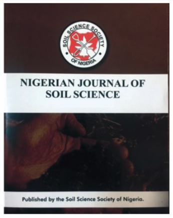
DOI: https://doi.org/10.67042/njss.2023.e062k0ea

Ologunde et al. *NJSS 33 (1) 2023 6-14*

Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com



Changes in Soil Physical Properties Due to Variable Weather Conditions Under Two Soil Types in South Western Nigeria

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ARTICLE INFO

Article history:
Received July 19, 2023
Received in revised form August 24, 2023
Accepted August 27, 2023
Available online September 6, 2023

Keywords:
Seasonal variation
Soil texture
Soil properties
Soil productivity

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ISSN– Online **2736-1411**
Print **2736-142X**

ABSTRACT

Soil physical properties changes with weather conditions over time. The degree of variation might be influenced by different soil textural classes. This study aimed at understanding the changes in soil physical with varying weather conditions under two soil textures. The research was conducted in cassava fields at the Federal University of Agriculture, Abeokuta and Psaltry International Limited, Iseyin, with sandy clay loam (SCL) and loamy sand (LS) textural classes, respectively. At each location, the cassava fields were established in the months of April and August, 2017. In 2018, soil measurements and sample collection were conducted immediately prior to the cassava harvesting at 9 (early sampling) and 11 (late sampling) months after planting. This correspond to January and March (dry season) for April planting and May and July (rainy season) for August planting. At both season, soil bulk density was higher under SCL than LS and higher during the rainy (1.41 g cm^{-3}) than dry season (1.34 g cm^{-3}). The SCL texture had higher soil moisture content in both rainy (17.8 cm^3 cm^{-3}) and dry (10.7 cm^3 cm^{-3}) seasons, than LS. Soil temperature was significantly higher during the rainy season than dry season. The LS had significantly higher saturated hydraulic conductivity than SCL with 41.9% and 21.4% increase during dry and rainy season, respectively. Infiltration parameters were higher for SCL than SCL texture. The changes in weather condition and variation in soil textural class alters the state of soil physical properties, which may require site specific management practices.

1.0 Introduction

Soil physical properties play a key role in soil productivity and also influence the chemical and biological properties of the soil (Phogat et al., 2015). The ease of accessing soil nutrients by plant roots, and water flow through the soil for nutrient delivery and retention of nutrients in the soil are directly related to the soil physical properties (Almendro-Candel et al., 2018; Phogat et al., 2015). Due to climatic and seasonal variations, the intensity and distribution of temperature and rainfall changes with time (Audu et al., 2021). These variation in weather conditions can alter directly or indirectly a range of soil properties in space and time, and consequently influence crop growth and development (Ray et al., 2015).

Cassava (*Manihot esculenta* Crantz) is one of the most important staple crops grown mainly for its roots and young leaves in the tropics. It is the second most important staple food for energy in Sub-Saharan Africa providing up to 285 calories per person per day (Benesi et al., 2004). Cassava is usually planted throughout the rainy season in the south-western Nigeria covering the period March to October. The shifts in weather condition, especially precipitation and temperature, influence the growth, root bulking and starch accumulation in cassava (Enesi et al., 2022). The high vegetative growth during the rainy season and closure of stomata during moisture stress in the dry season are some of the crops adaptive mechanisms to weather variation. In addition, soil nutrient dynamics and physical processes are factors that indirectly influence crop production which changes with weather condition (Javed et al., 2022).

In tropical environment, soil pH has been reported to be higher in the rainy reason (Sonko et al., 2016), coupled with the alteration in total nitrogen, exchangeable bases and organic matter content (Olojugba, 2018). In addition, soil texture, which refers to the size distribution of the mineral fractions of the soil, may indirectly or directly influence rate of changes of soil properties (Vinhal-Freitas et al., 2017). Reports on the impact of seasonal variation on physical properties is deficient as compared to chemical properties. We hypothesized that weather conditions influences the variation in soil physical properties and that the effect also varied due to soil textural difference. Therefore, the objective of this study was to investigate the changes in soil physical properties with seasonal variation in two textural classes under cassava production.

2.0 Materials and Method

2.1 Description of Study area

The study was conducted at the Directorate of University Farms of the Federal University of Agriculture, Abeokuta (FUNAAB), Ogun state and the cassava field of Psaltry International Limited (PSALTRY), Ado-Awaye, Oyo state, both in south west, Nigeria. The FUNAAB study site is located within a forest-savanna transition zone with slightly gravelly sub surface (Salako et al., 2007) and has a sandy clay loam texture (SCL) (Table 1). PSALTRY is localized in Iseyin Local Government of Oyo state, Nigeria and falls under Southern savanna zone with loamy sand textural soil (LS) (Ayanlade et al., 2018).

