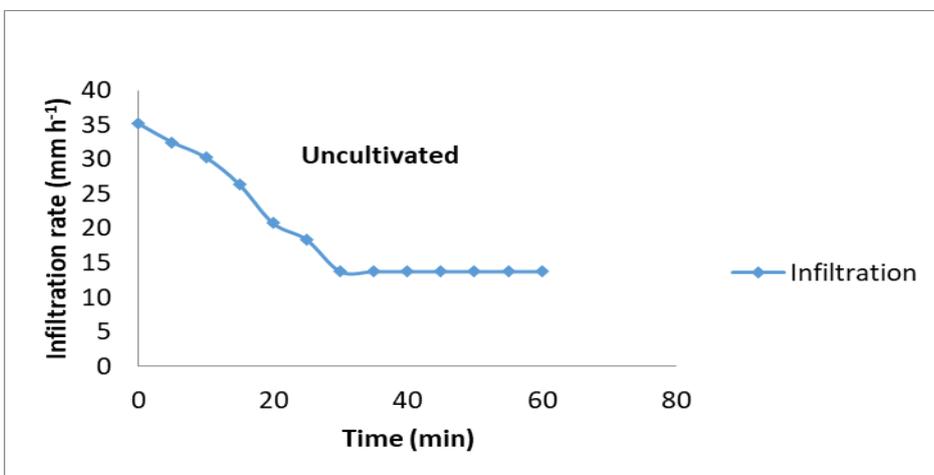


Figure 3. Infiltration rates under uncultivated land use

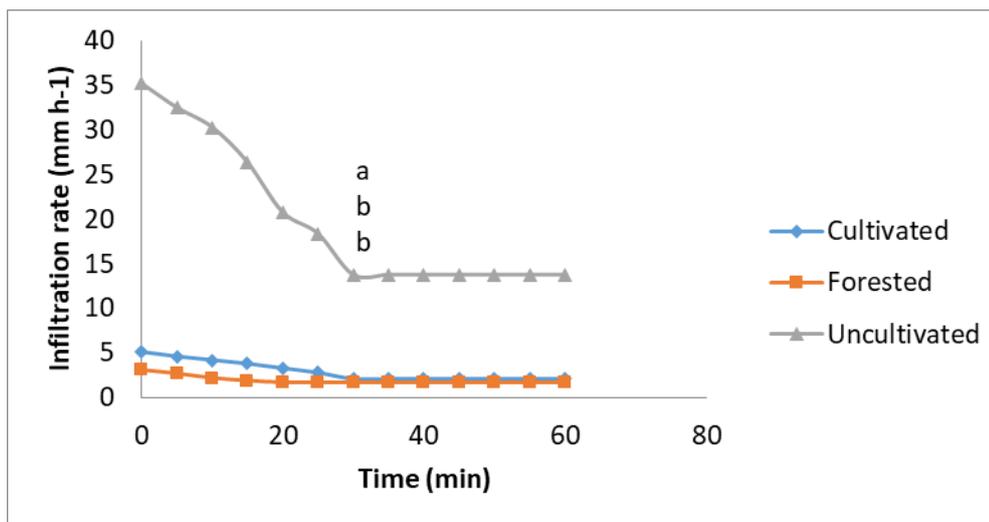


Figure 4 Summary of infiltration rate on different land used types

The results obtained in the infiltration measurement of the three different land used were slow as shown in figures 1, 2 and 3. For instance initial infiltration rate of 5.1mm/hr⁻¹ was obtained in the cultivated (cassava) plot and decreases gradually to about 2.1mm/hr⁻¹ for 30mins before attaining a steady state at about 35mins. Initial infiltration rate of 3.4mm/hr⁻¹ was also obtained in the forested plot which decreases gradually to about 2.5mm/hr⁻¹ for about 20mins before attaining a steady state for about 40mins. Furthermore, an initial infiltration rate of 35mm/hr⁻¹ was recorded for the uncultivated plot which decreases gradually to 13mm/hr⁻¹ in 30mins before attaining a steady state for about 31mins.

The slow/very slow infiltration rates experience in the different land used types especially the forested plot is in contrast with the work of (Gonzalez *et al*, 2010) which shows that forested environment improves infiltration rates of the soils but, agreed with the work of Udom *et al*. (2016) that showed prolong decomposition can cause the formation of a biological mats or clogging existing in the soils that can resist infiltration of water into the soil. These biological mats occur as a result of microbial biomass and their by-products such as Extracellular Poly Metric Substances (Wang *et al.*, 2016). The microbial biomass blocks the pathway of water in the pore space, forming a certain thickness that reduces infiltration rate. The steady state was measured at 1.7mm/hr after 20minutes. The highest initial infiltration rate was measured at 35.9mm/hr in the uncultivated treatment.

This is supposedly due to the land area being undisturbed over a period of time. Disturbed soils due to cultivation can cause soil compaction and reduce infiltration rate as a result of blocked pore spaces (Gonzalez *et al*, 2010). The summary of infiltration rates under different land used types is giving as fellow: uncultivated (fallow) > cultivated (cassava) > and forested plot (*Gmelina and treculia*) as presented in figure 4.

