

Topsoil removal and cultivation effects on structural and hydraulic properties

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ABSTRACT

Topsoil removal and intensive cultivation of fragile sandy loam soil may reduce water movement into and within the soil and decrease available water capacity. The purpose of this study was to determine if topsoil removal (SSR) and 10-year cultivation have adverse effects on the structural and soil water retention properties. The study was conducted on a fine sandy loam soil in humid tropical coastal plain soils in southern Nigeria. We measured particle size, soil organic matter, pore size through water desorption analysis and infiltration and related water retention properties. Results showed that topsoil removal and cultivation resulted in significant reduction in infiltration, saturated hydraulic conductivity and available water contents and increased the bulk density. Topsoil removal increased fine particle-size fractions and created a shift in pore size distribution to a greater micro porosity. Soil water storage in terms of useful available water (UAW) and easily available water (EAW) were significantly low ($p < 0.05$) in SSR, reaching 62% reduction. Top soil removal and cultivation resulted in 67% and 32% decreased OM respectively. Loss of OM leading to low water retention at 10 kPa and 1500 kPa indicates a high risk of water stress and quicker soil drying even after heavy rainfall. Loss of organic matter and silt + clay fraction were the major drivers of changes in UAW and EAW in SSR soils. The results of this study confirmed that many structural and water retention characteristics are altered by cultivation and topsoil removal, and are useful in defining the physical quality response indices of fine sandy loam soils.

1. Introduction

The soil surface state regarding to water movement away and into the soil mass may affect its evaporation, infiltration and distribution. Compaction, topsoil removal and cultivation may alter the soil surface properties, through changes in structural and water retention properties of the topsoil layer (Kargas et al., 2012). Such changes depend on the soil type and structure, amount of organic matter removed, the extent of topsoil removal, and antecedent water holding capacity of the soil (Azzoz and Arshad, 2001; Kargas et al., 2012). In fine-textured soils, topsoil removal may lead to development of surface crusts due to direct impact of raindrop on the unprotected soil surface and decreasing infiltration of water into the soil profile (Houlbrooke and Laurenson, 2013). In coarse-textured soils, high incidence of soil and nutrient losses has been reported in continuous cultivated soils (Lal, 1990). Increase in the risk of floods and droughts due to adverse influence of topsoil removal on rainfall acceptance and infiltration capacity of soil have also been reported (Shu et al., 2015). A few other effects include changes in pore size distribution induced from breaking down the exposed surfaces of micro aggregates and dispersed clays leading to

increased risk of floods and drought (Lal, 1990; Woodland, 1996).

Soil organic matter (SOM) depletion following topsoil removal and cultivation is one of the critical problems in most soils of the world, because, SOM is an excellent indicator of surface soil quality and contributes to improved soil air diffusion, infiltration, water holding capacity and aggregate stability (Blanco-Canqui and Lal, 2008; Smith et al., 2013; Li et al., 2016). In high rainfall areas such as in the Niger Delta in Nigeria, topsoil removal has been found to increase soil penetration resistance (Udom and Adesodun, 2016). Faster soil warming and quicker soil drying after heavy rainfall have also been noticed in fine sandy soils due to topsoil removal, compaction and cultivation, which according to Smith et al. (2000) occur especially in the top 0–15 cm of the soil profile.

In assessing topsoil removal and cultivation effects on soil water-retention properties, information on infiltration and soil water retention characteristics (SWRC) is needed. This information permits quantification of effective pore-size distribution viz.: air-filled porosity (AFP), useful available water (UAW) and easily available water (EAW) (Cassel and Nielsen, 1986; Wall and Heiskanen, 2003) and its contribution to physical quality of the topsoil. Such quantification

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assessment is useful for developing long-term and process-based strategies to improve and maintain the structural and hydraulic properties of the topsoil. This quantification assessment would help farmers and land users to manage and/or improve critical soil quality functions such as bulk density, water stable aggregates, and hydraulic conductivity.

