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EFFECT OF SLOPE ASPECT AND POSITION ON SOIL INFILTRABILITY IN AN ULTISOL IN AKWA IBOM STATE, SOUTHERN NIGERIA

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ABSTRACT

Soil infiltrability is an important hydrological process that enhances soil water storage and the minimization of runoff. A study was conducted to evaluate the effect of slope aspect (north, NfS and south, SfS) and positions [(crest (CR), upper (US), middle (MS) and lower (LS)] on soil infiltrability, that is, initial infiltration rate (i_o), steady-state infiltration rate (i_c) and cumulative infiltration (I), and sorptivity (S) and transmissivity (A) on the University of Uyo Teaching and Research Farm (T&SF) located on an Ultisol in Akwa Ibom State, southern Nigeria. Results show that the initial infiltration rate (i_o) was 43.20 cm h^{-1} on SfS and significantly ($p < 0.05$) higher than 36.60 cm h^{-1} on NfS. The final infiltration rate (i_c) was not significantly different between NfS (9.60 cm h^{-1}) and SfS (7.20 cm h^{-1}). The Cumulative depth of water (I) infiltrated was similar between NfS (28.18 cm) and SfS (21.46 cm). Soil water sorptivity (S) was moderately high on the two slopes but significantly ($p < 0.05$) lower in NfS (0.49 cm $min^{-1/2}$) than in SfS (0.70 cm $min^{-1/2}$) soil. Soil water transmissivity (A) was similar in NfS (0.19 cm h^{-1}) and SfS (0.16 cm h^{-1}) soil. The results indicate that the aspects were similar in i_o, i_c, I, S and A. However, since soil texture is similar among the aspects, similar soil management practices, example tillage and mulching, could be adopted to enhance water infiltration to improve i_c for increases in soil water conservation and crop production on the T&SF.

Key words: slope aspect and position, soil infiltrability, sorptivity and transmissivity, soil water management

INTRODUCTION

Soil infiltrability is an important hydrological process in the vadose zone, the unsaturated zone of soils (Lal and Shukla, 2005; Shukla, 2014). It is related to the timing and amount of runoff during a rainstorm, root zone water storage and groundwater recharge (Pla, 2007), the entrainment of passenger chemicals (nutrients and pollutants) dissolved in it, and soil erosion and sustainable food production (Moore *et al.,* 1981; Shukla, 2011). Quantification of infiltration is necessary to determine the availability of water to crops and to estimate the amount of additional water needed for irrigation, evaluating the surface and groundwater resources, determining the needed irrigation parameters (Li *et al.*, 2009), and for identifying water conservation strategies and runoff and erosion control practices (Shukla *et al.,* 2003). It is for these reasons that infiltration has been the research focus over the years (Green and Ampt, 1911; Philip, 1957; Wooding, 1968; Brutsaert, 1977).

The principal parameters of infiltration are soil infiltrability and cumulative infiltration which are related by Equation 1:

$$i = \frac{dI}{dt} \quad (1);$$

where i is the infiltration rate (cm min^{-1}); t is the time (min) with $t = 0$ at the beginning of the infiltration process; I is the cumulative infiltration or equivalent depth of water (cm). The infiltration rate is the flux density of water flowing into the soil per unit time when water at atmospheric pressure is made freely available at the soil surface (Hillel, 1971). The infiltrability approached after a sufficiently large time (Horton, 1940), is a measure of the extent a given soil under specified surface and profile conditions can take in water. The cumulative amount is the time integral of the infiltration rate (Hillel, 1971); its prediction is important in understanding the amount of water entering and its distribution in the soil. Thus, infiltration integrates three independent processes: (i) entry through the soil surface; (ii) storage within the soil, and (iii) transmission through the soil (Dunne and Leopold, 1978) all of which combine to influence soil quality, e.g., its ability for agronomic productivity.

The ability of a soil to accept the influx of water is controlled by soil biophysical interacting forces that create a stable soil structure with enough macropores to rapidly transmit water. Soil infiltrability is a surrogate of many other soil properties which can exert a direct influence on the

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stability of the land surface. That is, soil infiltrability is a reflection of the inherent properties of the soil predominantly soil texture and soil structure which affect pore geometry and organic matter content (Lal and van Doren, 1990; Franzluebbers, 2002), antecedent soil moisture content and matric potential in the vadose zone. Saxton *et al.* (1986) stated that soil texture and structure are the predominant factors affecting water infiltration into soils. For this reason, soil texture and structure are uniquely important in the prediction of infiltration rate and water retention (Philip, 1973; Arya *et al.,* 1999a,b). Thus, factors that adversely affect soil structure and soil texture will as well affect soil water storage and availability to crops.

