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INFLUENCE OF LAND-USE SYSTEMS ON HYDRAULIC PROPERTIES OF SOILS IN YENAGOA AND AMASSOMA, BAYELSA STATE, NIGERIA

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Abstract

This research aimed to determine the effect of different land-use systems on the matric potential, and hydraulic conductivity of the soils of Yenagoa and Amassoma communities. Soil samples were collected from four respective land-use types namely: Fallow land, Oil Palm Plantation, Plantain Plantation, and Virgin land. A total of 12 samples were bulked from three replicates at each land use type and were collected at depths of 0-15cm, 15-30cm, and 30-45cm respectively. The samples were taken to the laboratory to analyze their physical, chemical, and hydrological properties. The result showed that the different land use had a significant effect ($P<0.05$) on some soil physical, chemical, and hydraulic characteristics. The different land-use systems had a significant effect on the soil hydraulic conductivity with the highest in virgin (13.6 cm/hr) and lowest in the plantain plantation (7.6 cm/hr). The virgin land recorded the highest Soil Water Holding Capacity (SWHC) of 2.85 cm with a range of 1.55 – 2.85cm and Plant Available Water Capacity (PAWC) of 0.19 cm^3cm^{-3}, with a range of 0.10 - 0.19 cm^3cm^{-3}, while the plantain plantation recorded the lowest (1.55 cm and 0.10 cm^3cm^3). Based on the study, it is recommended that soils with high Plant Available Water Capacity (PAWC) and Soil Water Holding Capacity (SWHC) be used to cultivate crops that are non-tolerant to water stress while organic amendments are used on soils with low fertility.

Keywords: Landuse, Hydraulic, Bayelsa State

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Introduction

Agricultural production is projected to increase over the years which will require more water resources to irrigate the crops (Sauer *et al*., 2010). Soil is an important and dynamic component of the biophysical environment; its quality and management determine the productivity of all (natural and managed) ecosystems. Soil quality defines soil's inherent and dynamic properties and functionality to human needs. Soil quality attributes affecting the sustainability of soil functions are its physical, chemical, and hydrological properties and characteristics which have developed as a result of the factors and processes of soil formation (Lal and Shukla, 2005). The increase in temperature and change in rainfall pattern in the Niger Delta Region caused majorly by crude oil processing alongside gas flaring has undoubtedly increased temperature, leading to increased evaporation in soil and rapid evapotranspiration leading to moisture stress in crops. To achieve optimal crop growth and yield, the soil must possess sufficiently available nutrients and water; which will ultimately affect the survival of man. Moisture retention capacity and availability largely control air and gas exchange in the soil, which affects the respiration of roots and activities of soil microorganisms. For sustainability in agricultural production and food security, knowledge of this water loss phenomenon and its management must be determined and properly documented (Fasona and Omojola, 2005).

Research has shown that land use patterns in Bayelsa State have significant effect on soil-moisture phenomena such as its infiltration capacity. Agbai *et al.* (2022) reported that undisturbed lands such as virgin lands recorded the highest infiltration rate, cumulative infiltration, transmissivity, and sorptivity compared to those under anthropogenic activities. As stated by Matemilola (2018), very little information is available about the effect of petroleum exploration on land use changes in the oil-rich Niger Delta Area. This is similar to the land use effect on soil hydraulic properties in Bayelsa State. Nigeria's economy is diversifying away from oil and toward agriculture, among other things. More forests will be converted to agricultural land as a result of this. Thus, good soil management is required to prevent land deterioration. Few scholars have looked into the long-term implications of forest conversion to farmland in tropical southern Nigeria.

Thus, soil properties govern transport processes (water retention, hydraulic conductivity, and so on) and water balance in the vadose zone of soils, playing a critical role in the hydrological cycle because it divides incident water into runoff and infiltration, for which saturated hydraulic conductivity has the most influence (Zimmermann *et al.*, 2013). Water, on the other hand, plays a key part in the formation of most soil properties, and soil attributes influence and governs soil hydrological characteristics. For determining local energy and water balances, transport of applied chemicals to plants and groundwater, and irrigation management, the interactive link between soil and hydrological parameters is critical (Seyfried and Murdock, 2004; Souza *et al.*, 2004).

The soil, soil surface, land use, and soil management are all factors that affect hydrological parameters, with the latter having the biggest influence. Land-use patterns, in other words, are critical to soil hydrology because they alter surface soil hydraulic characteristics and pore-size distribution in general. Tillage, erosion, compaction, and pore structure evolution are all blamed for the impacts (Harden, 2006). Comprehending the physical and hydrological features of soils is critical to understanding the practical agricultural issues surrounding soil productivity (Shukla, 2014). The objective of the study is to determine the effects of land-use systems on some hydraulic properties of soils in Yenagoa and Amassoma communities, Bayelsa State, Nigeria. To determine the matric potential (Field capacity, wilting point, and plant available Water) of the soils under different land-use systems, the effect of the land-use systems on the hydraulic conductivity of the soils of the study areas, and to correlate the hydraulic properties with other Physico-chemical properties of the study area.

