



## Interaction Effect of Land Uses and Time on Some Water Transmission Properties and Fertility Status of an Ultisol in Imo State, Nigeria

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### Authors' contributions

This work was carried out in collaboration among all authors. Author UOO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NUA and SGII managed the analyses of the study. Author RCE managed the literature searches while author LCO helped with the discussions. All authors read and approved the final manuscript.

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### ABSTRACT

The interaction of land use and time on some soil water transmission properties and fertility status of an Ultisol was examined. Results indicate that the texture of the soils ranged from sandy loamy to sandy clay loam and was unaffected by land use and time. The bulk density varied significantly across the land uses with the Sand mining site SM having the highest bulk density of 1.7 and 1.78 g/cm<sup>3</sup> in the first and second years respectively. The Primary forest, PFL had the lowest BD of 1.50 and 1.78 g/cm<sup>3</sup> in the first and second year of studies respectively. Similarly the percentage porosity varied significantly across the four land uses and has its highest value of 43.1 and 42.3% in the first PFL of the first and second year studies. Also the saturated hydraulic conductivity Ksat and moisture content MC were significantly different across the four land uses, the Ksat was highest in the PFL in both first and second year of studies (17.2 and 14.7 cm/min), the least Ksat values of 6.70 and 5.88 cm/min occurred in the 1<sup>st</sup> year sand mining site SM. Similarly there was a significant difference (P>0.05) in the percentage organic matter OM, Total nitrogen N, available

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phosphorous P, exchangeable acidity, Percentage base saturation BS, and CEC across the land uses, however the total N was only significant in land uses PFL and not in the other land uses. Generally the soil quality indicators ranged from low to moderate in ratings and have affected productivity of recent in the area. Appropriate land uses that will restore the productive potentials of the soil should be adopted and sustained. Similarly the organic matter of the soils should be improved on as this will go a long way in improving appreciably the poor soil water transmission properties.

**Keywords:** Land uses; organic matter; saturated hydraulic conductivity; water transmission properties; pH.

## ABBREVIATIONS

OPPL	: Oil palm plantation
PFL	: Primary forest
SM	: Sand mining site
CCL	: Continuously cultivated land
Ea	: exchangeable acid
BS	: Base Saturation
CB	: Carbon biomass
AL <sup>3+</sup>	: Aluminium ion
P	: Phosphorus
Ksat	: Saturated hydraulic conductivity

## 1. INTRODUCTION

The role of water in the soil plant atmosphere-continuum is unique. Water is important in every physical, chemical or biological process and greatly affects every aspect of soil development and behavior. Processes such as rock weathering, organic matter decomposition, plant growth, recharge of underground water as well as the pollution of nearby water bodies are some of the processes where water plays a major role [1]. It is also a necessary component of the soil environment in addition to other requirements namely, adequate nutrients supply, good aeration, optimum temperature, all of which jointly make the varied life forms in the soil possible. Its importance also accounts for seed germination and development, plant nutrients uptake processes, translocation of these nutrients within the plant organs, various microbiological activities and temperature control within the plant systems by way of transpiration processes.

A good knowledge of the soil water transmission properties is essential for the efficient land and water management [2]. Water as an essential component of the soil makes it imperative that management decisions concerning types of crops to cultivate, plant population, irrigation scheduling as well as the amount of fertilizers to apply will be based on the amount of moisture

that is available to the crop throughout the growing season [3]. As a result of urbanization, fallowed lands are being cleared and converted to other marginal uses. It is common seeing forested lands being converted to plantations, rangelands, grassed or landscaped for aesthetics. These changes from the original forest land to the current land use systems have affected water transmission in the soil resulting to low productivity as well as erosion witnessed in the state of recent [4].

Despite the general recognition of the threats of degradations, low productivity as well as ecosystem instability as a result of land use systems, little or no studies have been made to determine the interaction effect of land uses and time on soil water transmission properties as well as on the fertility status of soils in the area hence this study whose objectives are to determine the interaction effect of land uses and time on some water transmission properties as well as the fertility status of soils in the area.

## 2. MATERIALS AND METHODS

### 2.1 Description of the Study Area

The study was conducted in Uloanondu gba in Isu L.G.A of Imo state. The area lies on latitude 05°39'52" N and longitude 007°02'52" E. The soils of the study area are derived from coastal plain sand. The area has a tropical humid climate with daily minimum and maximum temperatures of 20°C and 30°C respectively. The mean annual temperature of the area ranges from 27-28°C with relative humidity ranging from 75-80% [5]. The area is characterized by rainy and dry seasons. The rainy season starts in March/April with its peak in July and September, while the dry season starts in November and ends March. The vegetation type in the area is tropical rainforest with mean annual rainfall of 2000-2500 mm [5]. The common land use system in the area is arable farmlands planted with maize,