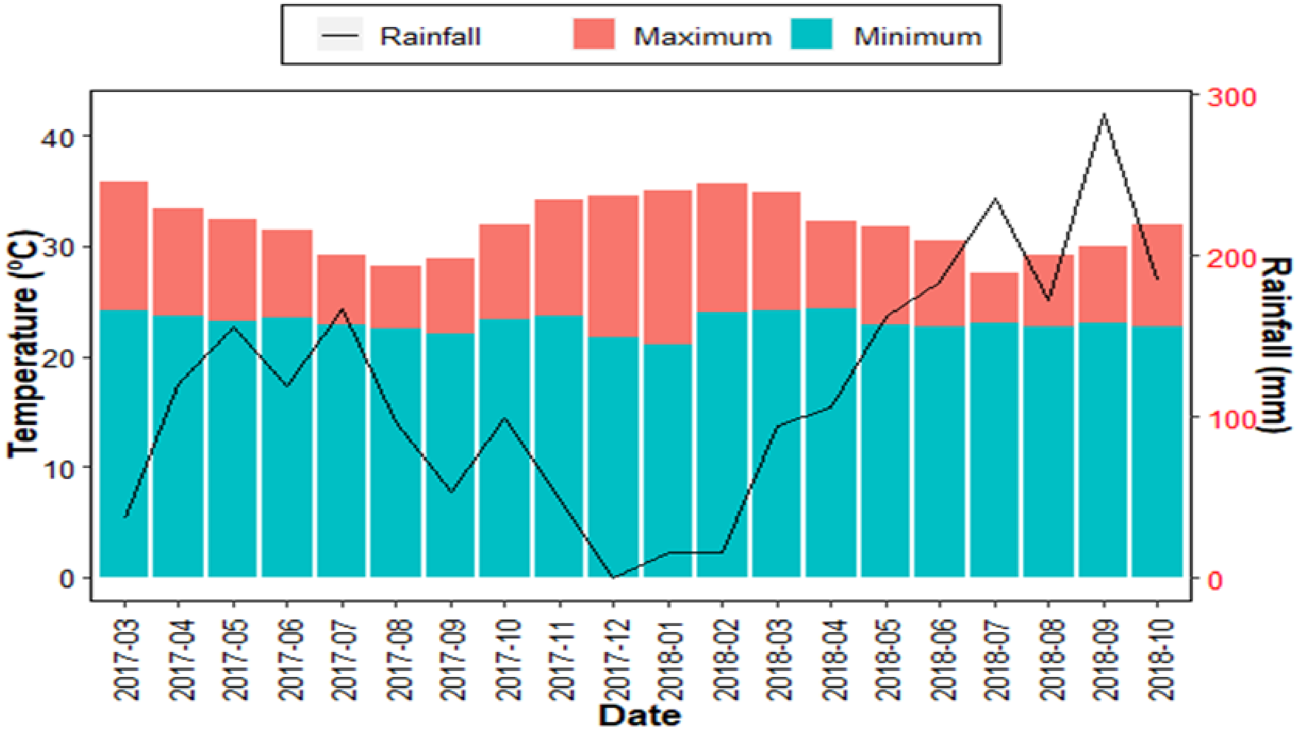
Table 1 Soil textural composition of the study areas

Location	Latitude	Longitude	Elevation (m)	Sand →	Clay (g kg^{-1})	← Silt	Textural Class
FUNAAB	7^0 14’ N	3^0 26’ E	160.9	685.4	209.0	105.6	SCL
PSALTRY	7^0 47’ N	3^0 23’ E	194.4	840.3	119.0	40.7	LS

SCL; Sandy clay loam, LS; Loamy sand

2.2 Weather conditions during the study

The two locations are characterized with two main alternating rainy seasons between April to October and dry seasons between November to March (Figure 1). During the sampling and harvesting periods in 2018 at both location, the rainfall peaks in September while there was little or no rainfall during the dry season. During the study period, FUNAAB received rainfall of 1997.61 mm while PSALTRY had 1075.2 cm. At FUNAAB, the daily minimum temperature and maximum temperature for dry season ranged from 27.5 to 33.4 ºC and 31.9 to 35.8 ºC, respectively while at PSALTRY it ranged from 27.3 to 32.8 ºC and 31.6 to 33.7 ºC, respectively.



