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Infiltration and water retention characteristics of soils of Owena irrigation project site in Idanre in Ondo State

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Abstract

Information on soil infiltration capacity and water retention characteristic curves are vital in the evaluation of irrigation water needs and scheduling and soil management in terms of land preparation and erosion control. This study was conducted on about a 4,000 ha area delineated for Owena River Basin Project in Idanre in Ondo State. Infiltration rates and soil water retention characteristics (SWRC) at specific pressure potentials were measured in 10 profile locations in two mapping units. Results showed that water retention at -10 kPa representing field capacity could generally support the growth and productivity of a wide range of arable and cash crops. Saturation water content at 0 kPa was higher in mapping unit ONEG I, indicating the tendency of the soil to puddle if tillage is carried out when the soil water content is slightly higher than the field capacity. The initial infiltration rate of water in Mapping Unit II was generally higher but decreased to a minimum within 1 hour. There was a narrow range between water retention at field capacity (-10 kPa) and permanent wilting point (-1500 kPa) in soils in mapping unit ONEGII, an indication that the soils can quickly dry up after rainfall and irrigation. The shape of the water retention curves showed slow water release pattern within the 0-35 cm topsoil, and reach very gradual release within 150 cm depth. A mean of 12.5% of the soil water was released between saturation and field capacity water potentials. The pattern of change of water content per unit change in matric potential was ultimately related to particle size-distribution. About 25% of the SWRC between saturation and field capacity lied within at least 15 cm depth in all the profiles.

Keywords: Infiltration capacity; soil water retention, water needs; field capacity; wilt point.

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1.0 Introduction

Soil infiltrability, together with rainfall characteristics is the most crucial hydrological parameter for evaluation and diagnosis of the soil water balance and soil moisture regime. Infiltration rate is an essential factor controlling agricultural production in terms of irrigation efficiency, irrigation uniformity, amount of water entering the soil during irrigation and rainfall and the advance rate of water down the furrow (Trout 1990). Infiltration is governed by two factors: gravity and capillary action. Smaller soil pore offers greater resistance to movement of soil water by gravity, whereas; very small pores pull water through capillary action in addition to and even against the force of gravity. The magnitude and direction of infiltration are affected by soil texture, pore configuration, soil structure, and amount of organic residues, slope factor and the antecedence of soil water content (Franzluebbers 2002; Green et al. 2003).