### 3. RESULTS AND DISCUSSION

The mean values of the percentage sand, silt and clay across the various land uses for the first and second year studies are shown in Tables 1 and 1.1. The results indicated that the percentage sand, silt and clay varied significantly across the four land use ( $p < 0.05$ ) in both years. In Table 1, the highest percentage sand (77.5%) occurred in the OPPL while the SM, CCL and SM recorded 69.8%, 76.2% and 69.8% respectively. There was no significant difference in percentage sand between the OPPL and PFL land uses ( $p > 0.05$ ). Significant difference was observed in the SM and CCL. The SM had the lowest percentage sand and higher bulk densities in both studies and this can be adduced from the compact nature of the site. There was no significant difference in the percentage silt across the four land uses ( $P > 0.05$ ) with the PFL and CCL having the highest percentages of silt (6.19 and 6.16%) respectively. The SM had the highest percentage clay (24.2%) which differed significantly from the other land uses types ( $P < 0.05$ ). The percentage clay in the OPPL and CCL (16.55 and 17.5%) were not significantly different ( $P > 0.05$ ).

The high sand fractions in the land uses was as a result of the Coastal plain nature of the area. The soils of the Southern Eastern Nigeria to which the soils of the study area belong are eroded and stripped of organic rich horizons. The higher percentage of clay which was observed in the SM was due to excavations that has exposed the sub soils. The texture of the soils ranged from sandy loam to sandy clay loam across the land uses and showed no change in the second year. Meanwhile the bulk density varied significantly across the four land uses. The highest bulk density of  $1.7 \text{ g/cm}^3$  was observed in the SM while the least bulk density value occurred in the PFL ( $1.50 \text{ g/cm}^3$ ). Similarly in table 1.1, the SM had the highest bulk density value of  $1.78 \text{ g/cm}^3$  while the PFL had the lowest bulk density value of  $1.53 \text{ g/cm}^3$ . The bulk density values varied significantly across the four land uses  $p < 0.05$ . The low bulk density in the PFL was premised on the improved organic matter content as bulk densities have been reported to vary inversely with the organic matter (Gupta, 2004) of soils. The increase in bulk density in the SM may be attributed to the loss of vegetative cover from the soil and large scale use of machinery which led to the loss of organic matter thereby resulting to high bulk density, Oguike et al. [12] corroborated the above findings. Also the

percentage total porosity varied significantly across the four land uses ( $P < 0.05$ ). Similarly the total porosity varied significantly across the four land uses in Table 1. While the highest mean total porosity of 43.1% occurred in the PFL, the SM had the least mean porosity of 34.1%. The OPPL and CCL had 36.8 and 40.3% respectively. The increase in the total porosity in the CCL compared to the OPPL may be attributed to the mechanical manipulation of the soil during previous tillage operations. This may have led to the loosening of the soils and development of macro pores thereby affirming the report of Nwite [13]. Similarly, the increased porosity in the PFL was as a result of improved organic matter on one hand and the loosening of soil by the root of plants on the other hand. Forest trees have been widely reported to create macro pores [14,15].

In the second year study, similar trend was observed, while the highest mean percentage porosity was observed in the PFL (42.2%), the SM had the least percentage total porosity (33%). The percentage porosity was significantly different across the four land uses  $P < 0.05$  (Table 1.1). There were also significant variations in the saturated hydraulic conductivity ( $K_{\text{sat}}$ ) across the four land uses in both the first and second year study ( $P < 0.05$ ), (Tables 1 and 1.1). In the first year and second year, the most rapid  $K_{\text{sat}}$  was observed in the PFL (17.2 cm/sec) and this was significant across the other 3 land uses. The slowest  $K_{\text{sat}}$  rate of 5.8 and 6.7 cm/sec were observed in the SM of the first and second year studies respectively. The increased  $K_{\text{sat}}$  rate in the PFL in both years was as a result of increased biomass from the forest floor. Increased organic matter has been reported by many researchers to affect positively the  $K_{\text{sat}}$  of soils [16,17]. Similarly the percentage moisture content in the Table 1 and 1.1 varied significantly across the four land uses ( $P < 0.05$ ). In Table 1, the OPPL had the highest moisture content (21%) while the PFL had 20.7%. The lowest moisture content 17.7% occurred in the SM land use.