Woodland (1996) reported increased in bulk density and micro-porosity due to soil compaction in the Amazonian Ecuador. There are also indications that topsoil removal could impact negatively on water availability and drought stress functions, such as UAW, EAW and field capacity (Wall and Heiskanen, 2003). Cultivation of agricultural land, including tillage and use of machinery, alters the air-filled porosity and related properties of soils, similar to topsoil removal by bulldozer (Whalley et al., 2012; Udom and Ogunwole, 2015), leading to adverse impact on soil ecological services and functions, especially in high rainfall areas. However, these impacts have not been properly addressed in some tropical soils which have exposed ironstone through topsoil removal. The objective of this study was to determine the effects of topsoil removal and long-term cultivation on surface soil structure and water retention properties compared with an undisturbed forest soil. This will advance our knowledge on the impact of topsoil removal and cultivation on rainfall acceptance and infiltration capacity and topsoil structural quality in fine sandy loam soils.

2. Materials and methods

2.1. Description of study site

The study was conducted in 2015 and 2016 in the humid Niger-Delta of Nigeria (04°15'N, 07°30'E). The soil is derived from unconsolidated coastal plain sands and alluvium of the Niger Deltaic and classified as *Arenic Acrisol* (USDA, 2012), dominated by kaolinite and oxides of Fe and Al. The soil is moderately well-drained with a low base saturation, low pH of 4.6, and low fertility status. Organic matter content is < 1.0% below the 20 cm depth (Akamigbo and Igwe, 1990). The rainy season is from March to November; with two peaks in July and September (NIMET, 2014). Mean annual rainfall is in excess of 2000 mm, with 80% of the rainfall between the months of May and October. Mean temperature at wet season ranged from 26 °C to 33 °C, and at dry season between 26 °C and 36 °C (Okpon et al., 1998). The site was previously cleared with bulldozer for construction works, removing the topsoil in the process, leaving exposed compacted subsoil.

2.2. Experimental area

Three locations were used for soil sample collections: (1) 10-year forested area, extending about 50 ha, dominated by *Imperata cylindrica* and shrubs such as *Alcornea cordifolia* and *Ficus exasperata* as undergrowth (Site A). (2) 10-year continuous cultivated area, extending about 420 ha, cultivated to maize and cassava (Site B). (3) Compacted subsoil, extending about 20 ha, with 25 to 30 cm of top soil previously removed with a bulldozer during site clearing for construction, leaving exposed compacted subsoil (SSR) (Site C). After 10 years, the exposed subsoil is characterized with regenerated scanty vegetation consisting mainly of *Panicum maximum* and *Cynodon dactylon*. Each of the sites located on a 5% slope was divided into four replicate subareas based on physiographic/landscape positions for soil sample collections. Since the slope of the land can influence infiltration rate and amount of water retained in the soil, the study area was delineated into upslope, middle slope, downslope and the relatively flat areas for representative soil sampling.

2.3. Soil sampling and measurement of infiltration

Ten disturbed and undisturbed core soil samples were collected at 0–30 cm depth in duplicates, making a total of 120 bulk and core samples. The bulk soil samples were air-dried, sieved through 2 mm mesh and stored for laboratory analysis.

Infiltration measurement was carried out along a transect at 120 positions in the field using the double ring infiltrometer (Carter, 1993) with inner and outer rings of 30 cm and 60 cm diameters, respectively. A constant head of 5 cm was maintained for 2 h until steady state infiltration was achieved. The infiltration rate (I) was calculated according to Bower (1986) as:

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

where Q is the volume of water infiltrating, A is area of the soil surface exposed to infiltration and t is time.

2.4. Laboratory analyses

2.4.1. Particle size distribution, bulk density and water-retention characteristics

Particle size distribution was determined with air-dried soil sample by the method of Gee and Bauder (1986). Bulk density determined with core samples by the method of Black and Hartage (1986) as:

$$\text{Bulk density} = \frac{M_d \text{ (g)}}{V_b \text{ (cm}^3\text{)}} \quad (2)$$

where M_d is mass of oven-dried soil and V_b is the volume of bulk soil.