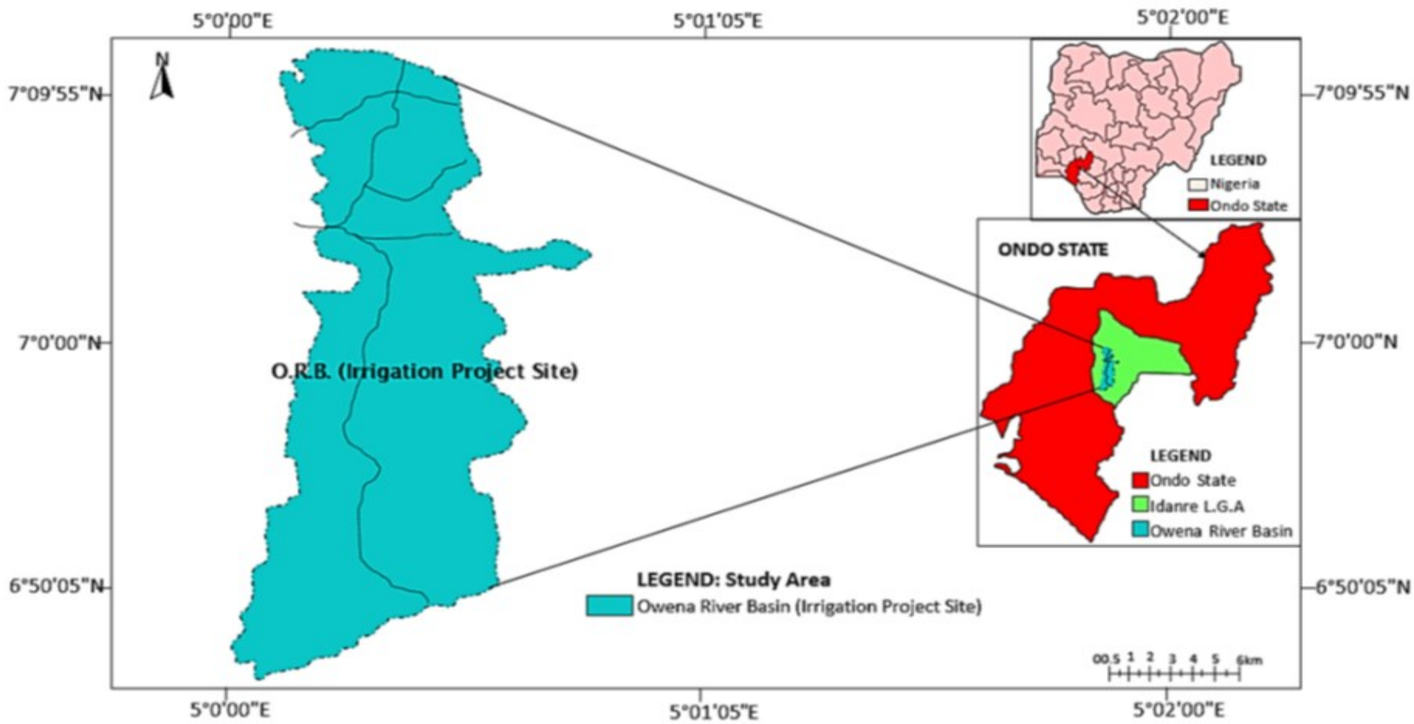
Water movement and retention in soils is a function of pore-size distribution which determines the amount of water stored in the soil for crop use (Barthes and Roose, 2002). Water-retention characteristics (WRC) are essential growth factors since they directly determine the amount of air and water that can be retained by the soil at a given matric potential. Water retention characteristics allow calculation of effective pore-size distribution, air-filled porosity (AFP) and the amount of plant-available water Udom and Ogunwole, 2015; Udom and Kamalu, 2016; Udom et al., 2018). One of the unsaturated soil characteristics is soil water retention curve (SWRC), which is widely used in the determination of total available water (TAW) in soil, irrigation frequency, and effective porosity; the latter is used in drainage and leaching studies. Water retention at specific matric potential values or parameters of water-retention models have been related to readily available physical properties of soil such as bulk density, organic matter and particle-size distribution (Wall and Heiskanen, 2003). Hence, infiltration and water retention characteristics studies of Owena Basin were studied to provide a model on total available water (TAW) content of the soil and the readiness of the soil to accept water and rainfall for agricultural production.

2.0. Materials and Methods

2.1. The Study Area

The study was carried out in the Owena River Basin Irrigation Project located in Idanre Local Government Area of Ondo State (Figure 1). Idanre lies between latitudes 6° 00′ and 8° 00′ N and longitudes 5° 00′ E and 4° 48′ E. The river basin occupies an area of about 15,500 km^2 (Mohammed and Ajayi, 2014). The landscape of the study area in most cases is characterized by lowlands, undulating grounds and rugged hills with granitic rock outcrops in many places.

Five (5) locations were identified, based on the physiographic position, vegetation, and landform characteristics of the area viz: Arun village, Owena Egbeda, Iramuje, Fayomi and Ganupe. Nine (9) profile pits were sited across the five physiographic locations and later delineated into two mapping units: ONEG I and ONEG II. Disturbed and undisturbed soil samples were collected from each profile locations.



2.2. Infiltration

Infiltration measurement was carried out on the field using the double-ring infiltrometer (Carter, 1993) with inner and outer rings of 30 cm and 60 cm diameters, respectively. A constant water head of 5 cm was maintained for 2 hours until steady-state infiltration was achieved. The infiltration rate (I) was calculated according to Bower (1986) as:

$$I = \frac{Q}{A\,t} \quad (1)$$

where Q is the quantity of water infiltrating (cm^3), A is an area of the soil surface exposed to infiltration (cm^2), and t is time (h).