Land use and soil management primarily change soil structure and alter pore geometry and pore-size distribution and thus soil infiltrability (Lal and Shukla, 2005). Sharma *et al.* (1980) and Tricker (1981) stated that soil management has a more pronounced effect on infiltration than soil type. Soil that is continually disturbed by tillage and other anthropogenic activities often loses its resilience and develops poor structural characteristics, including surface sealing and crusting. This is because intensified land use primarily affects soil's intrinsic and dynamic properties including soil structure and structure-moderated soil properties. The consequence is reduced infiltration and high runoff and erosion. Ogban *et al.* (2000) had reported low values of the infiltration characteristics which indicated potentially high runoff (erosion) hazard, which would adversely affect the water economy of the plant rooting depth. Wuddivira *et al.* (2001) indicated that such soils would have difficulty in meeting the water requirements of crop where water is a limiting factor.

Research has shown that infiltration characteristics were closely related to soil structure and were a good indicator of changes in soil physical and biological properties under different soil use systems (Radke and Berry, 1993). Mukhtar *et al.* (1985) observed that the amount of water entering the soil was determined by the soil surface conditions including the presence of macropores. Mbagwu (1997) related soil bulk density with soil carbon and infiltrability. Davidoff and Selim (1986) reported that the infiltration characteristics of the soils they studied were influenced by residue addition, soil compaction and bulk density. Later, Mukhtar *et al.* (1985) and Radke and Berry (1993) concluded that soil use and management that include soil surface cover would maintain high soil infiltrability by reducing compaction from the impact of rainfall and crusting.

However, soil properties influencing soil water storage, runoff and erosion are significantly influenced by climate (rainfall characteristics), landscape features, including landscape position, topographic features (slope gradient), parent material and vegetation (Beckett and Webster, 1971; Jenny, 1980; Jungerius, 1985; Dunne *et al.*, 1991) and surface conditions (Li *et al.,* 2011). It is common knowledge that topography influences soil characteristics (Ollinger *et al.,* 2002; Yimer *et al.*, 2006) because topography through its slope element drives geomorphic processes (Evans, 1972), and influences the fluxes of materials on and within the soil. However, studies on the effect of slope characteristics on soil surface features and properties have produced contrasting results between south aspects and north aspects (Coble *et al.*, 2001). Geroy *et al.* (2011) reported that north aspect slope tended to be deeper and have greater soil porosity, soil organic matter and silt content than the opposing south aspect slope. Mukhtar *et al.* (1985) observed that the amount of water entering the soil increased proportionately with increased in the amount of macropores in the soil surface layer. Cerdia (1996) found infiltration rate was higher on the upper slope position than the middle slope or lower slope positions in South-east Spain. Guzman and Al-Kaisi (2011) reported that infiltration rates were much greater in the toe-slope than the summit. Gogo (2018) reported that soil infiltrability was significantly higher on the north-facing slope than on the south-facing slope on the coastal plain sands in southern Nigeria. Despite the effect of slope on soil processes, few studies have been conducted in the area on the relationship between soil infiltrability and slope characteristics. This study was conducted to evaluate the effect of slope aspect and position on soil infiltrability in order to guide soil use and water conservation for increases in crop production on the University of Uyo Teaching and Research Farm (T&RF).

MATERIALS AND METHODS

Study Area

The study was conducted on the University of Uyo Teaching and Research Farm (T&SF) at Use Offot, in Akwa Ibom State. The farm is located between latitudes 5° 00´ and 5° 10´and longitudes 7° 50´ and 8° 00´.The farm is bisected by a dry valley between two moderately sloping aspects; a 5% south-facing slope (SfS) and a 6% north-facing slope (NfS).