Soil water-retention characteristics (SWRC) were measured on undisturbed core samples 5 cm × 6 cm (diameter × height) in the laboratory, using the pressure chamber apparatus with ceramic plates. Saturation of the soil samples was achieved by adding water slowly until water was about half way to the top of the soil core and allowed to soak for 24 h. After saturation, samples were subjected to pressures 0–10 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 plate until balance was established between pressure force and water retention force in the soil samples after 2 days. The gravimetric water content (θ_m) in the samples was measured after oven-drying the soil at 105 °C and was converted to volumetric water content (θ_v) by multiplying θ_m by the bulk density of each core sample. The following suctions were obtained: 0, 6, 10, 100, 1000 and 1500 kPa. The water content at 10 kPa and 1500 kPa represent the field capacity (FC) and permanent wilting point (PWP), respectively as suggested by Cassel and Nielsen (1986). The useful available water (UAW) and easily accessible water (EAW) which was used to assess the tendency of water stress were calculated from the water retention relationship using the following equations:

$$\text{UAW (mm)} = \frac{1}{10} \times (FC - \text{PWP}) \times BD \times Z \quad (3)$$

where BD is the dry bulk density, Z the depth of soil (cm), and FC – PWP is the available water (AW) (Hillel, 2004), and

$$\text{EAW (mm)} = \text{UAW} \times \frac{2}{3} \quad (4)$$

2.4.2. Aggregate stability, saturated hydraulic conductivity, porosity and organic matter

Aggregate stability was measured by the mean weight diameter (MWD) of water stable aggregates using the wet-sieving method as described by Kemper and Rosenau (1986). In this method, 50 g of 4.75 mm dry-sieved aggregates were placed in the topmost of a nest of sieves: 2.0, 1.0, 0.5, and 0.25 mm. The aggregates were pre-soaked by capillary in distilled water for 15 min and oscillated vertically in water 20 times, using 4 cm amplitude in a mechanical agitator. The remaining stable aggregates on each sieve were oven-dried at 50 °C for 24 h and weighed. The percentage of the stable aggregates on each sieve representing water stable aggregates (WSA) was calculated as:

$$\text{WSA} = \frac{MR}{MT} \times \frac{100}{1} \quad (5)$$

where MR is the mass of resistant aggregates (g) and MT the total mass of wet-sieved soil (g). The mean weight diameter (MWD) of the water stable aggregates was calculated by the following equation (Hillel, 2004):

$$\text{MWD} = \sum_{i=1}^n x_i w_i \quad (6)$$

where x_i is the mean diameter of each size fraction, and w_i is the weight of aggregates in that size range as a fraction of the dry weight of the sample analyzed. Saturated hydraulic conductivity was measured by the constant-head permeability test procedure and calculated using the transposed Darcy's equation for vertical flow of liquids (Reynolds et al., 2002). With this method, leachate volume was measured over time until flow was constant at which time the final flow rate was determined from the equation:

$$K_{\text{sat}} = \frac{Q}{AT} \times \frac{L}{\Delta H} \quad (7)$$

where K_{sat} is saturated hydraulic conductivity (cm h^{-1}), Q is volume of water that flows through a cross-sectional area (cm^3), A is cross sectional area of core (cm^2), T is time (s), L is length of core (cm), and ΔH is hydraulic head difference (cm). Permeability class was according to Soil Survey Staff (1993). Total porosity was calculated with core samples using the method of Flint and Flint (2002) as:

$$\% \text{Total porosity} = \frac{\text{Volume of water at saturation}}{\text{volume of bulk soil}} \times \frac{100}{1} \quad (8)$$

This method is appropriate for fine sandy loam soils, because, at saturation (0 kPa) tension after 24 h, all the pore spaces were filled up. The air-filled porosity (AFP) (%) was estimated from total porosity (TP) and water retention (WR) at matric potential of -10 kPa (WR 10) i.e. field capacity as follows: $\text{AFP} = \text{TP} - \text{WR}10$. Micro-porosity was obtained as follows: $\text{TP} - \text{AFP}$ (representing the ratio of pores volume retained at -10 kPa to the volume of bulk soil).