2.3. Soil Water Retention Characteristics (pF Curves)

Soil water-retention characteristics (SWRC) were measured on undisturbed core samples 5 cm in diameter and 6 cm in height, using the pressure chamber apparatus and Tension Tables with ceramic plates. The following suctions were obtained: 0, -3, -10 and -1500 kPa. The water content at -10 bars and -1500 kPa represent the field capacity (FC) and permanent wilting point (PWP), respectively, as suggested by Cassel and Nielsen (1986) for most tropical soils. In this procedure, a saturation of the soil samples was achieved by adding water slowly until the water was about halfway to the top of the soil cores and allowed to soak for 24 h. After saturation, samples were subjected to pressures 0, -3, -10 kPa using the Hanging Water Column Method as described by Wang and Benson (2004), and -1500 kPa using the pressure plate apparatus. Excess water drained through the ceramic plates until the balance was established between pressure force and water retention force in the samples after 2 days. The gravimetric water content in the samples was measured after oven-drying the soil at 105°C and the values converted to volumetric water content (cm^3 cm^{-3}) by multiplying it by the dry bulk density of each core sample.

2.4. Bulk Density

Bulk density was determined with core samples by the method of Blake and Hartge (1986) using the formulae:

$$\text{Bulk density} = \frac{mass\ of\ oven-dried\ soil\ (g)}{volume\ of\ bulk\ soil\ (cm3)} \quad (2)$$

Total Porosity: Total porosity was calculated with core samples using the core method as described by Flint and Flint (2002) as:

(3)

3.0. Results and Discussion

3.1. Infiltration

Infiltration in most of the profiles 1, 2, 3 and 6 representing mapping unit ONEG1 attained steady state within 45 min (Fig. 1a), whereas profiles 4,5,7,8, and 9 attained mean steady-state infiltration rate before I hour (Fig. 1b). Initial infiltration in all the profiles in ONEG I was relatively low (about 34 cm h^{-1}) indicating that the soils could accept rainwater and irrigation during the dry period. Steady-state infiltration ranged between near zero and 10 cm h^{-1}. Water transmission in the subsoil was low in the Mapping Unit. Similar results had reported in fine-textured submerged soil (Udom and Nuga, 2014), and the effect of antecedent moisture content (Franzluebbers 2002; Green et al. 2003). In mapping unit ONEG II (Fig. 1b), the values for initial infiltration ranged between 50 and 56 cm h^{-1} indicating high water transmission in the subsoil. This would have an implication on irrigation frequency and the possibility of quick-drying up of the soil after irrigation and rainfall.

$$\% \, Total \, porosity = \frac{volume \, of \, water \, at \, 0 \, kPa}{volume \, of \, sample} \times \frac{100}{1}$$

3.2. Soil Water Retention Curves (pF-Curves)

The soil water retention curves (SWRCs) of soils in Mapping Unit ONEG I in Fig 2a showed that water release pattern was slow within the 0-35 cm soil and decreased with depth, reaching very gradual release pattern within 150 cm depths. In the top 0-10 cm and 0-7 cm soil, a mean of 12.5% of the soil water was released between saturation and field capacity water potentials.

In Mapping Unit ONEG II representing profiles 4, 5, 7, 8 and 10 (Fig 2b), the shape of the water retention curves also showed relatively slow release pattern within the 0-45 cm soil depth, reaching very gradual release within 20-45 cm soil depth. The pattern of change of water content per unit change in matric potential (specific water capacity) could have been ultimately related to particle size-distribution (Nemes *et al*., 2006; Zacharias and Wessolek, 2007). The Plateau of the water retention curve can be projected from Figures 2a and b for irrigation studies. Usually, between saturation and field capacity water potentials, about 25% of the water retention curves lie within at least 15 cm depth in all the profiles.

3.3. Soil bulk Density and Total porosity

The bulk densities of the soils in mapping unit ONEG I representing profiles 1, 2, 3 and 6 are shown in Table 1a. Bulk densities were generally somewhat moderate to high in all the profiles with mean values ranging between 1.58 g cm^{-3} to 1.63 g cm^{-3}. A similar trend was found in Mapping unit ONEG II with a mean value of 1.65 g cm^{-3}. The relatively high bulk density of the soils can be attributable to the gravelly nature of the profiles. This is consistent with Wall and Heiskanen (2003) that soil bulk density increased with sand and gravel contents). Topsoil bulk densities were within acceptable threshold values, indicating that the soil can support crop production on sustainable bases if well managed. The soils may be prone to flooding if they are within flooding area. Poor drainage below 45 cm soil depth could be the major constraint in the area.