The climate of the area is the hot humid tropical characterized by distinct wet and dry seasons (Inyang, 1975); the wet or rainy season generally lasts from April to October and the dry season lasts from November to March. The annual average rainfall may be over 3,500 mm with high peak intensities ranging from 60-120 mm h^{-1}. The average annual temperature in the area is about 26°C and the relative humidity is about 70% (Petters *et al.,* 1989). The area is located on the coastal plain sands geological formation with undulating topography and with gradients generally less than 5%. The parent material consists of unconsolidated Coastal Plain Sands and the soils are classified as Ultisol in the USDA Soil Taxonomy system, corresponding to Acrisols or Alisols of the World Reference Base (FAO, 2014). The soils are deep, permeable, characterized by a narrow texture range having loamy sand to sandy loam surface layers over sandy clay loam to sandy clay subsoil, inherently low organic matter content (Ojanuga *et al.*, 1981; Ofomata, 1981; Petters *et al.,* 1989), and low structural stability (Ogban and Ekerette, 2001). A variety of soil-use practices, including forest, bush fallow, and cultivation are common, and soil use is the low input rainfed traditional farming that leaves more than 80% of the surface soil bare and exposed to the high intensity rainfall in the area (Petters *et al.,* 1989; Udosen, 2017).

Field Study

The study was conducted on the 6% NfS and 5% SfS, measured with the global positioning system (GPS).At the time of the study, the middle slope of NfS and crest of SfS were cultivated to cassava and pumpkin intercrop and garden egg, respectively. The crest of NfS was under a thirty-year oil palm plantation. Bare soil surface management is the rule on both slopes, a common practice in the area, subjecting the erodible soil on the slopes to the erosive rainfall. Other slope positions of NfS and SfS were under a two-year natural fallow.

A transect was taken from the crest to the valley bottom of each slope, each of which was then categorized into four slope positions, namely, crest, upper, middle and lower, at 20-m interval. At each slope position, three random soil samples were collected and bulked for the determination of particle-size fractions (PSF) and soil organic carbon (SOC) content. Two undisturbed core samples were also taken at each sampling point for the determination of bulk density (BD) and saturated hydraulic conductivity (Ksat).

Four infiltration runs were carried out at each slope position at intervals of 5 m across each transect, that is, perpendicular to slope, with the double ring infiltrometer (Reynolds *et al.*, 2002) for a cumulative time of two hours. Measured cumulative infiltration was used to compute the infiltration rate (i_o), steady-state infiltration (i_c), and the curve-fitting procedure was used to obtain the soil sorptivity (S), and soil transmissivity (A) from Equation 1.

Laboratory Study

The bulk soil samples were analyzed in the laboratory for PSF (Gee and Or, 2002) and SOC (Sparks, 1996), while the core samples were used for Ksat and BD (Grossman and Reinsch, 2002) from which total pore space (TP) was computed (Flint and Flint, 2002).

Statistical Analysis

The means of the infiltration data were used to plot graphs of the effect of slope aspect and position on the infiltration process. The data were fitted into a split-plot in randomized complete block design and subjected to analysis of variance (ANOVA) at the 5% probability level for quantifying differences in the infiltration parameters among the slope aspects and positions. Also, Pearson's product moment correlation analysis was used to identify the soil properties influencing the infiltration characteristics on the T and SF.

RESULTS AND DISCUSSION

Effect of Slope and Aspect on Infiltration Characteristics

The data of the effect of slope and slope position on soil physical properties are shown in Table 1, and the interaction of these properties with the infiltration characteristics is shown (Tables 3 and 4).

There was no consistent pattern of differences in the effect of slope aspect on the infiltration parameters (Table 2 and Figure 1). In Table 2 and Figures 1(a) NfS and 1(b) SfS, the initial infiltration rate (i_o) was significantly (p < 0.05) higher on SfS (0.72 cm min^{-1} or 43.20 cm h^{-1}) than NfS (0.61 cm min^{-1} or 36.60 cm h^{-1}). Averaged over the slope positions (Figure 3), i_o was about 0.60 cm min^{-1} (36 cm h^{-1}) on SfS and 0.50 cm min^{-1} (30 cm h^{-1}) on NfS. Differences in i_o on both slopes began to manifest at about 50 min from the commencement of the infiltration process. In other words, differences in i_o appeared probably when the absorptive and capillary forces or hydraulic gradient began to diminish shown by the divergence in NfS and SfS. Although the slopes were similar in particle-size fractions (PSF) (Table 1), the higher in SfS soil was attributed to the inherent lower bulk density and significantly higher Ksat and OC than in NfS soil (Table 1). The higher i_o on SfS compared to NfS may also be connected to their relative slope gradients: 5 vs 6%, which indicates longer resident time and thus increases in infiltration on the former than on the latter slope. Compared to rainfall intensity of about 75 mm h^{-1} recorded in the area (Petters *et al.*, 1989; Udosen, 2017), the i_o values are high, indicating that even with continuous cultivation common on the T&SF, the soils could continue to accept and transmit the rainwater for a cumulative time of about 125 min on NfS and SfS under the bare cultivation common on the farm.