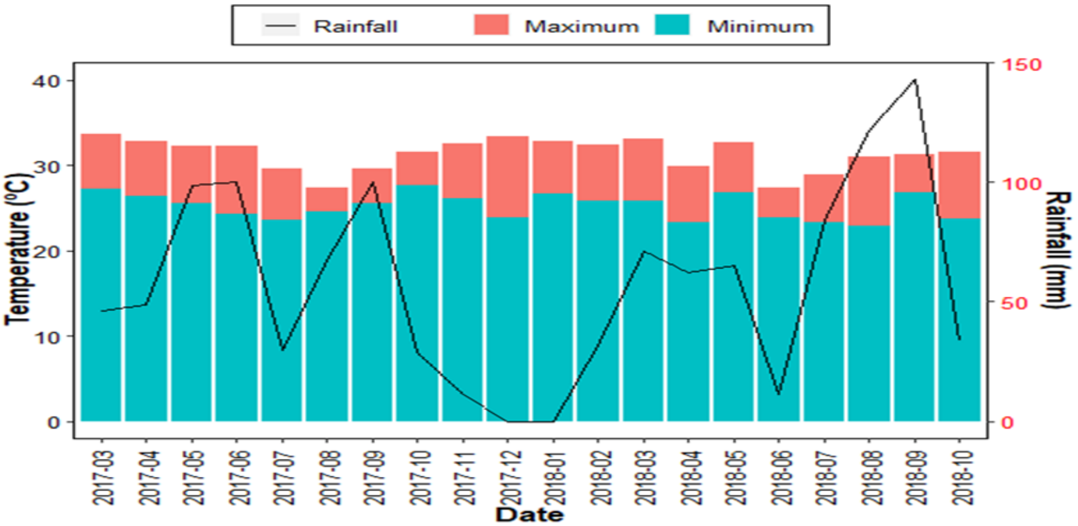


Figure 1: Monthly rainfall and minimum and maximum temperature at FUNAAB (a) and PSALTRY (b). Data source: CHIRPS, 2021.

2.3 *Experimental set-up and soil sampling*

Soil samplings and measurements were conducted immediately prior to the harvesting between cassava stands. At each of the location, the cassava crops were planted during the 2017 season in the months of April and August. Each cassava planting was harvested twice in 2018 at 9 and 11 months after planting (MAP). Under the cassava that was planted in April, the soils were sampled in January (9 MAP - early sampling) and March (11 MAP - late sampling), both signifies the dry season sampling periods. Likewise, the samplings were carried out in May (9 MAP - early sampling) and July (11 MAP - late sampling) for cassava that were planted in August to signify the rainy season sampling. Plot size of 44.8 cm^2 were marked out with three replications for each sampling plots. Each plot contained 49 cassava plants which were planted at the spacing of 1 m × 0.8 m.

2.4 Determination of soil physical properties

The bulk density was determined using 5 cm x 5 cm soil core to collect undisturbed soil samples (McKenzie *et* al., 2004) and was expressed in g cm^{-3}. Saturated hydraulic conductivity was determined in the laboratory with core samples using the constant head method (Klute, 1986). Three random samplings were taken in each plot for soil temperature measurements with a digital soil thermometer while a digital Delta-T moisture device (Cambridge, UK) was used to measure the volumetric water content. Infiltration measurements were determined with double ring infiltrometer (Klute 1986) with the diameters of 15 cm and 35 cm for inner and outer ring respectively. Soil total porosity was calculated from bulk density and the approximate of particle density value (2.65 g cm^{-3}), expressed in percentage as;

$$Tp=1-\frac{Bd}{Pd} \qquad (1)$$

Tp = Total porosity, Bd = Bulk density (g cm^{-3}) and Pd = Soil particle density (2.65 g cm-3)

2.5 Statistical analysis

Data were subjected to statistical analysis in the Rstudio environment using the lme4 package (R Core Team, 2021). For the linear mixed model, location of study and season were used a fixed factors while the replications were used as random factors. The normality of the data was confirmed using Shapiro-Wilk test before the statistical analysis and log transformed where necessary. The plots were generated using ggplot2 package.