Materials and methods

Study area

The towns of Yenagoa and Amassoma in Bayelsa State were chosen for this investigation. Bayelsa lies on approximately Latitudes 4°55' 36.30"N and Longitudes 6°16' 3.50"E with an elevation of about 206m above the sea level and is situated in the southern part of the Niger Delta Region of Nigeria. In Bayelsa, the wet season is warm and overcast, the dry season is hot and mostly cloudy, and it is oppressive year-round. The prevalent climate is characterized by a humid tropical climate with annual rainfalls of approximately 4900mm/year and relative humidity of 85% where the maximum is obtained during the rainy season from June to September, while the minimum is obtained during the dry season from November to March. The minimum temperature is 25°C while the maximum temperature is 31°C annually. The area is covered by grassland (28%), cropland (25%), shrubs (14%), trees (45%), water (16%), with soils formed from kaolinitic parent materials (Agbai *et al.*, 2022). Virgin land and fallow land are situated in Amassoma, while Plantain plantation and oil palm plantation are in Yenagoa. The virgin land is deep in the heart of Amassoma in Southern Ijaw Local Government Area of Bayelsa state and has had limited and controlled interference from anthropogenic activities for a long period; over 30 years. The fallow land in the Niger Delta University, Amassoma as the name implies has been left for over 10 years to regain and reconstitute its fertility. Regular weeding, fertilization, and harvesting have been carried out on the plantain plantation while the oil palm plantation has stayed for over 20 years with pruning, fertilization, and weeding by use of herbicides regularly carried out.

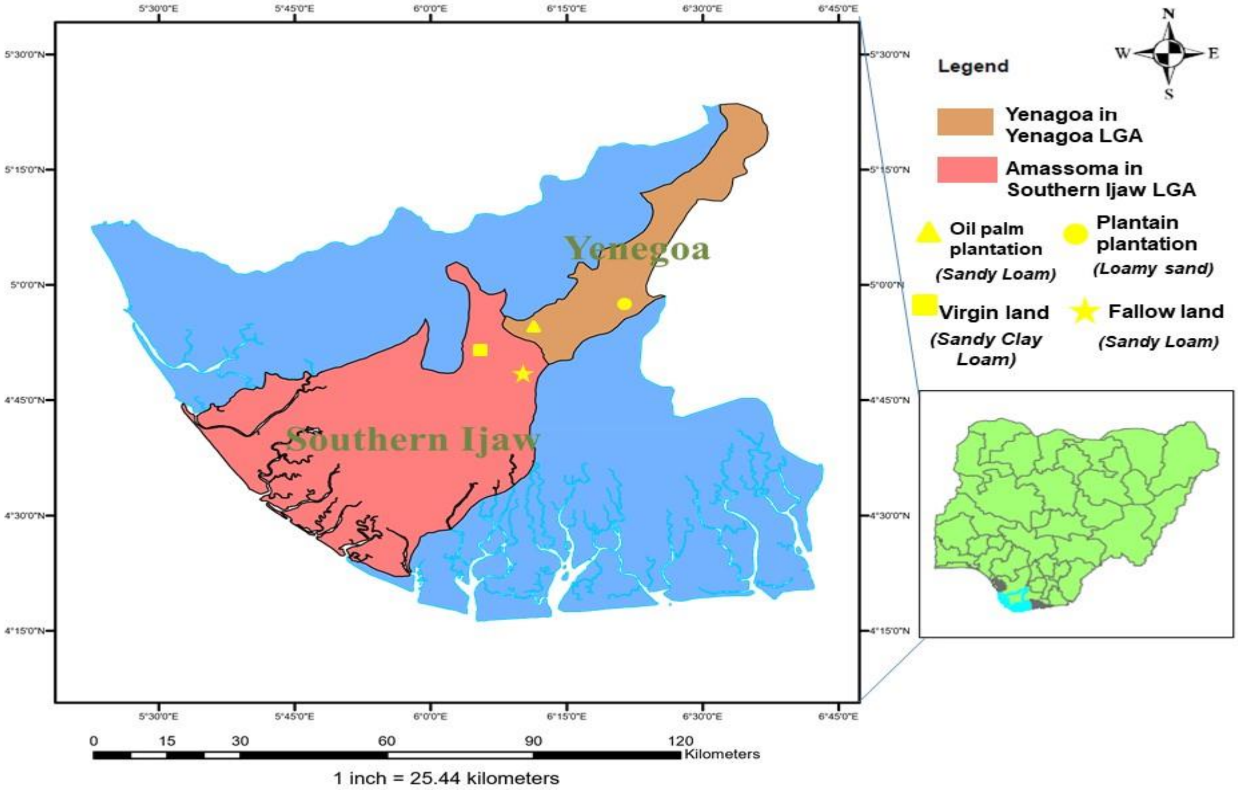

Fig 1: Map of Bayelsa State showing the two Local Government Areas housing the land-use types and the sampling points

Sample collection

Three replicate samples each were obtained from the sampling locations (virgin land, plantain plantation, fallow land, and oil palm plantation) respectively. Nine (9) samples were taken from three depths (0-15cm, 15-30cm, and 30-45cm) in each land use type, the replicate samples were later bulked to form three representative samples per depth in the respective land use type. A total of 12 composite samples were obtained. Virgin land (4°59'35" N, 6°07'21" E) and fallow land (4°53'06" N, 6°09'26" E) were situated in Amassoma while Plantain plantation (4°59'45" N, 6°22'20" E), and oil palm plantation (4°58'50" N, 6°06'15" E) were situated in Yenagoa.

Eijkelkamp Edelman OnePiece soil auger of diameter 5 cm was used to collect samples at three distinct sites at each land-use location. To serve as a representation of the location, the samples from the three spots were correctly blended and bulked with the hand. Each soil sample was placed in a clean polythene bag and tagged with a permanent marker. The soil samples were then taken to the Soil Science Laboratory of Niger Delta University where they were air-dried, crushed, and sieved through a 2mm sieve after which the physical and chemical properties were determined.

Steel cores of 5.8cm diameter and 6cm height were used to take samples for bulk density, porosity, hydraulic conductivity, and soil water retention determination at the 0-15cm, 15-30cm, and 30-45cm depths respectively.

