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COMPARATIVE ASSESSMENT OF SOME PHYSICAL PROPERTIES AND ORGANIC MATTER CONTENT OF SOILS DERIVED FROM DIFFERENT PARENT MATERIALS IN AKWA IBOM STATE, NIGERIA

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ABSTRACT

The study of soils derived from different parent materials is useful in formulating appropriate management schemes for soil health and agricultural production. A comparative assessment of some physical properties and organic matter content of soils formed from coastal plain sands (CPS), sandstone (SST) and river alluvium (ALV) was conducted in Akwa Ibom State, Nigeria. Topsoil samples (0 – 30 cm) were collected from ten points in soils of each of the three parent materials for laboratory analyses. The soil samples were analyzed for texture, macro and micro aggregate stability indices, soil water characteristics, bulk density and organic matter. Data generated were subjected to Analysis of Variance to compare properties of soils of the different parent materials. Significantly different means were separated using the Least Significant Difference at 5% probability level. Results showed that soils of SST and CPS parent materials both had loamy sand texture while that of ALV soil was clay. Bulk density of ALV soil (1.20 Mg m^{-3}) was significantly lower ($p \leq 0.05$) than those of CPS (1.55 Mg m^{-3}) and SST (1.39 Mg m^{-3}). Significantly higher ($p \leq 0.05$) mean weight diameter (MWD) (2.01 mm), aggregated silt+clay (51.96%) and clay flocculation index (89.00%) were observed in ALV soils than in CPS and SST soils while the dispersion ratio and clay dispersion index were significantly higher ($p \leq 0.05$) in CPS and SST soils than in the ALV soil. Alluvial soil had significantly higher ($p \leq 0.05$) saturation water content (SWC), field capacity (FC), permanent wilting point (PWP) and available water content (AWC) of 0.61, 0.45, 0.25 and 0.20 m^3 m^{-3}, respectively, than those of CPS and SST. Alluvial soil also had the lowest cumulative infiltration (3.05 cm) and saturated hydraulic conductivity (0.40 cm hr^{-1}) relative to those of CPS and SST. The CPS soil had significantly lower ($p \leq 0.05$) organic matter content (2.07%) than SST (3.06%) and ALV (3.34%) soils. Cumulative infiltration (I) significantly and positively correlated with total sand (TS) (r = 0.710*) in the CPS soil, and K_{sat} (r = 0.681*), MWD (r = 0.829**) and CFI (r = 0.655*) in the SST soil. In the ALV soil, cumulative infiltration positively correlated with total porosity (r = 0.770**) and negatively with bulk density (r = - 0.770**). Saturated hydraulic conductivity (K_{sat}) had a positive correlation with SWC (r = 0.745*) and TP (r = 0.833**), but a significant and negative correlation with BD (r = - 0.833**) in SST soil. Field capacity (FC) positively and significantly correlated with TP (r = 0.638*) in CPS soil, and with MWD (r = 0.713*), CFI (r = 0.647*) and OM (r = 0.651*) in SST soil and with TP (r = 0.790**) and OM (r = 0.672*) in ALV soil. The correlations of FC with BD (r = - 0.638*) in CPS soil, with CDI (r = -0.647*) in SST soil and with BD (r = - 0.790**) in ALV soil were significant and negative. MWD positively and significantly correlated with organic matter (r = 0.699*). The clayey ALV soil will be suitable for paddy rice production and dry season crops due to its higher water retention capacity than the CPS and SST soils which will be better utilized for vegetable crop production under irrigation. The CPS and SST soils can also be applied to intensive crop production under rain fed condition and supplemented with irrigation.

Keywords: Comparative assessment, Physical properties, organic matter, parent materials, Akwa, Ibom State.

INTRODUCTION

The nature of parent material from which a soil is formed has a profound effect on the soil properties and behaviour under different management options. Parent material provides the raw starting material of the soil upon which the other soil forming factors and the associated processes act to create a particular soil (Gray and Murphy, 1999).

Soils developed on parent materials that are coarse grained and composed of minerals resistant to weathering are likely to exhibit coarse grained texture. Fine grained soil develops where the parent material is composed of unstable minerals that readily weather (Ritter, 2006). Therefore, the influence of parent material on soil physical properties is largely due to its influence on soil texture as the latter affects almost all other soil properties (Phogat *et al.,* 2015), including organic matter.