3.0 Results

3.1 Effects of seasonal variation and soil texture on soil bulk density

The bulk density was significantly affected by seasonal variation while bulk density was not statistically affected by soil texture (Table 2). On the seasonal effect, the bulk density under the rainy season was higher than in the dry season with means of 1.44 g cm^{-3} and 1.35 g cm^{-3} for SCL and 1.33 g cm^{-3} and 1.38 g cm^{-3} for LS, respectively (Figure 2). For SCL texture, the bulk density significantly increased from early to late sampling period with increase from 1.27 g cm^{-3} to 1.43 g cm^{-3} and 1.31 g cm^{-3} to 1.56 g cm^{-3} for dry and rainy seasons, respectively. The trend of increase in the soil bulk density for SCL was similar to that at SL, with increase of 6.2% and 3.7%, although not statistically different.

Table 2 Main effects of seasonal variation and soil texture on soil physical properties

	Bulk density (g cm^3)	**Total porosity (%)**	**Ks (cm hr^{-1})**	**SMC (cm^3 cm^{-3})**	**Temp (°C)**	**IC (cm)**	**IR (cm min^{-1})**
Season							
Dry	1.34	49.40	28.24	9.76	30.01	46.77	8.78
Rainy	1.41	46.84	15.47	14.95	25.30	33.99	4.39
LSD ($p<0.05$)	0.07	2.79	3.77	1.65	1.10	10.65	2.46
Location							
FUNAAB	1.40	47.32	18.66	14.25	27.40	35.73	5.15
PSALTRY	1.35	48.92	25.06	10.45	27.91	45.04	8.02
LSD ($p<0.05$)	NS	NS	3.77	1.65	NS	NS	2.46

Ks - Saturated hydraulic conductivity; SMC – Soil moisture content; Temp. – Temperature; IC - Cumulative infiltration; IR – Infiltration rate.

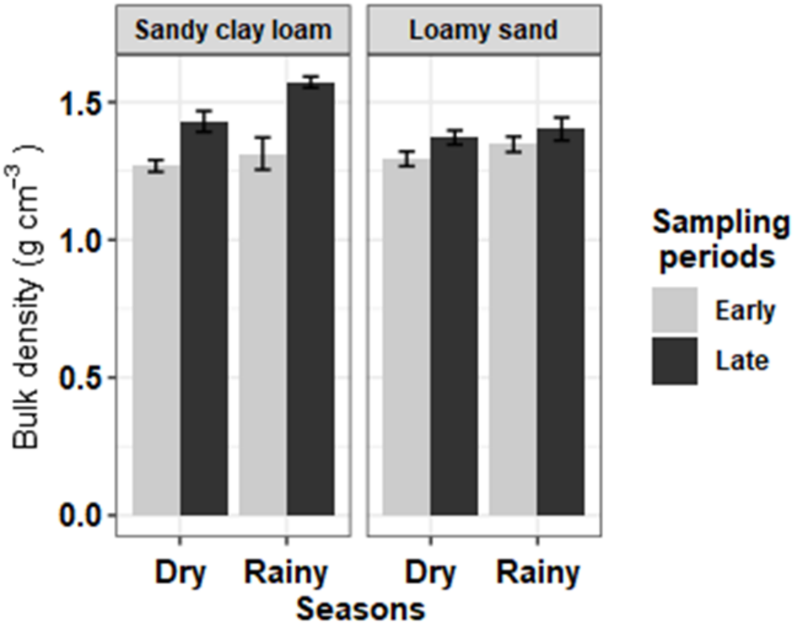


Figure 2: Changes in seasonal variation and soil texture on soil bulk density

3.2 *Effects of seasonal variation and soil texture on soil total porosity*

As expected, the bulk density measurement inversely relates with the total porosity (TP). Total porosity was significantly affected by seasonal variation with higher TP in the dry season than the rainy season (Table 2). The total porosity was significantly higher at early sampling than late sampling for SCL texture. The higher total porosity at early sampling was also observed for LS texture at both seasons, although not statistically different (Fig. 3).