The time-dependent infiltration process is generally governed by the Richards (1931) equation subject to the spatially variable physical conditions of the soil near the surface and the vertical soil matric-potential gradient at the onset of the process. Generally, the trend in infiltration rate in this study agreed with theory (Reynolds *et al.,* 2002) because infiltration of water was rapid at the initial stages when the vadose zone was dry, with large suction gradients in both horizontal and vertical components of water flow, but rapidly decreased with time as soil became increasingly wet, i.e., matric potential increased, until it reached a steady state or near constant rate, which was attained at about a cumulative time of 125 min on NfS and SfS, and reflects the fact that steady-state conditions are attained at large times in coarse-textured soils. The decrease in infiltration rate with time may be due to reduction in moisture potential gradient, transient changes in soil structure through aggregate slaking, colloidal dispersion and clogging of the soil pores following tillage (Webster and Wilson, 1980) and repellency (Dekker and Ritsema, 1994). Lal (1986) observed that the infiltration rate of most upland soils declines with cultivation because of the rapid deterioration in soil structure and the susceptibility of these soils to surface crust and seal. In addition, Linsley *et al.* (1975) stated that the decreasing rate of infiltration with time of water application was due to the continuous diversion of gravity water into capillary-pore spaces by capillary forces.

The final infiltration rate (i_c) was similar but higher on NfS (0.16 cm min^{-1} or 9.6 cm h^{-1}) than SfS (0.12 cm min^{-1} or 7.2 cm h^{-1}). Although both slopes attained i_c at about 125 min from the outset of the infiltration process, it decreased faster on SfS than NfS. The i_c, besides the field water capacity, is a critical factor in irrigation management because it indicates the maximum rate of water application which in this study would be higher on NfS than SfS. The values of i_c are quite low compared to the rainfall amount and intensity in the area. The implication is that increases in soil water pressure potential, negates i_c by limiting the capacity of the soil to accept rainwater on the farm. The limiting i_c was also attributed to bare cultivation, especially the plough-harrow practice which allows soil particles to resettle to the state prior to tillage, as well as that it may, over the years, have resulted in the compaction of the lower soil layers which could not be remedied by the transient changes in soil structure and structure-moderated soil properties, e.g., bulk density, pore-size distribution, and hydraulic conductivity in the soil surface zone, following tillage. It also implies that when irrigation is adopted, water application may not exceed 9.6 and 7.2 cm h^{-1} on NfS and SfS, respectively, if soil erosion and degradation are to be avoided or minimized on the farm.

Table 2: Effect of slope aspect and position on infiltration characteristics in the University of Uyo T&RF

Slope position	i_o (cm min^{-1})	i_c (cm min^{-1})	I (cm)	S (cm min$^{-1/2}$)	A (cm min^{-1})
			Slope Aspect		
NfS	0.61	0.16	28.18	0.49	0.19
SfS	0.72	0.12	21.46	0.70	0.16
LSD$_{(0.05)}$	0.10	ns	ns	0.15	ns
			Topographic Position		
CR	0.91	0.22	40.34	0.85	0.30
US	0.63	0.12	20.90	0.53	0.15
MS	0.59	0.11	20.69	0.52	0.15
LS	0.54	0.10	17.35	0.48	0.11
LSD$_{(0.05)}$	0.15	0.07	11.73	0.21	0.07
			Slope Aspect × Position Interaction		
NfS -CR	1.05	0.33	59.38	0.86	0.41
NfS -US	0.53	0.10	18.43	0.42	0.12
NfS -MS	0.38	0.09	15.75	0.25	0.13
NfS -LS	0.50	0.11	19.18	0.43	0.11
SfS-CR	0.78	0.12	21.30	0.84	0.19
SfS-US	0.73	0.13	23.38	0.63	0.17
SfS-MS	0.80	0.14	25.63	0.80	0.17
SfS-LS	0.58	0.09	15.53	0.53	0.10
LSD$_{(0.05)}$	0.21	0.09	16.59	0.29	0.10