The total porosity of the soil was generally low in all the profiles (Table 1a and b), due to the gravelly nature of the soil within 35 cm depth. There were general indications that total available water content (TAWC) between saturation (0 kPa) and field capacity (-10 kPa) would be low. Also, the ratio of the storage- to transmission-pores tended was high; indicating that more water would be stored in the rooting zone. Low total porosity with restricted drainage had also been reported in stony soils (Udom and Kamalu, 2016).

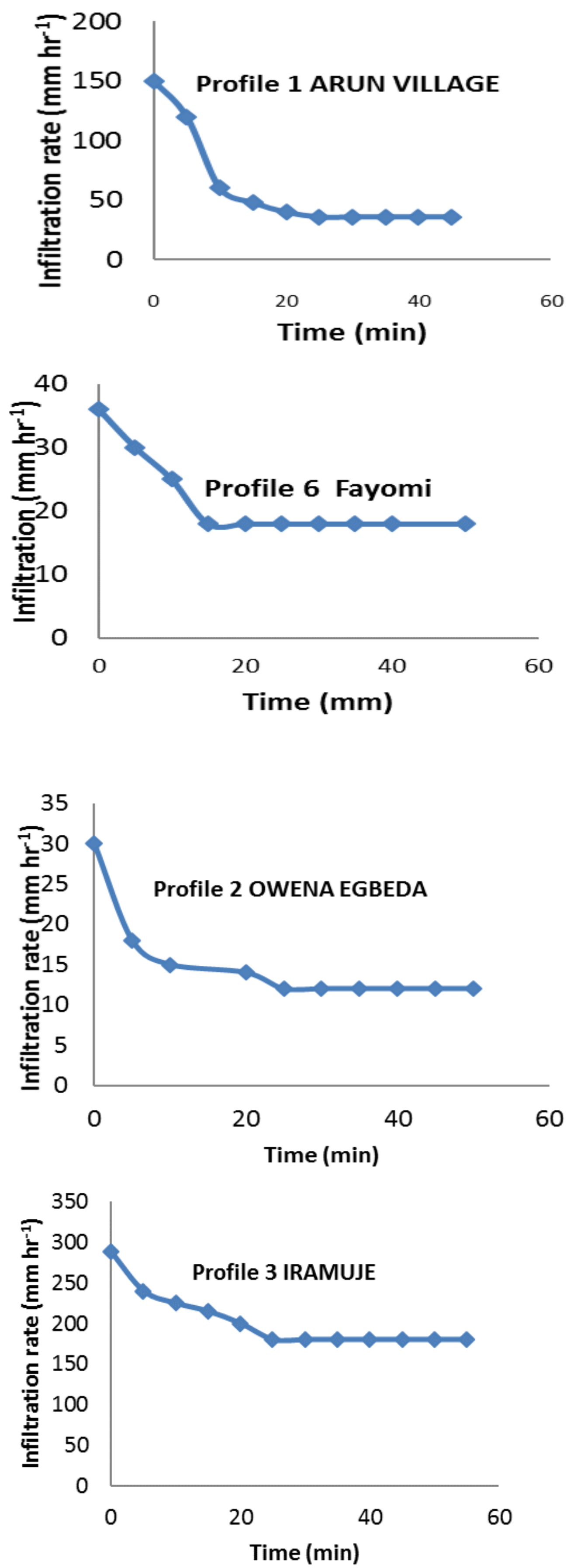
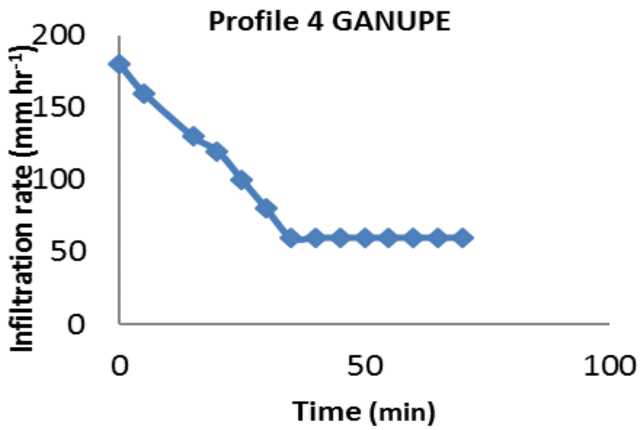
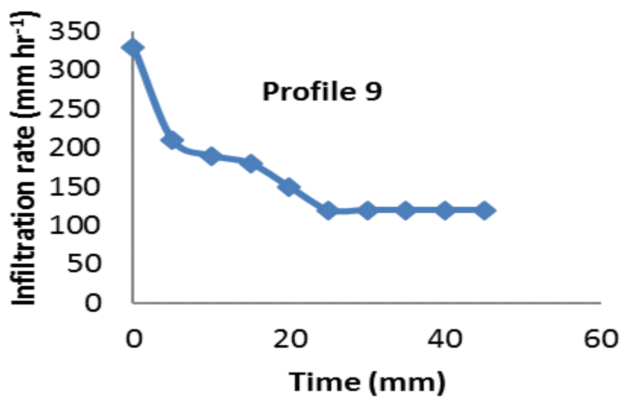
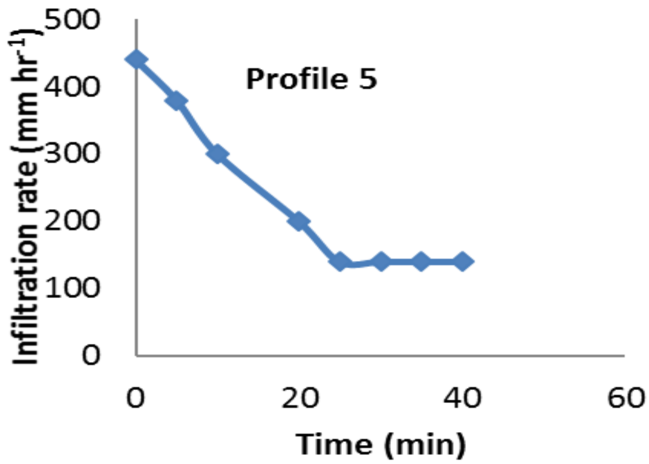
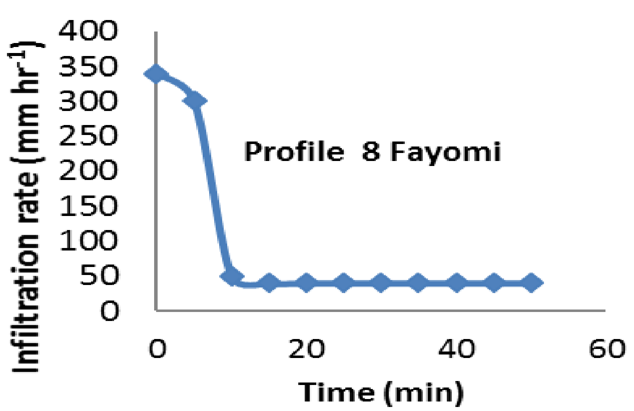