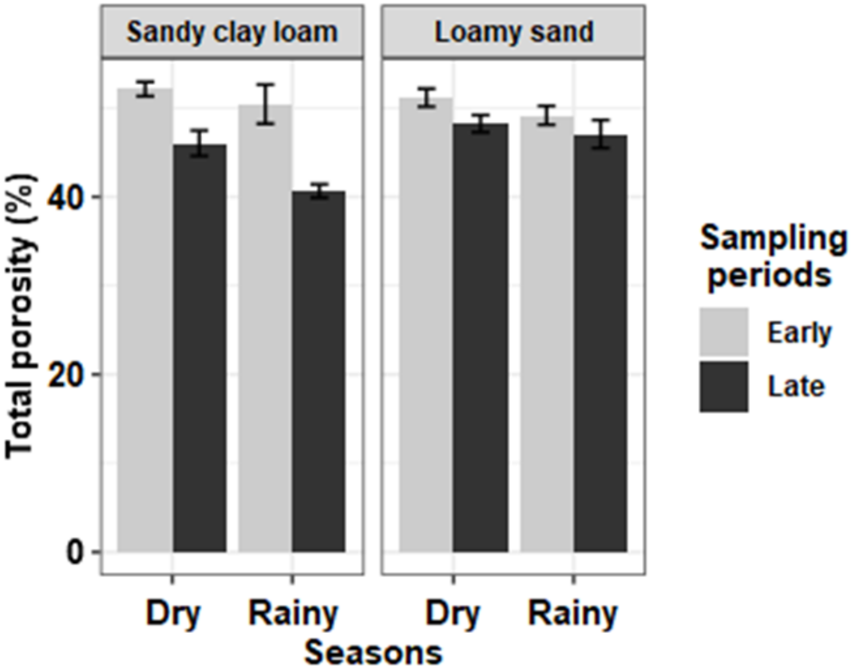


Figure 3: Changes in seasonal variation and soil texture on soil total porosity

3.3 *Effects of seasonal variation and soil texture on saturated hydraulic conductivity*

The saturated hydraulic conductivity (Ks) was significantly affected by seasonal variation and textural class (Table 2) with about 82.6% increase during dry season than rainy season and 34.2%increase under LS than SCL (Table 2). The Ks was significantly higher during the rainy season than dry season for both textural classes with percentage increase of 67.0% and 95.3% for SCL and LS, respectively (Figure 4). During the dry season, LS (33.14 cm hr^{-1}) had significantly higher Ks than SCL (23.35 cm hr^{-1}). For rainy season, the Ks for LS was also higher than SCL, although not statistically significant. Generally, higher Ks was observed at early sampling period than late sampling period (Figure 4).

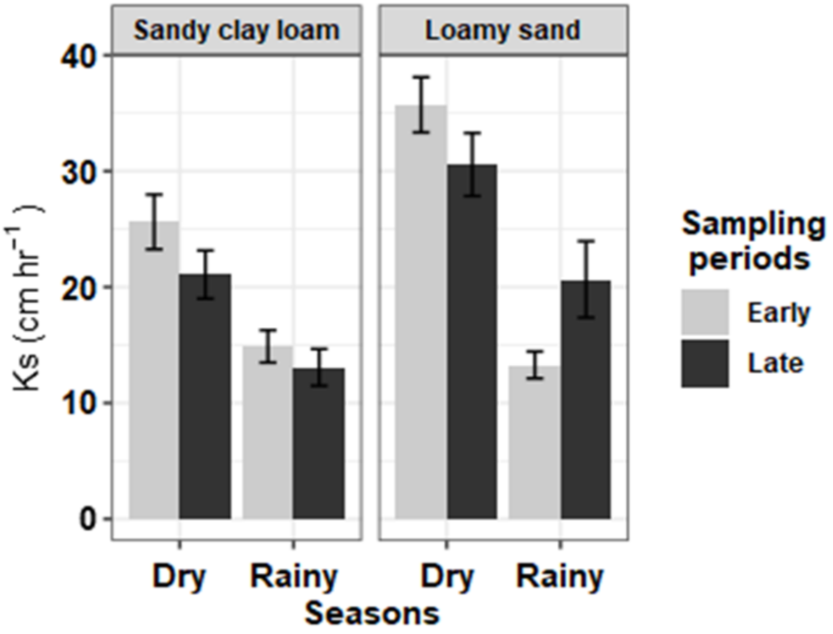


Figure 4: Changes in seasonal variation and soil texture on saturated hydraulic conductivity

3.4 Effects of seasonal variation and soil texture on soil moisture content

The seasonal variation and soil textural class of the study areas had significant effect on the soil moisture content (SMC) (Table 2). The SMC was higher for SCL than LS at both season with 20.6% and 30% increase during the dry season and rainy season, respectively (Figure 5). The soil moisture was significantly higher ($P<0.05$) during the rainy season with means of 17.8 cm^3 cm^{-3} and 12.1 cm^3 cm^{-3} for SCL and LS, respectively, than during the dry season (10.7 cm^3 cm^{-3} and 8.9 cm^3 cm^{-3} for SCL and LS, respectively). During the dry season for both textural classes, the soil moisture content was higher at early sampling than late sampling while SMC was higher at late sampling than early sampling during the rainy season (Figure 5).