NfS - North-facing slope; SfS - South-facing slope; CR - crest; US - upper slope; MS - middle slope; LS - lower slope; i_o - initial infiltration rate; i_c - final infiltration rate; I - cumulative infiltration; S - sorptivity; A - transmissivity; LSD - least significant difference

Table 1: Effect of slope aspect and position on soil physical properties at the University of Uyo T&RF

Slope position	FS	CS	TS	Silt	Clay	BD	TP	Ksat	SOC
			g kg^{-1}			(Mg m^{-3})	(m^3 m^{-3})	(cm h^{-1})	(g kg^{-1})
				Slope Aspect					
NfS	201	663	863	46	91	1.67	0.37	2.94	11.76
SfS	201	667	877	41	82	1.54	0.58	8.84	19.52
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	Ns	ns	ns	0.24
						Slope Position			
CR	205	659	864	45	91	1.58	0.41	4.75	12.82
US	180	691	883	39	78	1.64	0.45	9.07	14.94
MS	210	661	871	43	86	1.54	0.43	6.88	15.84
LS	209	648	861	46	93	1.66	0.41	2.87	18.95
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns	0.03	5.75	0.34
						Slope Aspect × Slope position			
NfS-CR	205	650	855	49	97	1.54	0.42	5.10	9.12
NfS-US	165	720	885	39	77	1.80	0.45	3.15	10.08
NfS-MS	225	621	846	52	103	1.58	0.41	1.11	11.71
NfS-LS	208	661	868	44	88	1.75	0.40	2.40	16.14
SfS-CR	205	669	874	42	84	1.61	0.40	4.39	16.51
SfS-US	195	662	882	40	79	1.48	0.45	15.00	19.80
SfS-MS	195	702	897	35	69	1.50	0.45	12.64	19.98
SfS-LS	210	636	854	49	97	1.57	0.41	3.33	21.77
LSD $_{(0.05)}$	ns	ns	ns	ns	ns	ns	ns	ns	Ns

NfS - North-facing slope; SfS - South-facing slope; CR - crest; US - upper slope; MS - middle slope; LS - lower slope; FS - fine sand; CF - coarse sand; TS - total sand; BD - bulk density;TP - total porosity; Ksat - saturated hydraulic conductivity; SOC – soil organic carbon; LSD - least significant difference

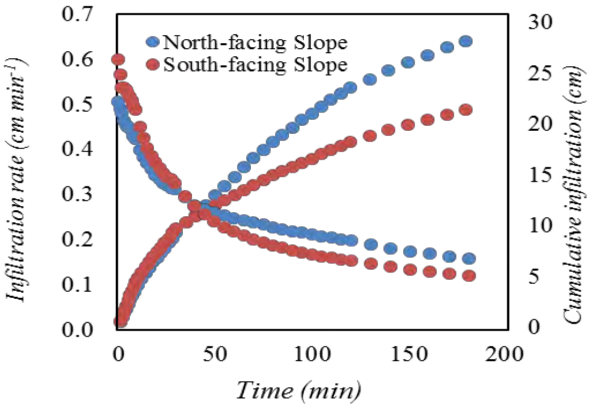

Figure 1: Effect of slope on infiltration rate and cumulative infiltration: north-facing slope (NfS) and (b) south-facing slope (SfS) at the University of Uyo T&RF.

The cumulative depth of water (*I*) infiltrated after a cumulative time of 180 min. was statistically similar but higher on NfS than SfS (Table 2 and Figure 1), and has a curvilinear time-dependence, with a gradually decreasing slope. From the outset of the infiltration process up to a cumulative time of 50 min (Figure 1), *I* was similar between NfS and SfS but thereafter diverged and became increasingly curvilinear. At a cumulative time of 50 min, both i_o and *I* appeared similar on both slopes and indicated a linear relationship between i_o and *I*, that is, the soil would absorb rain or irrigation water in spite of their differences in soil properties. The cumulative time of 50 min. corresponded to the point of sharp decline in i_o, probably due to aggregate slaking and sealing of pores and differences in subsoil profile characteristics influencing water transmission. The observed values of *I* are low for the deeply permeable coarse-textured soils and indicate limiting plant available water holding capacity and ease of runoff which may adversely affect the water economy of the plant rooting depth (Wuddivira *et al*., 2001) and crop production on the T&SF. Soil management practices such as mulch-tillage which will protect the surface and allow infiltration are needed on the farm.