Determination of Soil Physical and Chemical Properties

Particle Size Distribution

Particle size analysis was carried out to determine the relative proportions of sand, silt, and clay in the soil. These values obtained were used to assign a textural class to the soil samples (Gee and Or, 2002). In a 70 g soil sample, the organic matter was eliminated by applying consecutive aliquots of 40 mL hydrogen peroxide until the reaction effervescence was negligible. On an 80°C hotplate, the procedure was carried out. The oxidized samples were then dried in a forced-air oven at 80 degrees Celsius. The dispersion was achieved by mixing 50 g of dry soil sample in a shaker for 16 hours with 100 mL of 25 percent sodium hexametaphosphate. The mixture was then poured into a Bouyoucos blender cup and mixed with an electrical mixer for two minutes. The contents of each cup were transferred to a 2 L sedimentation cylinder, which was then filled to the 2000 mL mark with deionized water. The slurry was then manually stirred to homogenize it. Following 40 seconds of decantation, the solids in the suspension were measured with a hydrometer, with a second reading made two hours later. When the suspension was between 20 and 22 °C, the measurement was taken and then corrected for temperature. The first reading was used to estimate the sand content, whereas the second was used to estimate the clay content after two hours. The difference between those two readings was used to compute the silt fraction.

Organic Carbon content

Organic Carbon content was determined using Walkley and Black wet oxidation method described in Walkley and Black (1934). 1g of soil sample was weighed into a 250ml conical flask. 10ml of 1N $K_2Cr_2O_7$ solution was added and the mixture swirled for proper mixing. 20 ml of concentrated H_2SO_4 was added carefully. The mixture was again swirled to mix up and was left for 30 minutes. Afterward, 100ml of distilled water was added. The mixture was again swirled. 5 drops of ferroin indicator were then added. The excess chromic acid was titrated with 0.5N ferrous sulphate to a dirty brown end-point (Tml). A blank was run, using the sampling procedure, but without a soil sample (Bml).
The blank was used to measure the amount of reducing substance present in the reagents as impurities.

% organic carbon was calculated as follows:

$$\frac{(\text{Bml}-\text{Tml})\times 0.5\times 0.003\times 1.33}{\text{Weight of sample used}} X\, 100 \quad \text{-------------------------------------} \quad (1)$$

The Organic Matter

The Organic Matter was computed by multiplying the value of the organic carbon by a value of 1.725 as described by Douglas (2010).

Field Capacity (at 0.01bar), **Permanent Wilting Point** (at 15bar), and **Plant Available Water Capacity (PAWC)** were determined as described by Romano and Santini (2002). Plant available water (PAWC) was calculated as the difference between water retention at 10 kPa i.e. field capacity (FC) and water retention at 1500 kPa i.e. permanent wilting point (PWP). PAWC = FC – PWP.

The soil water holding capacity (SWHC) is the depth of water in the soil available for plant growth. SWHC is also known as Total Available Water (TAW); SWHC = TAW = (PAWC) (z)
Where SWHC or TAW = soil water holding capacity or total available water, z = root zone depth (Waller and Yitayew, 2016).

A block of hardwood was used to carefully insert the core into the various depths. To achieve a balance between the soil column and the core, excess soil was chopped away using a knife. The core samples were placed in an airtight bag, undisturbed and appropriately labeled, for bulk density, hydraulic conductivity, and soil water retention measurement. The soil moisture retention was then measured using the Eijkelkamp Soil & Water M10803e 08.03 pressure plate membrane apparatu**s** as stated by Azuka and Oka (2021).

Bulk density (BD) was determined as described by ISO (2017), and total porosity (TP) was computed from bulk density values and an assumed particle density of 2.65 Mg m^{-3} (Aikins and Afuakwa, 2012).

Bulk density was calculated from the mass-volume relationship of oven-dry soil as follows:

$\ell b = Ms/Vt$ -- (2)

where ℓb is bulk density (Kg m^{-3}), M_s is dry soil mass (Kg), and V_t is the total volume of soil (m^3) (volume of the core sampler)

Total porosity, f was calculated using the formula:

$f = 1 - \ell b/\ell p$ -- (3)

where f is total porosity (m^3m^{-3}), ℓb is bulk density (Kg m^{-3}), and ℓp is particle density, assumed to be 2.65 Kg m^{-3} for mineral soils.

The Saturated Hydraulic Conductivity (Ks)

Measurements were made on the cores in the laboratory using the modified falling head permeameter method similar to that described by Bonsu and Laryea (1989). The cores were soaked for 24 hours in water until they were completely saturated. A large empty can with perforated bottom was filled with fine gravel. The cores were placed on the gravel supported by a plastic sieve. The whole system was placed over a sink in the laboratory and water was gently added to give the hydraulic head in the extended cylinder. The fall of the hydraulic head h_t at the soil surface was measured as a function of time t using a water manometer with a 5 meter scale. The quantity of water (Q) draining through the soil column over a fixed time (t) was collected and hydraulic conductivity was calculated as follows:

$Ksat = QL / \Delta hAt$

where K_{sat} is saturated hydraulic conductivity (cm hr^{-1}), Q is water discharge (cm^3), L is the length of soil column (length of the core sampler) (cm), Δh is pressure head difference causing the flow, A is cross-sectional area (cm^2) of the core sampler and t is time (h).

Soil pH and **Electrical Conductivity (EC)**

Electrical conductivity (EC) and pH were analyzed with a 1:5 soil water suspension using a Hanna HI 9813-6N EC and pH meter (Udo *et al*., 2009).

Available Phosphorus

This was determined by the use of the Bray P-1 method of Bray and Kurtz (1945) as described by (Udo *et al*., 2009). 5g of soil was weighed into a 250 ml shaking bottle. 35ml of extracting solution (1M NH_4F) was then added. The mixture was shaken for 3 minutes and was filtered into a 100 ml volumetric flask and the leachate was determined in a spectrophotometer model S23A.