Figure 1a. Infiltration capacity of the soils in profiles 1, 2, 3, and 6 under Mapping Unit ONEG I









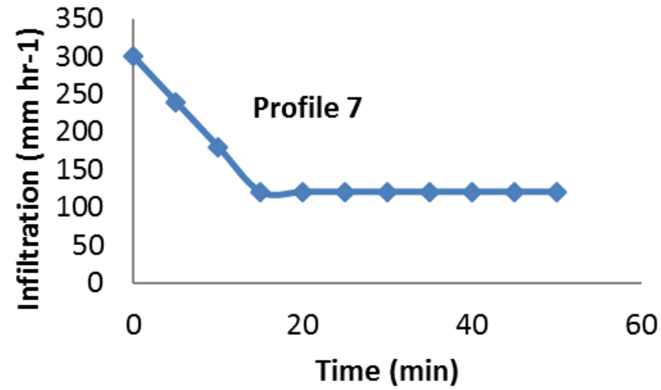
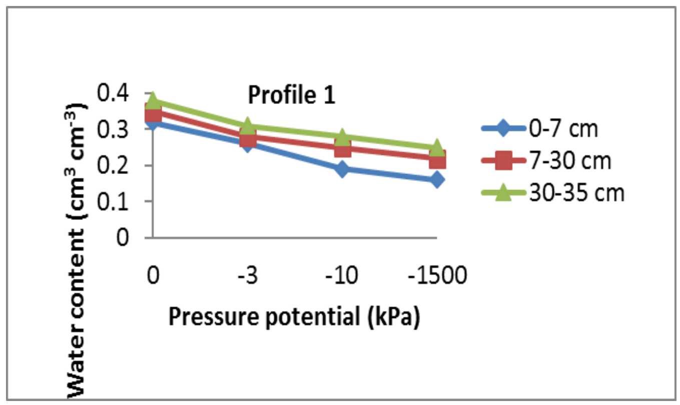
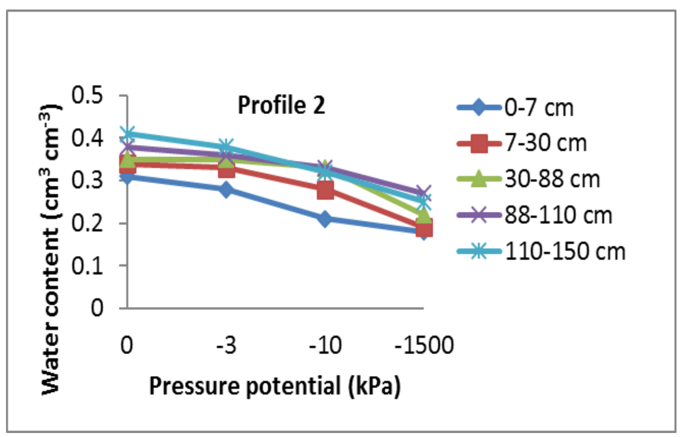
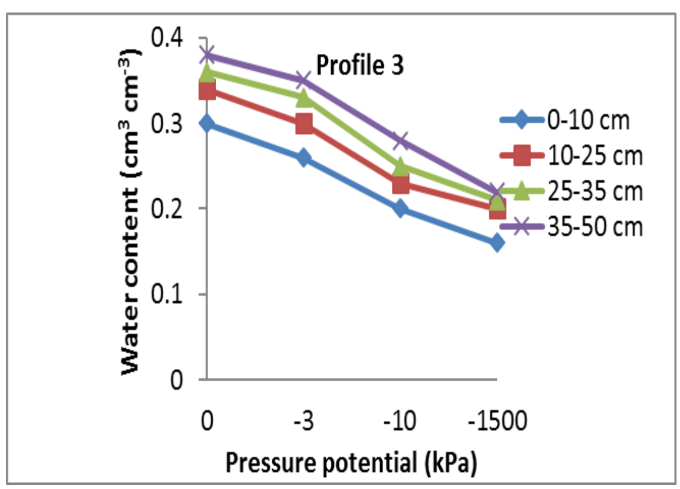


Figure 1b. Infiltration capacity of the soils in profiles 4,5,7, 8 and 10 under Mapping Unit ONEG II