Soil organic matter tends to increase as the clay content increases. This increase depends on two mechanisms. First, bonds between the surface of clay particles and organic matter retard the decomposition process. Second, soils with higher clay content increase the potential for aggregate formation (Bot and Benites, 2005). Macro aggregates physically protect organic matter molecules from further mineralization by microorganisms (Rice, 2002; Aoyama *et al.,* 1999). Under similar climatic conditions, the organic matter content in fine textured (clayey) soils is two to four times that of coarse textured (sandy) soils (Prasad and Power, 1997). Parent material influences organic matter accumulation not only through its effect on soil texture but also through their mineral compositions. Soils developed from inherently rich materials such as basalt, experience more organic matter accumulation because of abundant vegetative growth (Bot and Benites, 2005).

For sustainable agricultural production, knowledge of the properties of tropical soils and how they can be best managed is required (Chude *et al.,* 2011). The study of soil properties can be the basis of formulating appropriate management schemes and identifying areas with reasonable agricultural potentials (Vinay, 2007; Muya *et al.,* 2011).

Soils of Akwa Ibom State include those derived from coastal plain sands, sandstone and alluvium. Study of the properties of these soils would provide information on the status of the soils that will culminate in better soil management towards sustainable agriculture. The objectives of this study were therefore to compare the properties of soils from three different parent materials in Akwa Ibom State and to examine the relationship between the soil physical properties and organic matter content.

MATERIALS AND METHOD

Physical Environment

This study was conducted at three locations (on the basis of parent material) comprising the Teaching and Research Farm of Akwa Ibom State University, Obio Akpa (Coastal plain sand), located between latitudes 5°17'N and 5°27'N, longitudes 7°27'E and 7°58'E) and the Cross River Basin Development Authority Research Farm, Itu (which has Sandstone in the upland area and Alluvium in the floodplain), located between latitudes 5°00'N and 5°20'N and longitudes 7°49' E and 7°10' E. The State is located within the tropical rainforest and has basically uniform climate with slight variations from the coastal areas in the south to the north. The climate is typically warm and humid. The mean annual temperature is uniform, ranging from 26^{o} to 28^{o} C (UniUyo Met. Station, 2017). The climate is divided into the wet season (April to October) and dry season (November to March). The wet season is characterized by bimodal rainfall pattern with peaks occurring in July and September and a short dry spell in August, referred to as August break. The rainfall ranges from about 3000 mm along the coast to about 2000 mm in the hinterlands (Petters *et al.,* 1989). Relative humidity varies between 75 and 90% (UniUyo Met. Station, 2017).

Soil sampling

At each observation point, bulk soil samples were collected with auger at the depth of 0 – 30 cm for the determination of particle size distribution, aggregate stability and organic matter content. Undisturbed core samples were collected (with core samplers measuring 7.0 x 4.4 cm) at each of the sampling points for the measurements of saturated hydraulic conductivity, bulk density and moisture retention characteristics.

Field method

One infiltration run was made in each of the thirty (30) observation points, using the double ring infiltrometer method (FAO, 1979). The dimensions of the inner and outer rings were 30 cm and 55 cm, respectively. The rings were vertically driven into the soil to a depth of 15 cm. The soil surface was protected from scouring by laying grasses and leaves on the soil surface within the rings prior to the commencement of infiltration. The rate of fall of water level was measured in the inner ring while a pool of water was maintained at approximately the same level in the outer ring to reduce lateral flow from the inner ring. Other equipments used were water container, wooden plank and hammer (to drive the infiltrometer into the soil), stop watch and ruler. Infiltration measurement continued till the steady state infiltration rate was attained. The rate of fall of the water level in the inner cylinder was measured at an interval of 1 minute for 10 minutes, followed by 2 minutes interval for the next 10 minutes, then 5 minutes interval for the next 30 minutes and lastly, 10 minutes intervals until a steady state infiltration rate was reached (Abdulkadir *et al*., 2011; Ogbe *et al*., 2011; Musa and Adeoye, 2010; Adindu *et al*., 2015). Infiltration characteristics (initial and steady state infiltration rates, and cumulative infiltration) were obtained from field infiltration data.

Laboratory Methods

Particle size distribution: determined as described by Klute (1986).
Bulk density: calculated from the mass-volume relationship of oven-dry soil thus:

$$\ell_b = \frac{M_s}{V_t} \quad \text{------------------------------------} \quad (1)$$

where, ℓ_b is bulk density (Mg m^{-3}), M_s is dry soil mass (Mg), V_t is total volume of soil (m^3) (Hillel, 2003).