Total organic carbon was determined by the wet oxidation dichromate method with $\text{H}_2\text{SO}_4\text{-K}_2\text{Cr}_2\text{O}_7$ followed by residual titration with 1 N HCl (Nelson, 1996), and was converted to organic matter (OM) by multiplying the TOC values by the Van Bemmelen factor of 1.724 (Van der Ploeg et al., 1999).

2.5. Data analysis

For each location an analysis of variance (ANOVA) was used followed by multiple comparisons to compare the effects of topsoil and cultivation on the measured parameters using the SAS software (SAS, 2001). Means were separated according to the least significant difference using Fisher's protected test (Gomez and Gomez, 1984) at 5% probability. We used correlation analysis to determine the relationships between water retention properties with some physical properties. Significant correlation coefficient was tested at 5% probability.

3. Results

3.1. Infiltration rate

The topsoil removal and cultivation affected initial and steady state infiltration rates of the soils. Steady state infiltration attained before 2 h was as low as 12 mm hr^{-1} in cultivated soils and near zero in SSR plots (Fig. 1). The highest mean infiltration rate of 123 mm hr^{-1} was found in forested soils. The seemingly initial rapid infiltration rates of 62 mm hr^{-1} in SSR and 75 mm hr^{-1} found in cultivated soils depleted suddenly to near zero and 23 mm hr^{-1} respectively after 40 min. In the whole, steady state infiltration rates were in the order of forested > cultivated > SSR.

Assessing the effect of 10-year continuous cultivation on infiltration rates showed that the initial and steady infiltration rates were similar to

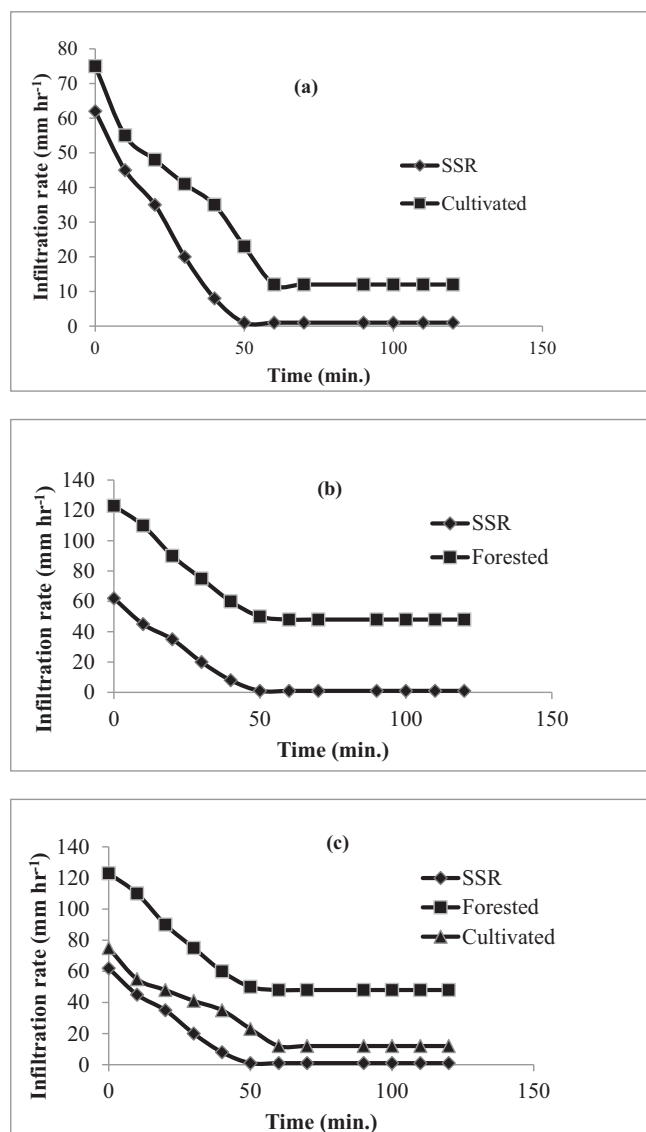


Fig. 1. Mean steady state infiltration rates of the soils under forested, cultivated and topsoil removal.