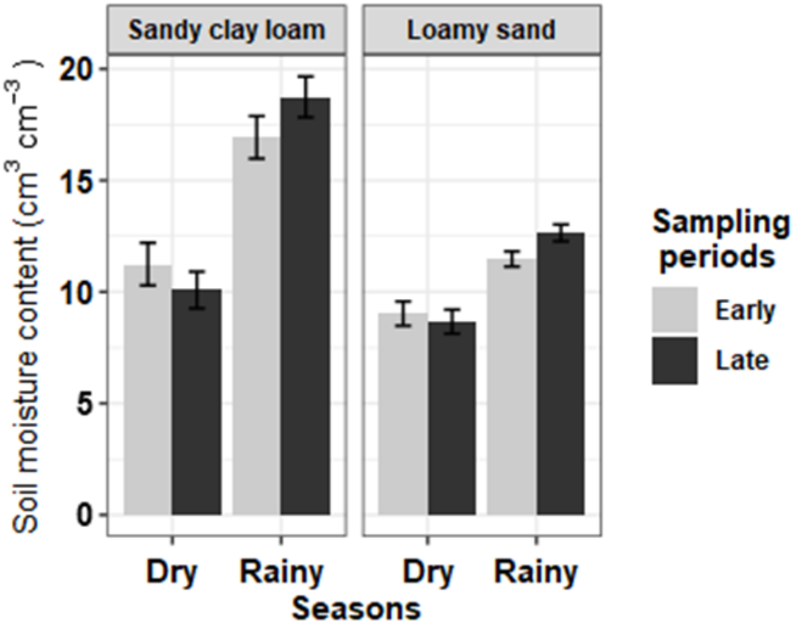


Figure 5: Changes in seasonal variation and soil texture on soil moisture content

3.5 Effects of seasonal variation and soil texture on soil temperature

The soil temperature was significantly higher during the dry season than the rainy season but there was no statistical significance of the effect of location on soil temperature (Table 2). For both textural class, the soil temperature was higher at late sampling than early sampling during the dry season but the inverse was the case during the rainy season (Figure 6). During the dry season, higher soil temperature was observed for LS than SCL with means of 31.04 °C and 28.97 °C, respectively. The temperature variation during the dry season follows the trend of rainy season, however, not statistically different. Higher soil temperature was obtained during the late sampling than early sampling for both textural classes.

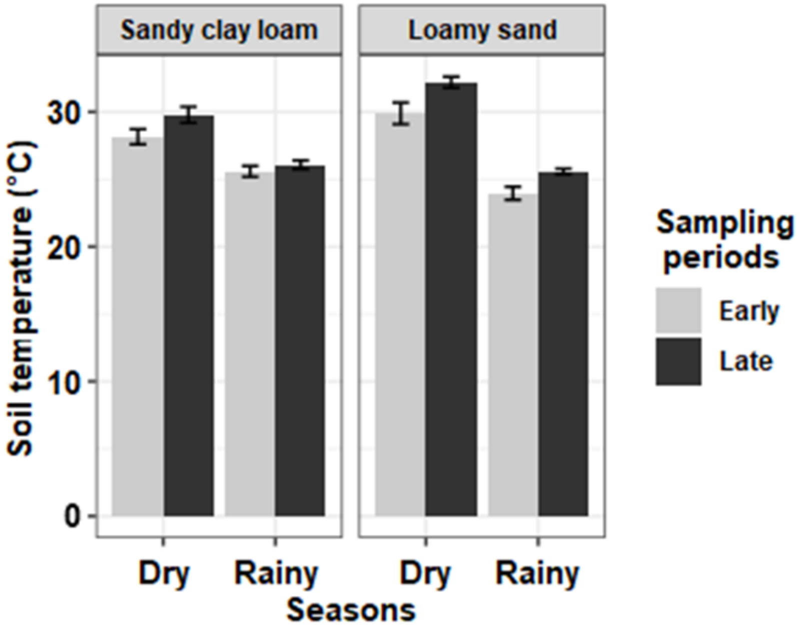


Figure 6: Changes in seasonal variation and soil texture on soil temperature

3.6 Effects of seasonal variation and soil texture on cumulative infiltration

The seasonal variation had significant effect on cumulative infiltration (IC) with about 27% increase in the dry season than rainy season and effect of soil texture was not statistical difference on IC (Table 2). For both soil textures, higher IC was observed at the late sampling periods during the dry season (Figure 7). Contrary to the dry season, late sampling led to decrease in cumulative infiltration by 12.3% and 15.7% for SCL and LS, respectively. The mean cumulative infiltration during the dry season was 29.1% and 35.9% higher than during the rainy season for SCL and LS texture, respectively. LS had significantly higher cumulative infiltration than SCL which was 23.8% and 29.2% higher during the dry and rainy seasons, respectively.