Total porosity: calculated using the formula:

$$f = 1 - \left(\frac{\ell b}{\ell p}\right) \qquad (2)$$

where, f is total porosity ($m^3 m^{-3}$), ℓ_b is bulk density (Mg m^{-3}), ℓp is particle density, assumed to be 2.65 Mg m^{-3} for mineral soils (Hillel, 2003).

Saturated hydraulic conductivity (K_{sat}): measured using the constant head method (Dane and Topp, 2002). The quantity of water (Q) draining through the soil column over a fixed period of time (t) was collected and hydraulic conductivity was calculated as follows:

$$Ksat = \frac{QL}{\Delta h A t} \qquad (3)$$

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

Mean Weight Diameter was determined by passing the air-dried bulk sample through a 4 mm mesh, after which 25 g of the < 4 mm soil sample was placed in the topmost of a nest of sieves of 2.00, 1.00, 0.5 and 0.25 mm. The soil sample in the topmost sieve was presoaked in water for 10 min. Then, the nested sieves with the sample were held tightly by the hand and oscillated vertically for 20 times in the water at the rate of one (1) oscillation per second. Mean weight diameter (MWD) of water stable aggregates (WSA) was calculated as:

$$MWD = \sum_{i=1}^{n} X_i W_i \qquad (4)$$

where Xi is the mean diameter of the i^{th} sieve size and Wi is the proportion of the total aggregates in the i^{th} fraction.

Micro aggregate stability indices were obtained by a second determination of particle size distribution, using water as the dispersant and then calculating:

1. $$Dispersion\ ratio\ (DR) = \frac{\%\ silt + \%\ Clay\ (water)}{\%\ silt + \%\ clay\ (calgon)}\ x\ 100 \qquad (5)$$
2. $$Aggregated\ silt + clay\ (ASC) = \%\ Clay + Silt\ (calgon) - \%\ Clay + Silt(water) \qquad (6)$$
3. $$Clay\ Flocculation\ Index\ (CFI) = \frac{\%\ Clay\ (calgon) - Clay\ (water)}{\%\ Clay(calgon)}\ x\ 100 \qquad (7)$$
4. $$Clay\ dispersion\ index\ (CDI) = \frac{\%\ Clay\ (water)}{\%\ clay\ (calgon)}\ x\ 100 \qquad (8)$$

Saturation Water Content (SWC) and Field Capacity (FC): were determined using core samples as explained by Mbagwu (1990). The weight of the core sample was taken at saturation (0 day) for SWC, after which sample was left to drain. On the second day of draining, another weight measurement was taken for FC. These moisture constants were calculated when the weight of soil was eventually determined after oven-drying the sample at 105^{o}C to a constant weight. This was done by subtracting the oven dry weight from the corresponding wet weights earlier taken at 0 and 2 days and dividing same by the oven-dry weight to give SWC and FC, respectively. These are expressed mathematically as follows:

$$SWC\ (\%) = \frac{\text{Ww (at 0 day)} - \text{Wd}}{\text{Wd}} \quad \text{-- (9)}$$

$$FC\ (\%) = \frac{\text{Ww (at 2nd day)} - \text{Wd}}{\text{Wd}} \quad \text{--- (10)}$$

where Ww and Wd are wet weight and dry weight of soil sample, respectively.

Permanent Wilting Point (PWP): to determine the permanent wilting point (PWP), an indicator plant (*Zea mays*) was grown in 500 g of the soil sample in a metal can. The plant was given adequate moisture until the third pair of leaves was formed. Then the top of the can was sealed with wax. The maize plant was kept outdoors and allowed to remain there until it wilted permanently (without recovery). The soil water content at the point of permanent wilting was then determined as the permanent wilting point (Taylor and Ashcroft, 1972).

Moisture contents were expressed in volumetric basis by multiplying their respective gravimetric values by soil bulk density.

Available water content (AWC) was obtained as follows:

$$AWC = FC - PWP \quad \text{-- (11)}$$

where, AWC is available water content (m^3m^{-3}), FC is field capacity (m^3m^{-3}), PWP is permanent wilting point (m^3m^{-3}).