Determination of Exchangeable Bases (Ca, Mg, K and Na)

Ca and Mg were determined from the extract using the 0.01m EDTA (Ethylenediaminetetraacetic acid) titration method as described by Black (1965), while K and Na were determined using a Jenway PFP7 flame photometer (Udo *et al*., 2009). 10g of soil sample was weighed into a 250ml soil shaking bottle and left overnight after adding 1M Ammonium Acetate (NH_4OAC), the mixture was filtered using Whatman No. 1 filter paper into a 100ml volumetric flask and was made up to mark with Ammonium Acetate (NH_4OAC). From the leachate, Ca and Mg were determined titrimetrically, while Na and K were read in the flame photometer, and each element was expressed in cmol/kg.

Total Nitrogen

Total Nitrogen was determined using the regular micro Kjeldahl method as reported by Bremmer and Mulvaney (1982); and Udo *et al*. (2009).

Experimental Design

The samples were arranged using Randomized Complete Block Design (RCBD), with three replicates each as blocks while the Duncan Multiple Range Test was used to separate the means at a 5% level of probability; after which the correlation coefficient was used the determine the relationship between some soil physical, chemical, and hydraulic properties.

Results and discussions

Physical and Chemical Properties of the Soils according to land use system

Soil Texture assessment

Table 1 depicts some of the physicochemical features of soils concerning the various land-use regimes. The first two layers of the plantain plantation were dominated by loamy sand (0-15cm and 15–30cm) and sandy loam from 30-45cm (PPT). The soil texture was sandy loam throughout the three strata of the Oil Palm Plantation (OPT), with an average of 736.73 g/kg sand, 121.87 g/kg silt, and 141.40 g/kg clay. There was a steady decrease in the sand fraction and an increment in the clay content. The sand proportion decreased steadily as the clay content increased. This suggests a gradual but downward rise in clay concentration along the profile, possibly due to illuviation (Niu *et al.*, 2015). The soils transitioned from sandy loam to sandy clay loam in the Virgin land (VVL), with an average of 676.7, 208.1, and 115.2 g/kg of sand, silt, and clay. Sandy loam dominated the fallow land (FFL), with an average of 720.01 g/kg sand, 151.40 g/kg clay, and 128.53 g/kg silt.

The soil texture in the plantain plantation was loamy sand, sandy loam in the oil palm plantation and fallow land; and sandy clay loam in the virgin land. The climate-dependent process of illuviation can cause a change in soil texture by moving clay to the B horizon during heavy rainfall, and Bayelsa state is one of these rainfall-prone regions (Sauzet *et al.,* 2016; Olorunfemi and Fasinmirin, 2012). Soil texture is an intrinsic soil characteristic according to Jamala and Oke (2013), however, intense cultivation may contribute to differences in particle size distribution at the surface horizon of cultivated and natural fallow land.

pH and Electrical Conductivity

Across all depths in the plantain plantation, pH ranged from 4.4 (highly acidic) to 4.7 (strongly acidic), with a mean of 4.6, which is likewise strongly acidic; acidity decreased down the profile. The first two layers (0-15 and 15-30cm) of the Oil Palm Plantation (OPT) had a pH of 4.5, with the lowest value of 4.3 at 30-45cm deep. The pH remained constant (4.7) throughout the depth change, with a mean of 4.7. The fallow land (FFL) soils were acidic throughout the depths, with an average pH of 4.5. The acidic status of soils was induced by the leaching of basic cations caused by the region's excessive rainfall, according to Niu *et al.* (2015). Electrical conductivity in the plantain plantation, oil palm plantation, virgin land, and fallow land was 0.0415 dS/m, 0.0542 dS/m, 0.0668 dS/m, and 0.0501 dS/m, respectively. According to Ganjegunte *et al.* (2018), these values position the soil at a non-saline level of less than four (four). This suggests that the soil structure is unaffected and that seedlings and salt-sensitive crops are unaffected.

Table 2 reveals that land use types have a considerable impact on pH and electrical conductivity, which is supported by Daniel (2020). The pH of the virgin land and plantain plantation were greater, whereas the pH of oil palm plantation and fallow land were lower. The increased acidity in the oil palm plantation and fallow land may be linked to the area's prolonged use, which has reduced soil fertility. Chemeda *et al.* (2017) also discovered that grassland and cultivated areas had a higher pH than forest and virgin regions. Electrical conductivity was highest in the virgin land followed by the fallow land, oil palm plantation, and plantain plantation, and this has been further confirmed by numerous researches (Abate and Kibret, 2016; Seyoum, 2016). The lower EC value in the cultivated soils can be appropriated with the loss of exchangeable bases from the soils due to leaching and erosion resulting from continuous farming. The results were also in line with Selassie *et al.* (2015), who observed that the washing away of solutes and basic cations lowers pH value in the Zikre watershed North West Ethiopia.

Organic carbon, organic matter, and total nitrogen

The research showed that different land use systems statistically affected ($P<0.05$) the organic matter, organic carbon, and total nitrogen. Organic carbon and organic matter were low in the plantain plantation and fallow land with mean values of 7.33 and 14.67 g/kg; and 11.67 &23.33g/kg respectively. It was however moderate in the oil palm plantation and virgin land with mean values (17.33 &34.67 g/kg) and (21.67 & 43.33 g/kg)**.** Total nitrogen was low across the four land-use types, PPT<FFL<OPT<VVL at the mean of 0.67, 1.03, 1.60, and 1.97g/kg in that particular order. The low Total Nitrogen can be attributed to the low organic matter content in the soil (Brady and Weil, 2005) and also the intensified cultivation (Khan *et al.,* 2013)**.** Duguma *et al.* (2010) stated that virgin or forest land soil generally possess high organic matter and carbon compared to other land use types. This resulted from decomposing organic materials, reduced temperature in the soil microclimate, and also a conducive environment for microorganism habitation (Feyisa *et al.*, 2018; Mulat *et al.*, 2018).