Soil water sorptivity (*S*) was moderately high on the two slopes but about 43% significantly ($p < 0.05$) lower in NfS than SfS soil (Table 2), and appeared to correlate with the lower bulk density and higher Ksat and SOC in SfS than in NfS soil. Sorptivity is a field-saturated water flow parameter, a measure of the ability of the soil to absorb water in the early stages of infiltration regulated by capillarity and surface tension forces (Philip, 1957) or a high vertical gradient in soil matric potential. Thus, sorptivity is a resistance factor that governs the early-stage infiltration (Bonsu, 1993; Stewart *et al.*, 2013), and is related to i_o and the potential for overland flow. The high S, relative to i_o, is therefore due to the dominance of capillary forces within the soil. However, both *S* and i_o, can be limited by the intensity of rainfall or rate of water supply to the field and the nature of the soil surface.

The fitted transmissivity, *A*, was similar in NfS and SfS soil but greater in the former than the latter (Table 2).Transmissivity, *A*, is a hydraulic property that is sensitive and related to changes in soil texture which in this study, becomes finer downslope (Table 1); soil texture also determines whether water transmission is capillarity- or gravity-driven (Reynolds *et al.*, 2002). The lower values of *A* compared with *S* generally, indicated that soil texture facilitated capillarity-driven transmission and that it dominated water transmission in the soil profile. Transmissivity, *A* is related to Ksat both of which are critical to soil's internal drainage. *A* often approaches Ksat at the later stages of infiltration, i.e., when $t \gg S^2/A^2$ (White *et al.,* 1992). However, from the data in Tables 1 and 2, a definite relationship could not be established between *A* and Ksat. With the average rainfall intensity of ca. 75 mm h^{-1} recorded in the area and that can occur within a 15-min. duration (Petters *et al.*, 1989; Udosen, 2017), rainfall rate always exceeds infiltration rate as it declines from high to low values over the cumulative time-period, affecting accumulative infiltration, transmission and storage, and may explain the low *A* recorded in the study.

Effect of Slope Position on Infiltration Characteristics of the Soils

The effect of slope position on i_o averaged over NfS and SfS is shown in Table 2 and the effect on each slope is shown in Figure 2 (a) NfS and (b) SfS). In Table 2, i_o was significantly higher on the crest (CR) and decreases down the other slope positions (US, MS and LS); US, MS and LS were similar in their effects on i_o but the pattern was US > MS > LS. In Figure 2 (a) NfS and (b) SfS), i_o was significantly higher on CR and similar among other slope positions of NfS and all slope positions of SfS. The generally higher i_o at CR irrespective of aspect was attributed to the fact that most crest landscape have flat to rolling nature that enhances infiltration than the lower members of the slope. The higher value of i_o at CR of NfS was due to the oil palm forest with the associated root effect on soil porosity and water infiltration.

The depth of water infiltrated was significantly ($p < 0.05$) higher at CR than at all other slope positions of NfS and SfS; *I* was similar among the latter slope positions (Table 2). In Figure 3(a), *I* was significantly ($p < 0.05$) higher on CR than US, MS and LS, but there were no differences among the slope positions in Figure 3(b). The trend in *I* among the slope positions was CR >> US > MS > LS. The lower cumulative infiltration observed downslope may indicate low capacity of the soil to hold water despite the higher clay content and organic carbon. Soil water sorptivity, *S*, was also significantly ($p < 0.05$) higher at CR than the other slope positions of NfS and SfS; differences among UP, MS and LS slope positions were not significant (Table 2). This indicates that much of rain water would infiltrate aided by absorptive and capillary forces into the soil, provided that the intake rate which averages 0.91 cm min^{-1}, is not exceeded by the