Physical properties of the different land use**Table 1:** Mean of some physical properties of the soil under different land use

Land use	Sand	Silt	Clay	Texture	TP	BD	K _{Sat}	WHC	MWD
	(g kg ⁻¹)	(g kg ⁻¹)	(g kg ⁻¹)		(%)	(g cm ⁻³)	(cm h ⁻¹)	(%)	(mm)
Cassava	76 ^a	11a	13a	SL	42.3c	1.54a	24.0b	28.6a	1.18b
Forested	76a	10a	14a	SL	46.4b	1.43a	34.0a	26.8a	0.85c
Uncultivated	78a	9a	13a	LS	50.6a	1.44a	22.8b	21.0b	1.62a

Means followed by the same letters within column were not significantly different at $p < 0.05$; TP- total porosity, BD- bulk density, K_{Sat} – saturated hydraulic conductivity, WHC- water holding capacity, SCL- sandy clay loam.

The particle-size distribution mean data for the various land use types is presented in table 1. The particle size distribution were dominated by sand fraction (76, 76 and 78 g kg⁻¹) for cassava, forested and uncultivated plots respectively with no significant different existed between them. This is not surprising as Ultisol soils are characterized with sandy particles since they are majorly derived from coastal plain sand parent materials. Onweremadu *et al.* (2011), attributed high sand content to nature of parent material. The observation is in agreement with the findings of Collis *et al.* (2018); and Askira *et al.* (2019b). The silt particles (11, 10, and 9 g kg⁻¹) for cassava, forested and uncultivated plots respectively with no significant different although, the values (11, 10, and 9 g kg⁻¹) are moderately high which is in consonance with the works of Nsor and Uhie, (2016); Ogbodo, (2011) and Askira *et al.* (2019a).

The clay content in the studied land used types are not also significantly different, but higher in forested plot (14 g kg⁻¹) compared to the cultivated (13 g kg⁻¹) and the uncultivated plots (13 g kg⁻¹) which could be attributed to the decomposition of large presence of organic litters present in the forest floor. Soil textural class are found to be sandy loam in the cassava and forested plot but loam sand in others. Soil texture is important as it influences nutrient holding capacity, organic matter content, water holding capacity and aeration (Kefas *et al.*, 2016). The texture of these soil may be attributed to the parent material (coastal plain sand) derived from sedimentary deposit (Ahukaemere *et al.* 2016) or the rate and nature of the weathering processes (Ahukaemere *et al.* 2012).

Total porosity (42.3, 46.4 and 50.6%) is statistically significant at ($p < 0.05$) in the different land used types. Land used under uncultivated plot had the highest mean value of 50.6%, followed by forested with 46.4% and then 42.6%. The high porosity value may be due to the dominance of macro-pores that dominates the study areas and loosening of soil materials by plant roots. The porosity percentage recorded satisfied the satisfactory soils (40-45%), good soils (45-50%), and optimum porosity (>50) value required for crop production (Maksim *et al.*, 2023). There was no significant difference in bulk density across the land used types. The mean data value for the various land used types range between 1.43 g/cm³ to 1.54g/cm³. These values are within the average range for bulk density of tropical soils and hence may not have any inhibition effects on root growth and penetration. There was no significant different in hydraulic conductivity (K_{sat}) values of the cassava

(24.0 cm h⁻¹) and uncultivated (22.8 cm h⁻¹) but significant different exits in forested plots (34.0 cm h⁻¹) at p<0.05. The (Ksat) for the different land use types was generally slow which may be due to crusting hazard cause by poor aggregation that promotes easy detachment of soil particle from the soil mass. There was no significant different in water holding capacity of the cassava (28.6 %) and forested (26.8 %) but significant different exits in uncultivated plots (21.1 %) at p<0.05.

Water holding capacity of the different land used types was very poor indicating moisture deficits due to poor moisture retention capacity of the soil attributed to the parents materials from which the soil were formed. However, the forested and cultivated plots recorded a relatively and moderately low water holding capacity of 28.6% and 26.8% respectively indicating improvement in the soil moisture retention which may be a contribution of organic litter's decomposition on the forest floor. Aggregate stability measured by mean wet diameter of water stable aggregates was significantly at p<0.05 in the different land use types with forested plot (0.85 mm) more stable compared to uncultivated and cassava plot (1.62 mm and 1.18 mm) respectively, which may be attributed to the presence of decomposed organic litter on the forest floor

CONCLUSION

This research investigated the effect of three different land-use types on infiltration capacity of Ultisols soils. Infiltration rates of the various land use types was observed to be very slow with the following order of infiltration rate recorded for forested, cassava, and uncultivated plots (3.4mm/hr⁻¹, < 5.1 mm/hr⁻¹, < 35 mm/hr⁻¹) respectively. Although Ultisols soils are known for rapid infiltration rate especially initial infiltration rate and low water retention capacity. This work demonstrated that land use type can significantly influence the rate of water entry into the soil even when the soil are formed from the same parent material and are under the same micro-climatic condition. It is therefore, recommended that different irrigation design be adopted for different land use types for optimum performance of the soil with respects to water application and water use efficiency.

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