Exchangeable Acidity and Basic Cations

The exchangeable acidity was found to be highest in the oil palm plantation (2.13 cMol/kg) and lowest in the virgin land (1.87 cMol/kg); the higher the organic matter and basic cations, the lower the exchangeable acidity. The virgin land had the highest organic matter and lowest exchangeable acidity, which also showed in the higher mean values of basic cation , as against the other land use systems - Na (**PPT**-0.14 <**FFL**-0.16 <**OPT**-0.20 <**VVL** – 0.23 cMol/kg), K (PPT-0.043 < FFL - 0.06 < OPT-0.09 < VVL-0.12 cMol/kg), Ca ((PPT-0.28 < FFL-0.38 < OPT-0.50 < VVL – 0.50 cMol/kg), and Mg (PPT-0.20 < FFL-0.26 < OPT-0.31 < VVL – 0.42 cMol/kg). The high sandy soil content across the four land use types having larger poor spaces and low surface area coupled with heavy rainfall during the sampling period resulted in exchangeable cation being leached out of the profile (Fasina, 2005).

Cation Exchange Capacity and Base Saturation

The result showed that the different land-use systems had a significant effect ($P<0.05$) on the Cation Exchange Capacity (CEC) and Base Saturation (BS), and both were directly proportional (Muche *et al.*, 2015). The result indicated that Low CEC followed low Base saturation. The average CEC and Base Saturation in plantain plantation (0.66 cMol/kg / 23.7%), Fallow land (0.87 cMol/kg / 29.12%), oil palm plantation (1.10 cMol/kg / 31.7%) and virgin land (1.38 cMol/kg / 42.4%); indicated that they were highest in the virgin land and lowest in the plantain plantation.

The low value of the basic cations and base saturation was due to the leaching and rapid mineralization of these cations in the soils caused by the high rainfall and temperature in the region (Niu *et al.*, 2015; Kebebew *et al.*, 2022), and also nutrient uptake by plants.

Table 1: Some physicochemical properties of the different land use systems. EC – Electrical conductivity , Org.C – Organic Carbon, Org.M – Organic Matter, T.N – Total Nitrogen, EA – Exchangeable acidity, Na – Sodium, K-Potassium, Ca – Calcium, Mg- Magnessium, Av.P – Available Phosphorus, CEC – Cation Exchange Capacity, ECEC, Effective Cation Exchange Capacity, BS- Base Saturation; µS/cm – microsiemens per centimeter, g/kg – gram per kilogram, cMol/kg – Centimole per kilogram; CODE: PPT- Plantain plantation, OPT – Oil palm plantation, VVL-Virgin land, FFL – Fallow land

CODE	Depth	pH	EC	Org.C	Org. M	T. N	EA	Na	K	Ca	Mg	Av.P	CEC	ECEC	BS	Sand	Clay	Silt	Soil texture
			µS/cm		**g/kg**					**cMol/kg**					**(%)**		**g/kg**		
PPT	**0-15**	4.4	41	11	22	1	2.2	0.17	0.07	0.41	0.3	2.32	0.95	3.15	30.16	853.4	91.4	55.2	loamy sand
PPT	**15-30**	4.7	30.4	7	14	0.6	2	0.15	0.04	0.27	0.19	1.70	0.65	2.65	24.53	813.4	111.4	75.2	loamy sand
PPT	**30-45**	4.7	53.1	4	8	0.4	2	0.09	0.02	0.17	0.11	1.03	0.39	2.39	16.32	793.4	131.4	75.2	sandy loam
		4.6	**41.5**	**7.33**	**14.67**	**0.67**	**2.07**	**0.14**	**0.04**	**0.28**	**0.2**	**1.68**	**0.66**	**2.73**	**23.67**	**820.0**	**111.4**	**68.53**	
OPT	**0-15**	4.5	78.1	36	72	3.3	2.3	0.32	0.18	0.89	0.51	5.82	1.9	4.20	45.24	773.4	111.4	115.2	sandy loam
OPT	**15-30**	4.5	36.3	11	22	1	2.1	0.19	0.07	0.41	0.27	2.24	0.94	3.04	30.93	723.4	151.4	125.2	sandy loam
OPT	**30-45**	4.3	48.1	5	10	0.5	2	0.1	0.03	0.2	0.14	1.21	0.47	2.47	19.03	713.4	161.4	125.2	sandy loam
		4.4	**54.17**	**17.33**	**34.67**	**1.60**	**2.13**	**0.20**	**0.09**	**0.50**	**0.31**	**3.09**	**1.10**	**3.24**	**31.73**	**736.7**	**141.4**	**121.87**	
VVL	**0-15**	4.7	74.3	29	58	2.6	1.9	0.26	0.15	0.7	0.47	3.52	1.58	3.48	45.4023	693.4	191.4	115.2	sandy loam
VVL	**15-30**	4.7	58	22	44	2	1.9	0.25	0.11	0.64	0.45	3.37	1.45	3.35	43.28	683.4	211.4	105.2	sandy clay loam
VVL	**30-45**	4.7	68.2	14	28	1.3	1.8	0.17	0.09	0.53	0.33	2.41	1.12	2.92	38.36	653.4	221.4	125.2	sandy clay loam
		4.7	**66.83**	**21.67**	**43.33**	**1.97**	**1.87**	**0.23**	**0.12**	**0.62**	**0.42**	**3.10**	**1.38**	**3.25**	**42.35**	**676.7**	**208.07**	**115.20**	
FFL	**0-15**	4.5	46.2	17	34	1.5	2.1	0.18	0.05	0.32	0.24	1.72	0.79	2.89	27.34	733.4	141.4	125.2	sandy loam
FFL	**15-30**	4.5	64.5	11	22	1	2	0.11	0.04	0.22	0.15	1.64	0.52	2.52	20.63	723.4	151.4	125.2	sandy loam
FFL	**30-45**	4.6	39.6	7	14	0.6	2	0.2	0.1	0.61	0.39	3.14	1.3	3.30	39.39	703.4	161.4	135.2	sandy loam
	MEAN	**4.5**	**50.10**	**11.67**	**23.33**	**1.03**	**2.03**	**0.16**	**0.06**	**0.38**	**0.26**	**2.17**	**0.87**	**2.90**	**29.12**	**720.0**	**151.40**	**128.53**	