Organic matter: organic carbon content of the soil was determined using the Walkley-Black Wet Oxidation Method as modified by Nelson and Sommers (1996). Organic matter was obtained from the value of organic carbon by multiplying the latter by a factor of 1.724 (van Bemmelen's factor).

STATISTICAL ANALYSIS

Data generated were fitted into the Randomized Complete Block Design and Analysis of Variance was performed to compare properties of soils from the different parent materials. Significantly different means were separated using the Least Significant Difference at 5% probability level. Correlation analysis was used to examine the relationship among the properties of soils from the different parent materials.

RESULTS AND DISCUSSION

Texture, Bulk Density and Total Porosity

The particle size distribution, bulk density and total porosity of the soils are shown in Table 1. Coarse sand, total sand and silt were significantly higher in CPS and SST soils relative to ALV soil whereas the reverse was the case when considering clay. Consequently, the texture of the SST and CPS soils was loamy sand while that of the ALV was clay. Textures of soils are directly related to the sources of parent materials from which they were derived (de Wit and Bekker, 1990; Akamigbo and Asadu, 1983). Both the coastal plain sand and sandstone parent materials unlike alluvium are made primarily of the resistant quartz and/or feldpars (Asadu *et al.,* 2015; Aird, 2019). This is the reason for the similarity of the textures (loamy sand) obtained in the SST and CPS soils.

Table 1: Particle size distribution, bulk density and total porosity of the soils

		CPS	SST	ALV	LSD (0.05)
CS	$g\ kg^{-1}$	595.0	632.6	371.0	51.2
FS		231.0	172.0	64.0	26.4
TS		826.0	804.6	435.0	43.3
Silt		55.7	70.9	152.0	20.7
Clay		118.3	124.5	413.0	30.9
Texture		loamy sand	loamy sand	Clay	
BD ($Mg\ m^{-3}$)		1.55	1.39	1.20	0.10
TP ($m^3\ m^{-3}$)		0.42	0.48	0.55	0.04

CPS = coastal plain sand, SST = sandstone, ALV = alluvium, CS = coarse sand, FS = fine sand, TS = total sand, BD = bulk density, TP = total porosity.

Udoh (2015) reported loamy sand texture for sandstone soils in the Niger Delta area of Nigeria while Oguike and Mbagwu (2009) observed same for coastal plain sand soils in Owerri, southeastern Nigeria. The clay texture of the ALV soil corroborated the findings of Akpan and Udoh (2015) who also reported clay texture in alluvial soils of Akwa Ibom State. Earlier, Yilmaz and Karacan (2002) reported clay texture for alluvial soil in Erbaa Basin, Turkey. However, Kalala *et al.* (2017) characterized some alluvial soils in Tanzania and observed that two of the three pedons were sandy clay loam while the other was clay. Alluvial soils are the result of processes of erosion and deposition, and therefore exhibit various characteristics reflecting the composition and properties of the materials transported (Weber and Gobat, 2006). The ALV soil reported here may have been transported from the massive clay deposits found in Akwa Ibom State and the neighboring Cross River State (Udofia *et al.,* 2017; Attah, 2008) into the Itu River floodplain.

Significant ($p \leq 0.05$) difference in bulk density was observed among soils of the three parent materials with soil of the CPS having the highest bulk density (1.55 Mg m^{-3}), followed by the SST soil (1.39 Mg m^{-3}) and the ALV soil (1.20 Mg m^{-3}) in that order. Higher bulk densities of the SST and CPS soils than the ALV soil were probably because of the preponderance of coarse sand fractions in the SST and CPS soils compared to that of ALV. Texture is one of the inherent factors that affect bulk density. Chaudhari *et al.* (2013) and Tanveera *et al.* (2016) observed the profound effect of soil texture on bulk density and also reported an increase in bulk density with increase in sand fraction. Consequently, the ALV soil had the lowest bulk density because of its high clay content and reduced sand fractions. The higher organic matter content observed in the soil derived from ALV (Table 2) may have also contributed to the lower bulk density when compared to CPS and SST soils. Araújo *et al.* (2009) noted a negative relationship between bulk density and organic matter content and this is confirmed by the results of this study.

Total porosity differed significantly ($p \leq 0.05$) among soils of the three parent materials. The clayey ALV soil had a higher total porosity (0.55 m^3 m^{-3}) than the sandy SST (0.48 m^3 m^{-3}) and CPS (0.42 m^3 m^{-3}) soils. This result confirmed that of Chaudhari *et al.* (2013) and Krull *et al.* (2001) who reported higher total porosity of clayey soils than sandy soils. The higher total porosity of the ALV soil is attributed to its fine texture.