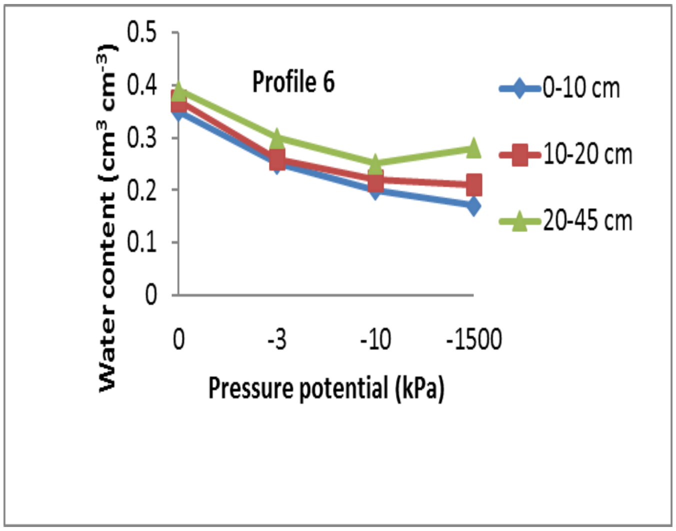
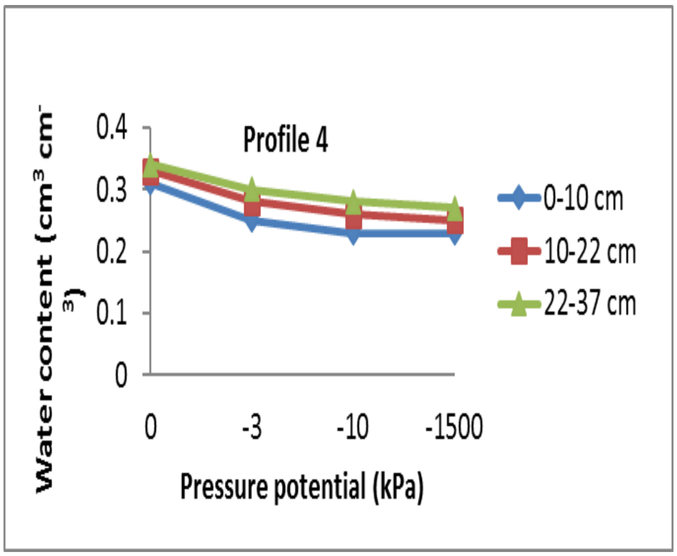
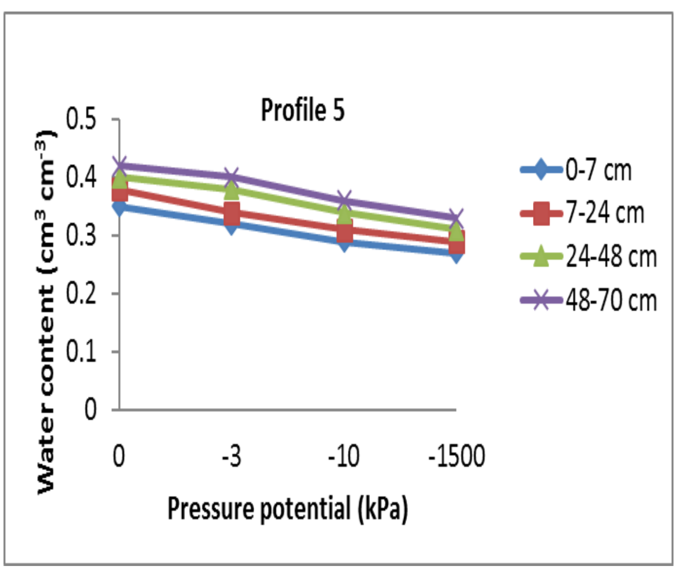
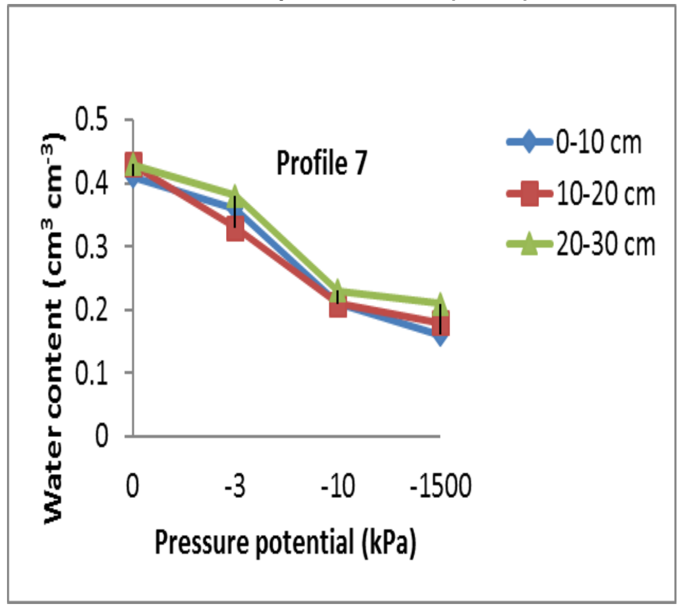
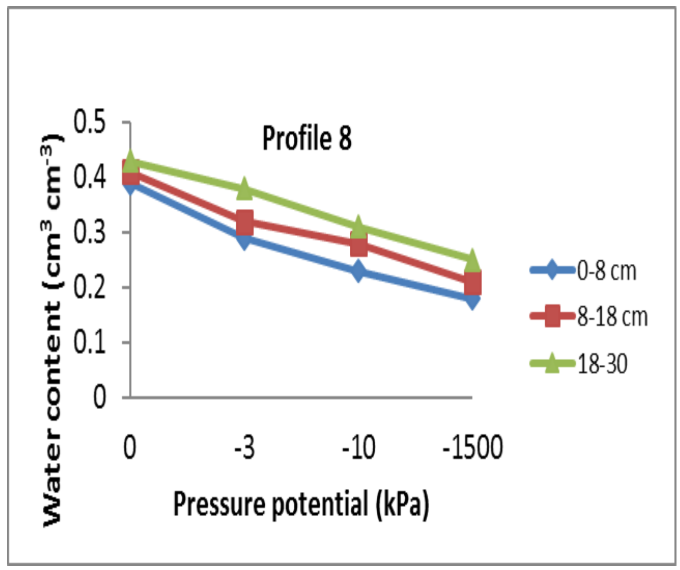