Table 2: Mean values of the soil physicochemical properties

CODE	pH	EC	Org.C	Org. M	T. N	EA	Na	K	Ca	Mg	Av.P	CEC	ECEC	BS	Sand	Clay	Silt	soil texture
		μS/cm		g/kg					cMol/kg					(%)		g/kg		
PPT	4.6b	41.5a	7.33a	14.67a	0.67a	2.07a	0.14a	0.04a	0.28a	0.20a	1.68a	0.66a	2.73a	23.67a	820.0c	111.4a	68.53a	Loamy sand
OPT	4.4a	54.17c	17.33c	34.67c	1.60a	2.13a	0.20a	0.09a	0.50a	0.31a	3.09b	1.10	3.24b	31.73b	736.7b	141.4b	121.87c	Sandy loam
VVL	4.7b	66.83d	21.67d	43.33d	1.97b	1.87a	0.23a	0.12a	0.62a	0.42a	3.10b	1.38	3.25b	42.35c	676.7a	208.07c	115.20b	Sandy clay loam
FFL	4.5a	50.10b	11.67b	23.33b	1.03a	2.03a	0.16a	0.06a	0.38a	0.26a	2.17a	0.87a	2.90a	29.12a	720.0b	151.40b	128.53c	Sandy loam

Mean value(s) with the same letters(s) in the column are not significantly different from one another at 5% level of probability in each. EC – Electrical conductivity , Org.C – Organic Carbon, Org.M – Organic Matter, T.N – Total Nitrogen, EA – Exchangeable acidity, Na – Sodium, K-Potassium, Ca – Calcium, Mg- Magnessium, Av.P – Available Phosphorus, CEC – Cation Exchange Capacity, ECEC, Effective Cation Exchange Capacity, BS- Base Saturation; μS/cm – microsiemens per centimeter, g/kg – gram per kilogram, cMol/kg – Centimole per kilogram; CODE: PPT- Plantain plantation, OPT – Oil palm plantation, VVL-Virgin land, FFL – Fallow land

Effect of the different land-use types on Hydraulic Conductivity of the Soils

The result in Table 3 shows that the different land-use types had a significant effect ($P \leq 0.05$) on the hydraulic conductivity, bulk density, and porosity of the soils (Sarki, 2014). Hydraulic conductivity was higher in the virgin (13.6 cm/hr) and fallow land (13.2 cm/hr) and lower in the plantain plantation (7.6 cm/hr) and oil palm plantation (9.8 cm/hr). Bulk density was also significantly affected by land use as it was highest in the plantain plantation (1.34 g/cm^3) but was not significantly different in the oil palm plantation (1.28 g/cm^3), virgin land (1.30 g/cm^3), and fallow land (1.25 g/cm^3). Porosity was inversely proportional to the bulk density and followed the path of the bulk density. Porosity was lowest (49.7%) in the plantain plantation and higher in the oil palm plantation (51.7%), virgin land (51%), and fallow land (52.7%). The higher hydraulic conductivity at the Fallow and virgin land might be associated with the low level of compaction in their soil pore spaces, and also with the coarse nature of the soils of the different land use types (Odumeke, 2014).

In the plantain plantation, hydraulic conductivity which depicts the ease of movement of water through the soil was low (9.2 cm/hr) at the surface (0-15 cm) and reduced downwards, with the lowest value of 6.7 cm/hr at the depth of 30 – 45cm. The decline in the movement of water vertically could be attributed to the increasing compaction rate (bulk density) down the soil. Bulk density was lowest (1.22 g/cm^3) at the topsoil (0-15 cm), but increased down the depth, with the highest value (1.41 g/cm^3) at the depth of 30-45 cm. In the Oil palm plantation, the hydraulic conductivity followed a similar trend, it was low (11.1 cm/hr) at the surface soil (0-15 cm), and lower (8.4 cm/hr) at the depth of 30-45 cm. Bulk Density was moderate (1.28 cm/hr), while porosity was higher (51.7%) in the oil palm plantation compared to the plantain plantation.

Similar to Zimmermann *et al.* (2012), in the virgin land, hydraulic conductivity was moderate (15 cm/hr) at 0-15 cm depth and 13.8 cm/hr at the 30-45cm depth; with a mean of 13.6 cm/hr. The increased permeability in the virgin soils could be attributed to the low bulk density and higher organic matter contents of the soil. Due to the low bulk density and high porosity, hydraulic conductivity was also moderate (Dorota, 2008) with an average hydraulic conductivity, bulk density, and porosity of 11.05 cm/hr, 1.25 g/cm^3, and 52.7%. A decrease in hydraulic conductivity was reportedly triggered by the increase in the bulk density and reduction in pore space distribution (porosity).