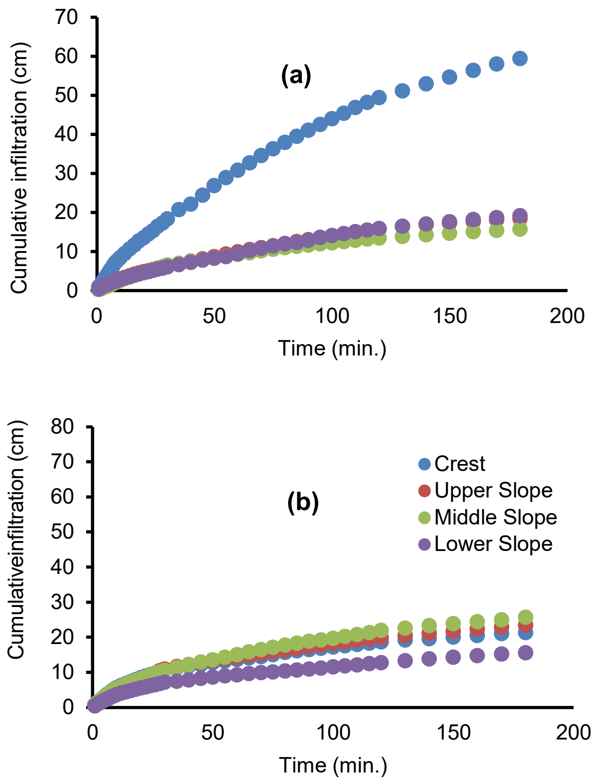

Figure 2: Effect of slope position on cumulative infiltration: (a) North-facing (NfS) and (b) South-facing slope (SfS) at the University of Uyo T&RF.

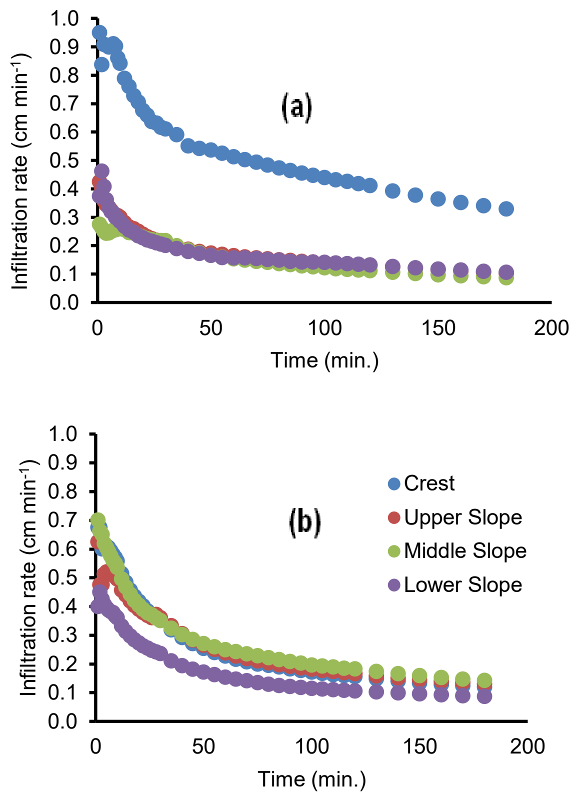

Figure 3: Effect of slope position on infiltration rate on: (a) North-facing slope (NfS) and (b) South-facing slope (SfS) at the University of Uyo T&RF

rainwater supply rate. The *S* also decreases downslope in both NfS and SfS. Also, soil water transmissivity, *A* was significantly ($p < 0.05$) higher at CR than UP, MS and LS slope positions, and exhibited a decreasing trend downslope (Table 2). Further, the observed effects appeared to be slope-specific.

Interaction Effects of Slope Aspect and Position on Infiltration Characteristics

The interaction effect of slope aspect and position on i_o was erratic, i.e., it decreases and increases down slope but significantly ($p < 0.05$) higher at CR than UP, MS and LS of NfS, and significantly ($p < 0.05$) higher at MS than LS of SfS. A similar trend was observed in i_c, *I*, *S* and *A* and that the interactions were slope-specific.

Interaction between Infiltration Characteristics and Soil Properties

The relationships between infiltration characteristics and soil properties were generally poor or lacking (Tables 3 and 4). In Table 3 (NfS) i_o and A were negatively ($p < 0.05$) related to SOC indicating that the latter is not critical to rainwater acceptance and transmission in the NfS soil. This observation suggests that increases in SOC adversely influence the surface and intrinsic structure of the coarse-textured soil under investigation (Ezenne ***et al.***, 2019). In Table 4 (SfS), *S* was significantly ($p < 0.05$) positively related to TS and negatively related to silt and clay which implies that the infiltration process is governed by the coarse fragments on this slope. The *S* is dependent on the suction gradient at the initial stages of the infiltration process, which was probably facilitated in coarse-textured soils. Thus, the relationship of infiltration and the two terms of the Philip equation and soil properties was different on the north and south slopes of the T&RF. However, to facilitate infiltration and soil water storage, tillage to loosen the soil and surface cover of mulch to conserve the soil would be needed to improve soil physical quality and productivity for crop production on the farm.