Organic Matter Content and Aggregate Stability

Organic matter content and aggregate stability indices of the soils are presented in Table 2. Soil of ALV origin had the highest organic matter content of 3.34%, which was not significantly ($p \leq 0.05$) different from that of SST (3.06%), but significantly higher ($p \leq 0.05$) than that of CPS (2.07%). The higher content of organic matter in ALV soil can be attributed to the fine texture of the alluvial clay. Fine textured soils have been reported to have considerably higher organic matter content than coarse textured soils (Bot and Benites, 2005). The higher organic matter content of ALV soils may have also emanated from the transportation and deposition of organic materials by water as alluvial soils have been noted to exhibit characteristics reflecting the composition of the materials transported (Weber and Gobat, 2006).

Mean weight diameter (MWD) of the ALV soil was higher than those of SST and CPS. This supported the observations of Oguike and Ndifreke (2016) who reported that soil derived from alluvium was more stable than soil derived from sandstone and coastal plain sands. Texture and OM are binding agents in the formation and stabilization of aggregates (Chenu *et al.,* 2000; Duchicela *et al.,* 2012; Portella *et al.,* 2012).

Table 2: Organic matter content and aggregate stability indices of soils of the three parent materials

Soil Property	CPS	SST	ALV	LSD $_{(0.05)}$
OM (%)	2.07	3.06	3.34	0.83
MWD (mm)	1.20	1.37	2.01	0.32
DR (%)	46.00	38.00	8.00	7.00
CDI (%)	43.89	39.65	11.00	8.41
ASC (%)	7.34	9.78	51.96	4.12
CFI (%)	56.11	60.35	89.00	8.41

CPS, SST and ALV are as indicated under Table 1, MWD = mean weight diameter, OM = organic matter, DR = dispersion ratio, CDI = clay dispersion index, ASC = aggregated silt + clay, CFI = clay flocculation index.

At the colloidal level, soil formed from ALV was better aggregated than those of CPS and SST. Elges (1985), classified dispersion as extreme when the dispersion ratio (DR) was greater than 50%, moderate when it was between 30 and 50%, low when it was between 15 and 30% and no dispersion when less than 15%. Based on this classification, CPS (46%) and SST (38%) soils in the present study were moderately dispersed while ALV soil (8%) was not dispersed. The CPS and SST soils, with DR greater than 10% were erodible while the ALV soil with DR less than 10% was not (Ezeabasili *et al.,* 2014). The lowest DR observed in soils of ALV when compared to those of SST and CPS could be due to the high organic matter content in ALV, which bonded with the clay particles to yield strong aggregates (Bot and Benites, 2005), thus resisting dispersion.

Clay dispersion index (CDI) for the CPS and SST soils were statistically similar but significantly higher ($p \leq 0.05$) than the ALV soil. Since lower values of CDI represent stable micro aggregates (Igwe and Nkemakosi, 2007; Opara, 2009), the result from the present study implied that the soil from ALV (CDI = 11.00%) was more stable against the disruptive forces of water than those of SST (CDI = 43.89%) and CPS (CDI = 39.65%). Evangelou and Wells (1984) reported a high propensity of clay soils to maintain their stability without dispersing when saturated. The high clay and organic matter contents of ALV soil proved to be excellent cementing agents.

Aggregated silt + clay (ASC) and clay flocculation index (CFI) were significantly higher ($p \leq 0.05$) in the ALV soil than in the SST and CPS soils. The CFI and ASC were directly proportional to micro aggregate stability (Igwe *et al.,* 1999; Igwe and Nkemakosi, 2007). Considering the values of the aggregation indices, the ALV soil was better aggregated than both the CPS and SST soils.