Table 3: Hydraulic Conductivity, bulk density, and porosity under the land use types

CODE	Depth	HC (cm/hr)	BD (g/cm^3)	Porosity (%)
PPT	0-15	9.2^c	1.22^a	54^c
PPT	15-30	7^b	1.38^b	48^b
PPT	30-45	6.7^a	1.41^c	47^a
	MEAN	**7.6^A**	**1.34^B**	**49.7^B**
OPT	0-15	11.1^c	1.22^a	54^c
OPT	15-30	10^b	1.30^b	51^b
OPT	30-45	8.4^a	1.33^c	50^a
	MEAN	**9.8^B**	**1.28^A**	**51.7^A**
VVL	0-15	15^c	1.24^a	53^c
VVL	15-30	11.9^b	1.36^c	49^b
VVL	30-45	13.8^a	1.30^b	51^b
	MEAN	**13.6^C**	**1.30^A**	**51^A**
FFL	0-15	12.8^b	1.26^b	52^b
FFL	15-30	15.9^c	1.20^a	55^c
FFL	30-45	10.8^a	1.30^c	51^a
	MEAN	**13.2^C**	**1.25^A**	**52.7^A**

Letters a, b and c depict similarities or differences at the different depths while A, B, and C represent similarities or differences in the depth means at 5% level of probability. Mean value(s) with the same letters in the column are not significantly different from one another at 5% level of probability in each location.

Effect of the land use types on Plant Available Water and Soil Water Holding Capacity

The average saturated moisture content (the maximum amount of water a soil can hold when all pores are filled with water) at zero bar as depicted in Table 4 was significantly highest ($p<0.05$) in the virgin land (0.61 cm^3cm^{-3}) when compared to oil palm plantation (0.52 cm^3cm^{-3}), Fallow land (0.42 cm^3cm^{-3}) and Plantain plantation (0.32 cm^3cm^{-3}). Also, the average Plant Available Water Capacity was found to be highest in the virgin land soils (0.19 cm^3cm^{-3}) greater than in Fallow land (0.18 cm^3cm^{-3}), Oil palm plantation (0.17 cm^3cm^{-3}), and plantain plantation (0.10 cm^3cm^{-3}).

A similar trend was observed in the Soil Water Holding Capacity/ water retention of the soils from the different land-use types: It was greatest in the Virgin land (2.85 cm), more than the fallow land (2.65 cm), oil palm plantation (2.55 cm) and plantain plantation (1.55 cm). Similar to the findings of Kodesova *et al.* (2011), the higher Plant Available Water Capacity and water retention values were due to the higher organic matter content found in the virgin and fallow land, while the loose sandy texture played a major role in the plantain plantation, having low plant water retention and available water capacity.

In the fallow land, the Soil Water Holding Capacity (SWHC) was highest at the subsurface soils (15-30 and 30-45cm) and was similar in the oil palm plantation and virgin land. The dissimilarity was observed only in the plantain plantation as its SWHC was highest at the surface and reduced down the soil column. This could be related to the soil texture; the soils of the plantain plantation registered the highest sand fraction at the surface (0-15cm) when compared to the other land-use types.

Table 4: Bulk Density and Water retention Capacity of the Research Areas

Locations	Depth(cm)	Water retention @ 0 bar cm^3cm^{-3}	Water retention @ 0.33 bar FC cm^3cm^{-3}	Water retention @ 15 bar PWP cm^3cm^{-3}	PAWC cm^3cm^{-3}	SWHC (cm)
FFL P1	**0-15**	0.41^a	0.26^a	0.09^a	0.17^a	2.55^a
FL P2	**15-30**	0.43^b	0.28^c	0.10^b	0.18^b	2.7^b
FFL P3	**30-45**	0.43^b	0.27^b	0.09^a	0.18^b	2.7^b
		0.42 ± 0.0067^B	**0.27 ± 0.0058^B**	**0.09 ± 0.0033^B**	**0.18 ± 0.0033^C**	**2.65 ± 0.05^C**
OPT 1	**0-15**	0.51^a	0.32^a	0.15^a	0.17^b	2.55^b
OPT 2	**15-30**	0.52^b	0.36^c	0.18^c	0.18^c	2.7^c
OPT 3	**30-45**	0.54^c	0.33^b	0.17^b	0.16^a	2.4^a
		0.52 ± 0.0088^C	**0.34 ± 0.0120^D**	**0.17 ± 0.0088^D**	**0.17 ± 0.0058^B**	**2.55 ± 0.0866^B**
PPT 1	**0-15**	0.31^a	0.19^c	0.07^a	0.12^c	1.80^c
PPT 2	**15-30**	0.32^b	0.18^b	0.08^b	0.1^b	1.5^b
PPT 3	**30-45**	0.32^b	0.17^a	0.08^b	0.09^a	1.35^a
		0.32 ± 0.0033^A	**0.18 ± 0.0058^A**	**0.08 ± 0.0033^A**	**0.10 ± 0.0088^A**	**1.55 ± 0.1323^A**
VVL 1	**0-15**	0.59^a	0.33^b	0.11^a	0.22^c	3.3^c
VVL 2	**15-30**	0.60^b	0.31^a	0.14^b	0.17^a	2.55^a
VVL 3	**30-45**	0.63^c	0.33^b	0.15^c	0.18^b	2.7^b
		0.61 ± 0.0120^D	**0.32 ± 0.0067^C**	**0.13 ± 0.0120^C**	**0.19 ± 0.0153^D**	**2.85 ± 0.2291^D**

Letters a, b and c depict similarities or differences at the different depths while A, B, and C represent similarities or differences of the depth means at 5% level of probability. Mean value(s) with the same letters(s) in the column are not significantly different from one another at 5% level of probability in each location. FC – Field Capacity, PWP – Permanent Wilting Point, PAWC – Plant Available Water Capacity, SWHC – Soil Water Holding Capacity

The correlation matrix in Table 5 shows that bulk density had a negative correlation with Plant Available Water Capacity (PAWC) and was highly negative at $r^2 = -0.745$ as corroborated by the study of Ogban (2017). The base saturation (BS) and Cation Exchange Capacity (CEC) were also highly significant at $P<0.05$ and showed a positive correlation with the Plant Available Water Capacity at $r^2= 0.774$ and 0.793. The base saturation and cation exchange capacity depict the fertility of the land and the ability of the soils to release nutrients to plants via moisture; thus, more fertile soils will promote higher available water for plants (Baker, 2017).