CONCLUSION

The results of the study show that both NfS and SfS were loamy sand-textured and had a narrow texture range. There was no consistent pattern of differences in the effect of slope aspect and position on the infiltration parameters. However, the initial infiltration rate (i_o) was significantly higher on SfS than NfS, while final infiltration rate (i_c) and cumulative depth of water (*I*) infiltrated were statistically similar between the slopes but higher on NfS than SfS. Soil water sorptivity (*S*) significantly lower in NfS than SfS soil, soil water transmissivity (*A*) was similar in NfS and SfS soil. Although there were statistical significant effects of slope and slope positions on infiltration characteristics, soil surface management practices with tillage and mulch could be applied to enhance water infiltration into the soil for increases in soil water storage and crop production on the T&SF.

Table 3: Correlations matrixof infiltration characteristics and soil physical properties on NfS on the University of Uyo T&RF

	i_o	i_f	I	S	A	FS	CS	TS	Silt	Clay	B.D	TP	Ksat	SOC
i_o	1.000													
i_f	0.783**	1.000												
I	0.783**	1.000**	1.000											
S	0.879**	0.543*	0.543*	1.000										
A	0.796**	0.979**	0.979**	0.579*	1.000									
FS	-0.115	-0.281	-0.281	0.015	-0.201	1.000								
CS	0.177	0.160	0.160	0.164	0.119	-0.754**	1.000							
TS	0.018	-0.179	-0.179	0.182	-0.122	-0.191	0.680**	1.000						
Silt	-0.018	0.179	0.179	-0.182	0.122	0.191	-0.680**	-1.000**	1.000					
Clay	-0.018	0.179	0.179	-0.182	0.122	0.191	-0.680**	-1.000**	1.000**	1.000				
B.D	0.023	-0.089	-0.089	-0.098	-0.141	0.061	0.061	0.056	-0.056	-0.056	1.000			
TP	-0.014	-0.050	-0.050	-0.030	-0.096	-0.725**	0.770**	0.522*	-0.522*	-0.522*	-0.063	1.000		
Ksat	0.057	-0.129	-0.129	0.090	-0.103	-0.495	0.723**	0.624**	-0.624**	-0.624**	-0.271	0.830**	1.000	
SOC	-0.594*	-0.490	-0.490	-0.335	-0.582*	-0.002	-0.018	-0.135	0.135	0.135	-0.083	0.013	-0.090	1.000

i_o- initial infiltration rate; i_f- final infiltration rate; I - cumulative infiltration; S - sorptivity; A - transmissivity; FS - fine sand; CS - coarse sand; TS - total sand; BD - bulk density; TP - total porosity; Ksat - saturated hydraulic conductivity; SOC – soil organic carbon

Table 4: Correlations matrix of infiltration characteristics and soil physical properties on SfS on the University of Uyo T&RF

	i_o	i_f	I	S	A	FS	CS	TS	Silt	Clay	BD	TP	Ksat	SOC
i_o	1.000													
i_f	0.840**	1.000												
I	0.840**	1.000**	1.000											
S	0.731**	0.403	0.403	1.000										
A	0.837**	0.777**	0.777**	0.538*	1.000									
FS	-0.028	-0.099	-0.099	0.030	-0.020	1.000								
CS	0.300	0.074	0.074	0.409	0.054	-0.611*	1.000							
TS	0.346	0.073	0.073	0.526*	0.143	-0.256	0.765**	1.000						
Silt	-0.346	-0.073	-0.073	-0.526*	-0.143	0.256	-0.765**	-1.000**	1.000					
Clay	-0.346	-0.073	-0.073	-0.526*	-0.143	0.256	-0.765**	-1.000**	1.000**	1.000				
BD	-0.057	-0.132	-0.132	-0.011	-0.029	0.578*	-0.415	-0.459	0.459	0.459	1.000			
TP	0.041	0.053	0.053	0.050	-0.035	-0.607*	0.440	0.432	-0.432	-0.432	-0.973**	1.000		
Ksat	0.236	0.113	0.113	0.212	0.000	-0.483	0.446	0.420	-0.420	-0.420	-0.791**	0.855**	1.000	
SOC	-0.142	-0.049	-0.049	-0.102	-0.369	-0.384	0.397	0.081	-0.081	-0.081	-0.461	0.479	0.472	1.000

Abbreviations same as in Table 3

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