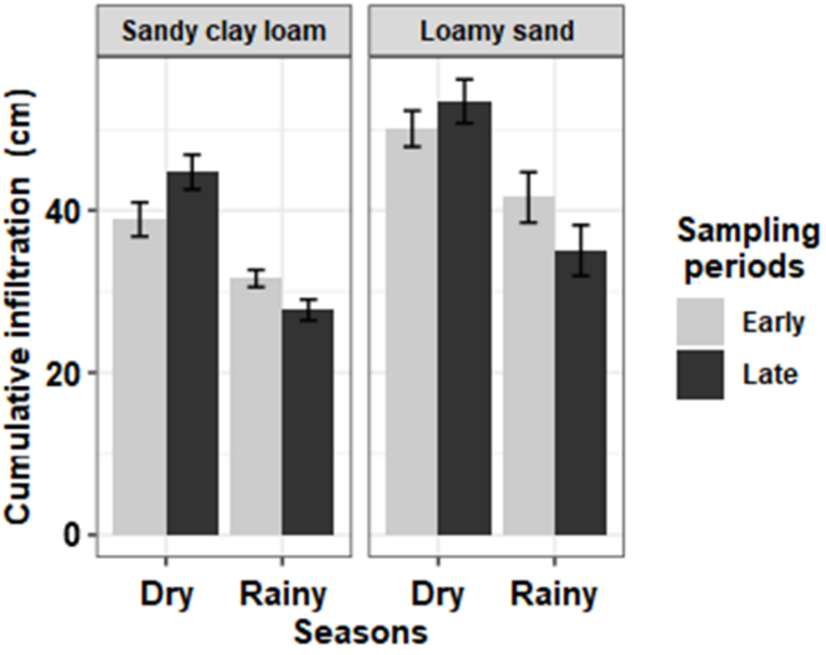


Figure 7: Changes in seasonal variation and soil texture on cumulative infiltration

3.7 Effects of seasonal variation and soil texture on infiltration rate

Infiltration rate (IR) was doubled during the dry season than rainy season (Table 2). LS had significantly higher IR than SCL with mean difference of 2.88 cm min^{-1} (Table 2). The IR value was significantly higher during the dry season than during the rainy season with mean increase of 50% and 49.44% for SCL and LS textures, respectively (Figure 8). During the dry season, the infiltration rate was higher at late sampling period than early sampling whereas during the rainy season, the infiltration rate was higher at early sampling than late sampling but not statistically different.

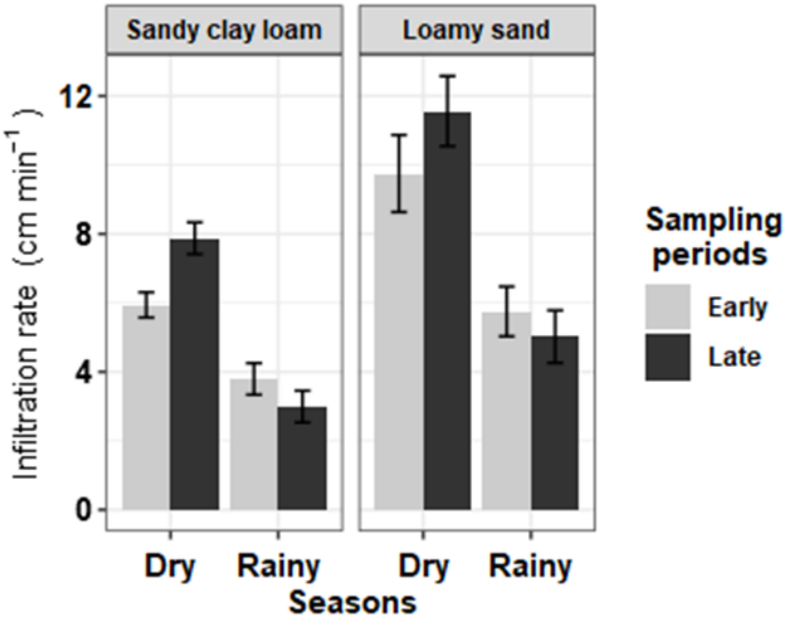


Figure 8: Changes in seasonal variation and sol texture on infiltration rate

4.0 Discussion

The observed changes in soil physical properties with season and time of measurement at both locations may be attributed to the temporal changes in soil properties usually caused by management practices, biological activities, rainfall, soil consolidation, wetting and drying processes, and initial soil moisture (Ciollaro and Lamaddalena, 1998; Bormann and Klaassen, 2008; Hu et al., 2009).