CEC also showed a strong correlation with Base Saturation at $r^2= 0.978$. Compacted soils will reduce the movement and exchange of cations in the exchange site, thereby reducing the fertility of the soil. Electrical conductivity (EC) of the soils showed a strong positive correlation ($r^2 =0.813$) with PAWC; increased salinity will reduce poor space distribution, thereby reducing plant-available water in the soil. The Electrical conductivity also showed a high positive correlation with base saturation and CEC at $r^2 =0.997$ and $r^2 =0.988$. Hydraulic Conductivity (HC) showed positive relationship with PAWC, BS, CEC, EC at $r^2 = 0.889$, 0.732, 0.656, 0.744 and negative correlation with bulk density at $r^2 = - 0.674$. The movement of water and its availability are interrelated, as soils with high hydraulic conductivity will permit water to get to areas where it can be trapped for plant utilization. Higher bulk density and EC will reduce pore spaces, thereby reducing the flow of water through the soil. Soils with high CEC and BS depict high fertility and soils as such have a higher capacity to retain water for plant use. Similar findings were included in the work of Yusuf *et al.* (2018).

Organic carbon and organic matter indicated a high positive correlation with PAWC, BS, CEC, EC, and HC as stated by Bezabih *et al.* (2016). Organic carbon and organic matter play a major role in the free movement of water, availability of plant water, and soil fertility. Higher organic carbon and organic matter will increase water retention and availability to plants. Also, higher organic carbon and organic matter would lead to increased CEC, BS, and reduced electrical conductivity. Organic matter creates more reactive sites for nutrients and water, making them available to plants.

The sand fraction of the soils showed a strong negative correlation with PAWC, BS, CEC, EC, HC, organic carbon, and Organic matter. Soil texture is an important factor to consider in deriving the PAWC, sandy soils have more macropores, which are unable to retain a large volume of water for plant use. Also, sandy soils have low surface areas to accommodate sufficient basic cations for plants in their exchange sites (Musa *et al.*, 2021).

Clay showed a highly positive correlation with the selected parameters except for sand which has inverse properties such as its density, porosity, water, and nutrient exchange properties, etc. (BD was not significant to it). Porosity indicated a high positive correlation with PAWC, HC, and silt and a negative correlation with bulk density and Sand. Higher porosity will lead to higher PAWC and HC and vice versa; while higher bulk density will lead to lower porosity (Agbai *et al.*, 2022).

Soil Water Holding Capacity (SWHC) showed high positive correlation with Plant Available Water Capacity (PAWC) (r^2 =0.992), BS (r^2 =0.804), CEC (r^2 =0.822), EC (r^2 =0.842), HC (r^2=0.891), Organic carbon and organic matter (r^2 =0.825) and negative correlation with bulk density (r^2 = - 0.744), porosity (r^2 = - 610) and sand (r^2 = - 0.976). The work of Baker (2017) also submitted similar relationship between the SWHC, PAWC and Organic Matter, and CEC

Table 5: Correlation Matrix of some selected physical, chemical, and hydraulic characteristics

	PAWC	BD	BS	CEC	EC	HC	OrgC	Org M	Sand	Silt	Clay	Por.	SWHC
PAWC	1												
BD	-0.745	1											
BS	0.7740	-0.214	1										
CEC	0.793	-0.292	0.978	1									
EC	0.813	-0.277	0.997	0.988	1								
HC	0.889	-0.674	0.732	0.656	0.7444	1							
OrgC	0.794	-0.280	0.954	0.996	0.9704	0.620	1						
OrgM	0.793	-0.279	0.954	0.995	0.970	0.619	1	1					
Sand	-0.962	0.614	-0.896	-0.879	-0.917	-0.925	-0.865	-0.865	1				
Silt	0.932	-0.920	0.533	0.589	0.593	0.777	0.615	0.615	-0.829	1			
Clay	0.801	-0.292	0.972	0.910	0.963	0.850	0.871	0.871	-0.927	0.559	1		
Por.	0.745	-0.989	0.204	0.247	0.268	0.672	0.272	0.272	-0.610	0.926	0.282	1	
SWHC	0.992	-0.744	0.804	0.822	0.842	0.891	0.825	0.825	-0.976	0.929	0.824	-0.610	1

The research was limited by the number of samples collected to cover the area of the individual land use types. This was caused by limited funding to cover such bogus work. Also, the different soil textural fractions across the land use types can affect the comparison of texture, Soil Water Holding Capacity, and Plant Available Water Capacity.

Conclusion

The research showed that land use types had significant effect on the considered soil hydraulic properties. Hydraulic conductivity was highest in virgin land and lowest in plantain plantations. The Particle size, bulk density, and porosity of the soils were key determinants. Plant Available Water Capacity (PAWC) and Soil Water Holding Capacity (SWHC) were significantly affected by diverse land-use regimes. The highest SWHC and PAWC were found on virgin land, whereas the lowest was found on a plantain plantation.

The following recommendations are based on the findings of this study: Crops that aren't resilient to water stress should be grown on soils with high Plant Available Water Capacity (PAWC) and Soil Water Holding Capacity (SWHC). Organic additions should be used on low-fertility soils because organic matter has been shown to boost Plant Available Water Capacity (PAWC) and Soil Water Holding Capacity (SWHC).

Conflict of interest

All authors confirm that there is no conflict of interest in this research

Authors contribution

Project design, experiment, write-up, and editing were done by Agbai Williams P., while supervision was done by Kosuowei Mouna T.

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