Water Infiltration and Conduction Characteristics

The initial infiltration rate (i_o), steady state infiltration rate (i_c) and cumulative infiltration (I) together with the saturated hydraulic conductivity (K_{sat}) are shown in Table 3. These parameters were significantly lower

($p \leq 0.05$) in the ALV soil than in the CPS and SST soils. This observation agreed with that of Turner (2006) who reported that soils with higher sand percentages have larger sized particles, larger pores, and higher hydraulic conductivity, diffusivity and infiltration rates when compared with clayey soils. Lower Infiltration characteristics and hydraulic conductivity observed in the soil derived from ALV were therefore due to the clayey texture of the soil. This result is similar to that of Nath (2014) who reported low and high infiltration rates for clayey and sandy soils, respectively. The low infiltration rates of ALV soils may be due to its high water retention (Table 4), caused by the high clay and organic matter contents. In this work, the high water retention capacity of ALV soil increased its initial water content, thus lowering the infiltration capacity. Mao *et al.* (2008) reported that at the wetting front, the suction gradient decreased with an increase in initial soil moisture content thus lowering the soil infiltration rate.

Table 3: Water infiltration and conduction characteristics of soils

Infiltration characteristics	CPS	SST	ALV	LSD $_{(0.05)}$
Initial infiltration rate (cm m^{-1})	1.08	1.42	0.05	0.36
Steady state infiltration rate (cm m^{-1})	0.56	0.81	0.03	0.26
Cumulative infiltration (cm)	67.37	97.60	3.05	31.26
Saturated hydraulic conductivity (cm hr^{-1})	3.32	5.85	0.40	3.21

CPS, SST and ALV are as indicated under Table 1.

Regarding moisture conduction of the soils, the ALV soil conducted less water than the CPS and SST soils. The CPS and SST soils were statistically ($p \leq 0.05$) similar, however, the SST conducted more water. The larger pore spaces (macro pores), as a result of higher coarse sand fraction, observed in the CPS and SST soils, may have influenced rapid drainage compared to the micro pores of the clayey ALV soil. Childs *et al.* (1993) had reported that coarse sandy soils have higher infiltration and intake rates due to larger pore sizes. Also, Haghnazari *et al.* (2015) maintained that water moves more quickly through large pores of sandy soils than it does through small pores of clayey soils.

Soil Water Characteristics

Water characteristics of the soils are presented in Table 4. The ALV soil retained significantly more ($p \leq 0.05$) water than CPS and SST soils. At all moisture constants, CPS and SST soils were statistically similar, although SST soil retained more water than the CPS soil except for the available water content (AWC). Turner (2006) reported that soil texture directly affected moisture retention capacity of soils. Therefore, the higher moisture retention characteristics (SWC, FC, PWP and AWC) of the ALV soil compared to those of the SST and CPS soils may be attributed to the clayey texture of ALV soil which stored more water than the loamy sandy texture of SST and CPS. These results corroborated that of Nath (2014) who reported high water retention and poor drainage for clay soils and low water retention and high drainage for sandy soils.

Table 4: Soil Water characteristics ($m^3 m^{-3}$) of the soils

Soil Water Characteristics	CPS	SST	ALV	LSD (0.05)
Saturation	0.36	0.41	0.61	0.05
Field Capacity	0.27	0.28	0.45	0.04
Permanent wilting point	0.14	0.16	0.25	0.03
Available water capacity	0.13	0.12	0.20	0.02

CPS, SST, and ALV are as indicated in Table 1.

The higher organic matter content observed in the ALV soil (Table 2) also contributed to the higher moisture retention when compared to the CPS and SST soils. Hudson (1994) showed that for every 1% increase in soil organic matter, the available water holding capacity of the soil increased by 3.7 percent.

Correlations of Some Soil Physical Properties and Organic Matter Content

Correlation matrix of the soil properties are presented in Tables 5, 6 and 7. Cumulative infiltration (I) significantly and positively correlated with total sand (TS) (r = 0.710*) in the CPS soil; K_{sat} (r = 0.681*), MWD (r = 0.829**) and CFI (r = 0.655*) in the SST soil. In the ALV soil, cumulative infiltration positively correlated with total porosity (r = 0.770**) and negatively with bulk density (r = - 0.770**). This implied that cumulative infiltration increased with increase in total sand, total porosity, K_{sat}, MWD and CFI. The increase in total sand content resulted in an increase in total porosity and K_{sat}, which altogether increased cumulative infiltration and water conduction. Cumulative infiltration increased with MWD and CFI because a high MWD and CFI indicated good structure. Significant and negative correlations of cumulative infiltration were observed with CDI (r = -0.655*) in SST soil. Higher value of CDI is an indicator of poor structure and it is associated with lower infiltration rates. Haghnazari *et al.* (2015) reported that most of the factors influencing infiltration have a direct effect on the soil structure.