Figure 2a. Soil water retention characteristics curves of profiles 1, 2, 3, 6 under Mapping Unit ONEG 1









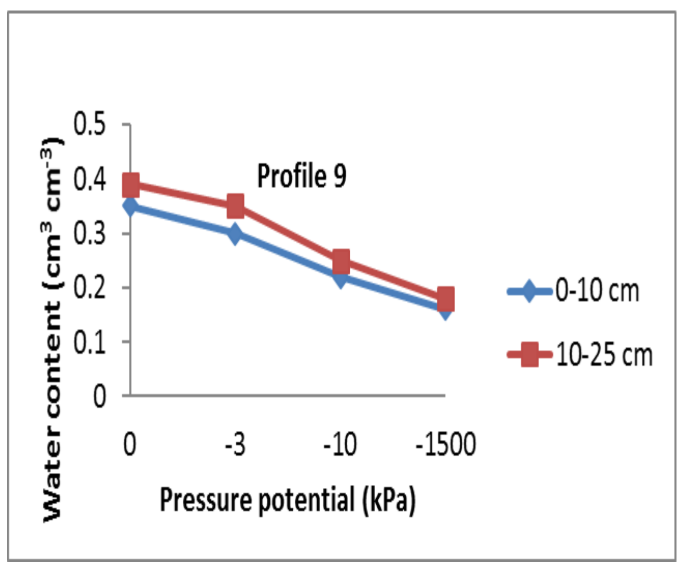


Figure 2b. Soil water retention characteristics curves of profiles 4, 5, 7, 8 and 10 under Mapping Unit ONEG 2

Table 1a. Bulk density and total porosity of soils under Mapping Unit ONEG I

Soil depth (cm)	Bulk density (g cm^{-3})	Total porosity (%)
ARUN VILLAGE	PROFILE 1	
0-7	1.57	20.5
7-30	1.56	20.9
30-35	1.68	21.3
Mean	1.58	20.9
OWENA EGBEDA	PROFILE 2	
0-7	1.57	43.0
7-30	1.63	38.1
30-88	1.68	36.1
88-110	1.60	39.6
110-150	1.67	42.5
Mean	1.63	39.9
IRAMUJE	PROFILE 3	
0-10	1.56	22.8
10-25	1.64	31.4
25-35	1.62	28.8
35-50	1.59	34.6
Mean	1.60	29.4
FAYOMI	PROFILE 6	
0-10	1.60	40.9
10-20	1.61	37.6
20-45	1.68	33.6
Mean	1.53	37.4

Table 1b. Bulk density and total porosity of soils under Mapping Unit ONEG II

Soil depth (cm)	Bulk density (g cm^{-3})	Total porosity (%)
GANUJE	PROFILE 4	
0-10	1.61	31.8
10-22	1.63	22.6
22-37	1.60	21.8
Mean	1.61	25.4
	PROFILE 5	
0-7	1.41	41.9
7-24	1,42	40.7
24-48	1.68	40.7
48-70	1.68	33.6
Mean	1.55	39.2
	PROFILE 7	
10	1.64	33.4
10-20	1.68	31.1
20-30	1.68	30.8
Mean	1.67	31.8
	PROFILE 8	
0-8	1.37	38.2
8-18	1.65	36.8
18-30	1.68	39.8
Mean	1.57	38.3
	PROFILE 9	
0-10	1.37	43.2
10-25	1.67	33.8
Mean	1.53	38.5

4.0. Conclusion

Conclusions drawn from the study are that: Initial infiltration rates in all the profiles in ONEG I was relatively low. Steady-state infiltration ranged between near zero and 10 cm h^{-1} in most of the profiles. Water transmission in the subsoil was low in the Mapping Unit ONEG I and slightly higher in Mapping Unit ONEG II. The soil can accept water during the dry season for cropping. Water release pattern within the 0-45 cm soil depth was slow. However, the surface can dry up quickly after rainfall and irrigation. Bulk density was relatively high due to the gravelly nature of the soils.

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