The decrease in the soil bulk density and increase in total porosity at early sampling periods for both soil textural classes could be attributed to early measurement of soil samples. Delayed harvesting at late sampling period may result in further compaction due to the influence of rainfall and particle resettlements. Results similar to this have been reported by Osunbitan et al. (2005) and Fohrer et al. (1999). The higher bulk density in the rainy season than dry season agreed with the findings of Agim et al. (2012) and Achmad et al. (2003). The high rainfall during the rainy season could have led to the breakage large soil aggregates, resettlement of soil particles and caused the clogging of soil pore **(**Assouline, 2004**)**, thereby, leading to the increase in compaction of soil surface. More so during the rainy season, there is usually slow accumulation of organic materials which may contribute to increased soil bulk density (Agim et al., 2012). Moreover, the mean values of bulk density obtained from this study falls within the range that will not affect crop growth and development (Landon, 1991).

Dirmeyer (2000) found that soil moisture has a positive relationship with precipitation patterns. The high moisture will create a cooling effect to the soil, thereby, reducing the soil temperature during the rainy season. Conversely, during the dry season, there was little or no rainfall with corresponding increase in temperature. Soil texture and structure are major determinant in the pore size distribution, which also affects the storage and distribution of soil water storage (Childs, 1940; O'Geen, 2013). The presence of higher clay content for SCL texture compared to the prominent granular sandy particles for LS texture, could be attributed to the variation in water storage. Predominantly coarse textured soil like LS are majorly composed of large pores with higher drainage capacity compared with SCL, which have higher distribution of meso-pores and micro-pores with higher ability to retain water. An increase in temperature from direct solar radiation has been identified to raise soil temperature, especially at the soil surface (Kidron and Kronenfeld, 2015). This is accompanied with increase in evapotranspiration rate, which could account for the lower soil moisture content during the dry season than during the rainy season (Sonko et al., 2016). During the dry season, vegetative biomass of plants are usually reduced as mechanism to adapt to the moisture stress (Yang et al., 2021). This process exposes the soil surface to direct sun light and invariably increase soil temperature and evaporation.

The changes in hydraulic and infiltration processes with seasonal variation could be attributed to the differences in the antecedent soil water content. The antecedent soil moisture content affects the pressure potential difference between the soil matrix and the water entering into the soil matrix (Greve et al., 2010). The lower soil moisture content during dry season (lower antecedent soil moisture) increases the matrix gradient, thus leading to fast movement of water into the soil. The result from this study is supported by the findings of Lili et al. (2008). Also, during dry periods, some clayey soil may shrink and in the process lead to cracks on soil surfaces which may influence the rate of water flow into the soil (Greco, 2002). Water movement on the soil is also influenced by texture (Gregory et al., 2006; Patle et al., 2019). The high volume of inter-related micropores in clay-rich soils create a more tortuous flow path, which slow water flow (O'Geen, 2013). Whereas, high sand textured soils having more macro pores and low tortuosity is characterized with high flow of saturated hydraulic conductivity and infiltration process. Clay loam texture is categorized to have slow permeability class while a loamy sand texture, obtained at PSALTRY has rapid permeability. The higher bulk density obtained on the soil surface layer for SCL texture could have influenced the infiltration process. Cerda (1997) attributed higher bulk density of agricultural soils to the presence of crust which will lead to a reduced infiltration rate and cumulative infiltration. Marshall et al. (1999) also found a negative relationship between bulk density and infiltration.

5.0 Conclusion

Seasonal and textural variation were evident on soil physical properties. The soil bulk density was higher during the rainy season, with higher values for sandy clay loam than loamy sand texture. Nevertheless, the bulk density obtained from this study falls below critical densities for root growth. At both textural classes, the soil moisture storage was higher while soil temperature was lower during the rainy season. In dry season, saturated hydraulic conductivity and infiltration parameters were observed to be higher than during rainy season, likely due to the low antecedent moisture content. The higher soil infiltration parameter in sand texture dominant location could ascertain the influence of textural class on soil properties.

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