Saturated hydraulic conductivity (K_{sat}) had a positive correlation with SWC (r = 0.745*) and TP (r = 0.833**), but a significant and negative correlation with BD (r = - 0.833**) in SST soil. The increase in K_{sat} with increased SWC and TP and decreased BD is basically a function of soil structure which determines the amount of pore spaces for water conduction. Saturation water content (SWC) correlated significantly and positively with FC (r = 0.728*), clay (r = 0.771**) and TP (r = 0.639**) in CPS soils; TP (r = 0.863**) in SST soil and with FC (r = 0.833**) and TP (r = 0.948**) in ALV soil. The correlations of SWC with bulk density in CPS soil (r = - 0.693*), SST soil (r = - 0.863**) and ALV soil (r = -0.948**) were significant and negative. The negative correlation of K_{sat} and SWC with BD was probably due to a reduction of water storage space possibly as a result of compaction. Soil compaction increases bulk density and reduces water retention (Page-Dumroese *et al.*, 2006).

There was significant and positive correlation of FC with TP (r = 0.638*) in CPS soil. Also, FC correlated significantly and positively with MWD (r = 0.713*), CFI (r = 0.647*) and OM (R = 0.651*) in SST soil and with TP (r = 0.790**) and OM (r = 0.627*) in ALV soil. However, FC correlated negatively with BD in CPS and ALV soils as well as with CDI in SST soil. The significant positive correlations of FC with TP, MWD, CFI and OM represented the role of good soil aggregation and structural stability in increasing field capacity while the significant and negative correlations of FC with BD and CDI were suggestive of the effect of high BD and CDI in reducing soil pore spaces, thereby reducing FC. The significant negative correlation of total sand with MWD (r = -0.672*) and ASC (r = -0.909**) in ALV soil indicated that the higher content of sand impeded soil aggregation. Mean weight diameter correlated positively (r = 0.699*) with organic matter, showing the influence of organic matter in the stabilization of soil aggregates.

Table 5: Correlations between soil properties studied under CPS soil

	I	K_{sat}	SWC	FC	TS	Silt	Clay	BD	TP	MWD	DR	ASC	CFI	CDI	OM
I	1.000														
K_{sat}	0.089	1.000													
SWC	0.094	0.467	1.000												
FC	-0.154	0.223	0.728*	1.000											
TS	0.701*	-0.250	-0.400	-0.412	1.000										
Silt	0.296	0.138	-0.444	-0.088	-0.427	1.000									
Clay	0.221	0.045	0.771**	0.405	-0.310	-0.727*	1.000								
BD	0.063	-0.190	-0.693*	-0.638*	0.259	0.120	-0.323	1.000							
TP	-0.063	0.190	0.693*	0.638*	-0.259	-0.120	0.323	-1.000**	1.000						
MWD	0.122	-0.272	0.337	0.504	-0.415	0.160	0.147	-0.504	0.504	1.000					
DR	0.402	-0.235	-0.080	-0.077	0.048	-0.124	0.094	0.295	-0.295	-0.093	1.000				
ASC	-0.165	0.309	0.212	0.215	-0.357	0.252	0.006	-0.371	0.371	0.223	-0.950**	1.000			
CFI	-0.402	0.354	0.242	0.183	-0.122	0.005	0.088	-0.343	0.343	-0.079	-0.825**	0.812**	1.000		
CDI	0.402	-0.354	-0.242	-0.183	0.122	-0.005	-0.088	0.343	-0.343	0.079	0.825**	-0.812**	-1.000**	1.000	
OM	-0.156	-0.239	-0.167	0.275	-0.067	0.339	-0.306	-0.381	0.381	0.223	-0.366	0.362	0.087	-0.087	1.000

I = cumulative infiltration, K_{sat} = saturated hydraulic conductivity, SWC saturated water content, FC = field capacity water content, TS = total sand, BD = bulk density, TP = total porosity, MWD = mean weight diameter, DR = dispersion ratio, ASC = aggregated silt + clay, CFI = clay flocculation index, CDI = clay dispersion index, OM = organic matter