In Table 1.1, the percentage moisture content also varied significantly across the four land uses except in the OPPL and CCL where there was no significant difference between the two land uses ( $P < 0.05$ ). The lowest percentage moisture content observed in SM land use was due to the sealing of soil pores arising from the use of heavy machines in the course of sand excavations. The sealing of the drainable pores

**Table 1. Variation in soil physical properties across the land uses for the first year study**

Land uses	%Sand	%Silt	%Clay	TC	BD	Poro	Ksat	MC
OPPL	77.59	5.81	16.55	SL	1.67	36.8	9.5	21.9
PFL	76.99	6.19	14.86	SL	1.5	43.1	17.2	20.7
CCL	76.2	6.16	17.54	SL	1.58	40.3	11.7	20.1
SM	69.8	5.65	24.7	SCL	1.74	24.12	5.88	17.7
LSD	0.76	0.1	1.39		0.04	1.44	1.26	0.77

**Table 1.1. Variation in soil physical properties across the land uses for the second year study**

Land uses	%Sand	%Silt	%Clay	TC	BD	Poro	Ksat	MC
OPPL	77.5	3.55	18.7	SL	1.67	36.37	9.00	17.9
PFL	74.5	4.21	18.6	SL	1.53	42.15	14.7	18.2
CCL	76.8	4.02	19.2	SL	1.63	38.19	8.32	18.2
SM	74.5	3.4	21.8	SCL	1.78	32.51	6.70	16.18
LSD	0.04	0.72	1.67		0.04	1.55	1.54	0.81

resulted to the low moisture content observed in the land use. This was corroborated by Onyegbule et al. [18].

The pH was significantly different only in the SM compared to the other land uses in the first year with an extremely acidic pH of 3.0 compared to the strongly acidic pH in the other land uses. Conversely the significant differences in pH across the land uses in the second year may not be unconnected to the declined organic matter that characterized the second year compared to the previous year. The inverse relationship between the soil pH and organic matter is well documented, Amanze (2018). The general acidity inherent in all the land uses was as a result of their parent materials (Coastal plain sand) as well as their highly weathered condition Lekwa and Whitesand (1986). Meanwhile the percentage organic matter in Table 1.2 shows that organic matter OM was highest in the PFL with a mean value of 2.18%. The OPPL, CCL and SM recorded 1.1, 0.9 and 0.6% respectively. The percentage organic matter varied significantly across the four land uses ( $P < 0.05$ ). In the second year study (Table 1.3), there was no significant difference in the three land uses namely, the OPPL, PFL and SM. The CCL recorded the lowest OM of 1.35% while the highest percentage organic matter of 1.8% was observed in the PFL. The lower percentage OM recorded in the CCL and SM can be attributed to the splash and burn system of land preparation that exposes the soil surface, as well as the excavations that have ripped off the organic rich surface of the SM. Slash and burn system of land preparation impacts negatively on the activities of beneficial soil microbes that cause the decomposition of organic substrates. The improved organic matter in the PFL and OPPL in

the two years' study compared to the rest of the land uses may be premised on the microclimate created by the adequate vegetation cover that moderated the soil temperature, air and moisture against the loss of organic matter.

Meanwhile, the total nitrogen in Table 1.2 was not significant in CCL, OPPL and SM. Significant difference was observed between the PFL and the other land uses. While the PFL had a highest mean value of 0.22%, the SM had the least amount of total nitrogen (0.03%). In Table 1.3, the total nitrogen varied significantly across the four land uses except in the CCL and SM that were statistically similar. The CCL had mean percentage total nitrogen of 0.07 which was not statistically different from the 0.04% observed in the SM. The highest percentage total nitrogen of (0.14) occurred in the PFL.

The relatively very low total Nitrogen (TN) observed in the CCL and SM may be attributed to volatilization of Nitrogen resulting from increased oxidation of nitrogenous compounds in the soil, arising from tilling and excavations. Amanze (2018) affirmed the findings of this research on a cultivated land in Umuahia. Also the increase in the mobility of Nitrogen arising from incessant pulverizations spurs the losses of nitrogen. Oguike and Mbagwu [19] corroborated the above findings. Conversely, the higher percentage total Nitrogen observed in the PFL and OPPL is attributed to the supporting vegetation which reduces nitrogen losses through volatilization. The percentage organic matter in table 1.2 shows that OM varied significantly across the four land uses with the PFL and SM having the highest and lowest OM content respectively.

**Table 1.2. Variations in soil chemical properties across the four land uses in the first year**

Land uses	%pH	%OC	%OM	%TN	P	Ea	CEC	%BS	Al <sup>3+</sup>	CB
CCL	4.42	0.93	1.61	0.06	13.5	1.62	5.93	66.8	0.6	0.26
OPPL	4.29	1.12	1.93	0.07	14.9	1.43	6.7	73.9	0.5	0.22
PFL	4.09	1.27	2.18	0.22	15.4	1.56	7.2	75.2	0.4	0.75
SM	3.1	0.63	1.13	0.03	7.9	1.88	4.1	48.4	0.8	0.21
LSD	0.58	0.11	0.17	0.09	0.64	0.04	0.6	2.64	0.05	0.12

**Table 1.3. Variations in soil chemical properties across the four land uses in the second year**

Land uses	%pH	%OC	%OM	%TN	P	Ea	CEC	%BS	Al <sup>3+</sup>	CB
CCL	5.11	0.77	1.35	0.07	13.28	1.59	5.75	1.59	0.65	0.32
OPPL	4.9	0.99	1.7	0.1	14.1	1.49	5.63	1.49	0.6	0.51
PFL	5.21	1.02	1.8	0.14	15.33	1.52	6.05	1.52	0.7	1
SM	4.17	0.97	1.71	0.04	11.06	1.74	5.72	1.74	0.6	0.27
LSD	0.28	0.2	0.34	0.04	1.02	0.1	0.45	0.1	0.2	0.2

In Table 1.2, the available phosphorus P varied significantly across the four land uses ( $p < 0.05$ ), with the PFL having the highest available phosphorus (15.40 mg/kg). This was closely followed by the OPPL which recorded a mean value of 14.9 mg/kg. Both land uses were significantly different. The CCL recorded a mean P value of 13.5 mg/kg while the lowest mean value of 7.9 mg/kg was observed in the SM. In Table 1.2, there was no significant difference in the CCL and OPPL (13.28 and 14.1 mg/kg) respectively. The PFL also had the highest available phosphorus (AV) value of 15.33mg/kg which varied significantly across the four land uses. The increased available phosphorus in the PFL and OPPL may be as a result of reduced acidity in those land uses manifested by the reduced aluminum ions in the land use. Similarly, the reduced available phosphorus in the SM and CCL may be attributed to increased exchangeable aluminum ion observed in both land uses. This according to Ano (2004), have formed aluminum mineral complexes with the available P thus rendering it unavailable. Exchangeable acidity significantly differed across the land uses ( $P < 0.05$ ) in Table 1.2. The SM had the lowest exchangeable acidity (1.88 mg/kg), while the lowest exchangeable acidity value of (1.43 mg/kg) was observed in the OPPL. In Table 1.3, the SM also had the highest exchangeable acidity (1.74 mg/kg). The mean Ea in the SM was significantly different when compared to the other land uses. The highest values of CEC in Table 1.2 was observed in the PFL (6.05) while the lowest value occurred in the OPPL. The variation in CEC across the four land uses was not significant ( $P > 0.05$ ). In Table 1.3, there was no significant variation in the CEC across the land uses. The PFL had the highest

CEC of 6.05 while the lowest mean CEC value was observed in the OPPL. The percentage base saturation BS varied significantly across the land uses except in the PFL and OPPL that were statistically similar (Table 11) The PFL recorded the highest percentage BS of 75.2%, while the SM had the least BS of 48.37. Similarly in Table 1.2, there was no significant difference in the OPPL and PFL though the PFL had the largest percentage BS of 72.42% as against the 70.42% recorded in the OPPL. The land use types also varied significantly with reference to Al<sup>3+</sup> in Table 1.2 ( $P < 0.05$ ). The highest value of 0.8cmol/kg was observed under SM which was significantly different from the other land use types. Conversely in Table 1.3 there was no significant difference in the exchangeable Al<sup>3+</sup>.The PFL had the highest value of 0.7cmol/kg while the lowest exchangeable Al<sup>3+</sup> of 0.57cmol/kg was observed in the SM .The highest value (0.75%) of carbon biomass (CB) was observed under the PFL in Table 1.2 while the lowest CB value (0.21) was observed in the SM .The CB was not significantly different across the CCL and the OPPL, however there was significant difference in the PFL and the other land uses. In Table 1.3, the land use types varied significantly ( $P < 0.05$ ) with reference to the CB, with the PFL having the highest CB value of 1% against the lowest percentage value (0.27) observed in the SM.

#### 4. CONCLUSIONS AND RECOMMENDATIONS

Progress in Agriculture is always dwarfed by unwholesome human activities as well as negative of the basic principles and practices that can forester significant results oriented crop production. The study revealed an obvious

significant interaction of land use types with time in influencing soil water transmission properties and soil quality indicators. There was no table variability in the bulk density total porosity, saturated hydraulic conductivity and soil moisture content across land uses. Similarly the organic matter content was affected by the land use changes that characterize the study area. This also impacted negatively on the available phosphorus, total nitrogen, CEC as well as the low levels of exchangeable bases witnessed in the soil. This has resulted to overland flow, topsoil depletion as well as low agricultural productivity witnessed of recent in the area.

Mulching continuously the soils using plant residues is necessary in order to prevent excessive loss of water as well as improving the intrinsic properties of the soils. The extreme acidic nature of the soil needs to be ameliorated as fast as possible to forestall further degradations. Sustained efforts should be made to improve the organic matter content of the soils as they were rated moderate compared to the high value obtained in the PFL. The application of mineral fertilizers is also recommended as a soil management practices for the continuously cultivated land, plantation as these will go a long way in resurrecting their fertility status and productivity within the shortest possible time.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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