Table 6: Correlation matrix of soil properties under SST soil

	I	K_{sat}	SWC	FC	TS	Silt	Clay	BD	TP	MWD	DR	ASC	CFI	CDI	OM
I	1.000														
K_{sat}	0.681*	1.000													
SWC	0.444	0.745*	1.000												
FC	-0.551	-0.256	0.236	1.000											
TS	0.457	0.155	-0.003	-0.305	1.000										
Silt	-0.449	-0.153	0.033	0.332	-0.998**	1.000									
Clay	0.030	0.021	-0.475	-0.539	0.339	-0.394	1.000								
BD	-0.631	-0.833**	-0.863**	0.213	-0.201	0.177	0.303	1.000							
TP	0.631	0.833**	0.863**	-0.213	0.201	-0.177	-0.303	-1.000**	1.000						
MWD	0.829**	0.487	-0.007	0.713*	0.609	-0.616	0.336	-0.311	0.311	1.000					
DR	-0.152	-0.477	-0.537	0.046	0.424	-0.424	0.168	0.536	-0.536	0.178	1.000				
ASC	-0.158	0.185	0.310	0.141	-0.841**	.840**	-0.287	-0.184	0.184	-0.452	-0.844**	1.000			
CFI	0.655*	0.274	-0.042	0.647*	0.528	-0.552	0.577	-0.164	0.164	0.604	-0.094	-0.217	1.000		
CDI	-0.655*	-0.274	0.042	-0.647*	-0.528	0.552	-0.577	0.164	-0.164	-0.604	0.094	0.217	-1.000**	1.000	
OM	0.172	0.212	-0.253	0.651*	0.124	-0.136	0.247	-0.198	0.198	0.459	-0.238	0.052	0.159	-0.159	1.000

I = cumulative infiltration, K_{sat} = saturated hydraulic conductivity, SWC saturated water content, FC = field capacity water content, TS = total sand, BD = bulk density, TP = total porosity, MWD = mean weight diameter, DR = dispersion ratio, ASC = aggregated silt + clay, CFI = clay flocculation index, CDI = clay dispersion index, OM = organic matte

Table 7: Correlation matrix of soil properties under alluvial soil

	I	K_{sat}	SWC	FC	TS	Silt	Clay	BD	TP	MWD	DR	ASC	CFI	CDI	OM
I	1.000														
K_{sat}	-0.185	1.000													
SWC	-0.753*	0.557	1.000												
FC	-0.411	0.285	0.833**	1.000											
TS	0.466	0.493	-0.355	-0.433	1.000										
Silt	-0.109	-0.554	-0.001	0.164	-0.723*	1.000									
Clay	-0.570	-0.262	0.500	0.481	-0.844**	0.239	1.000								
BD	-0.770**	-0.509	-0.948**	-0.790**	0.281	0.097	-0.471	1.000							
TP	0.770**	0.509	0.948**	0.790**	-0.281	-0.097	0.471	-1.000**	1.000						
MWD	-0.272	0.035	0.539	0.619	-0.672*	0.391	0.641*	-0.419	0.419	1.000					
DR	-0.374	-0.430	-0.170	-0.284	-0.124	0.241	-0.014	-0.007	0.007	-0.518	1.000				
ASC	-0.291	-0.305	0.397	0.513	-0.909**	0.581	0.826**	-0.246	0.246	0.851**	-0.298	1.000			
CFI	0.362	0.460	0.159	0.243	0.182	-0.338	0.007	0.009	-0.009	0.473	-0.993**	0.243	1.000		
CDI	-0.362	-0.460	-0.159	-0.243	-0.182	0.338	-0.007	-0.009	0.009	-0.473	0.993**	-0.243	-1.000**	1.000	
OM	-0.234	0.069	0.541	0.672*	-0.476	0.539	0.250	-0.419	0.419	0.699*	-0.363	0.580	0.284	-0.284	1.000

I = cumulative infiltration, K_{sat} = saturated hydraulic conductivity, SWC saturated water content, FC = field capacity water content, TS = total sand, BD = bulk density, TP = total porosity, MWD = mean weight diameter, DR = dispersion ratio, ASC = aggregated silt + clay, CFI = clay flocculation index, CDI = clay dispersion index, OM = organic matter

CONCLUSION

The clay – textured ALV soil was better in terms of aggregate stability, organic matter content and water retention but worse in water infiltration and conduction than the CPS and SST soils with loamy sand texture. Therefore, the ALV soil can be effectively harnessed for the production of dry season crops with little or no irrigation. The CPS and SST soils could be dedicated to intensive crop production under rain fed condition and supplemented with irrigation.

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