topsoil removal (Fig. 1b) and much higher in an undisturbed forest soils (Fig. 1a). However, the near zero steady state infiltration rate found in SSR soils was more important than its initial rapid infiltration rate, because steady state infiltration is not affected by the preceding soil moisture content or cracks on the soil surface. It is the most useful for comparative description of topsoil removal on the soil surface state for rainfall acceptance. It was also more relevant when considering the effects of tropical rains of long duration on fine soil particles in the case of soil disturbance during cultivation and exposed compacted subsoil in the case topsoil removal. The slope of the infiltration curves (Fig. 1c) showed that the amount of water entering the soil per unit time was gradual in forested soils, compared with that in cultivated and SSR. The constant narrow difference in steady state infiltration between SSR and cultivated soils explained their adverse effects on the soil infiltration rates.

3.2. Texture and pore-size distribution

The SSR significantly ($p < 0.05$) increased the silt + clay fractions of the soil at 0–30 cm layer by 51%, while cultivation tends to increase the sand fraction 12% when compared with the undisturbed forested

Table 1

Texture and pore-size distribution of the 0–30 cm soil under forested, cultivated and topsoil removal.

Location	Sand (g kg ⁻¹)	Silt (g kg ⁻¹)	Clay (g kg ⁻¹)	Texture	Air-filled porosity (%)	Micro-porosity (%)
Site A: forested	815a	110a	75b	SL	26.1a	20.1b
Site B: cultivated	825a	109a	66b	SL	14.3b	21.4b
Site C: SSR	720b	120a	160a	SCL	10.5b	27.2a

Means followed by the same letter in each column for each parameter are not significant at $p < 0.05$. SSR-topsoil removal, SCL-sandy clay loam, SL-sandy loam.

soils after 10 years (Table 1). Air-filled porosity, representing drainage pores was significantly higher (26.1%) in forested soils, while slake fine-particles dominating the surface of SSR soils reduced air-filled porosity by 161%. Micro-porosity ranged from 20.1% in forested soils to 27.2% in SSR plots, showing higher micro- to air-filled porosity in cultivated similar to that of SSR soils.

3.3. Saturated hydraulic conductivity, organic matter and water stable aggregates

Saturated hydraulic conductivity (K_{sat}) was slow in SSR, moderately rapid in cultivated soils, and very rapid in forested soils (Table 2). The highest K_{sat} (76.8 cm hr⁻¹) was obtained in forested soils. Topsoil removal reduced the overall K_{sat} of the soil by 290% while cultivation reduced K_{sat} by 60% compared with undisturbed forested soils. The highest OM content of 36.91 g kg⁻¹ was found in forested soils. Assessing the effect of topsoil removal and 10-year cultivation on soil organic matter (SOM), there was evidence that SSR and cultivation reduced SOM by 200% and 48.7% respectively compared with the undisturbed forested soils over the 10-year period. Soil organic matter was in the order of SSR < cultivated < forested soils. Aggregate stability measured by the mean weight diameter (MWD) of water stable aggregate 1.02, 0.96 and 0.49 mm in forested, cultivated and SSR soils. There were indications that topsoil removal promoted stable aggregates < 0.5 mm, while stable aggregates > 1.00 mm were significantly higher in forested soils.

3.4. Water retention and soil bulk density

Significant differences were found in soil water retention at field capacity (FC), permanent wilting point (PWP), and available water (AW) holding capacity among forested, cultivated and SSR (Table 3). Topsoil removal and cultivation affected soil water retention at 10 kPa (FC) and 1500 kPa (PWP) and other soil water retention parameters. The narrow range in water retention between FC and PWP (5.9–4.7%), was evidence of quicker soil drying in the SSR plots immediately after rains. Useful available water (UAW) and easily available water (EAW) capacity were high in forested soils and lowest in SSR soils, representing a decline of about 62%. Topsoil removal and 10-year

Table 2

Saturated hydraulic conductivity, organic matter and aggregate stability of the 0–30 cm soil under forested, cultivated and topsoil removal.

Location	K_{sat} (cm hr ⁻¹)	OM (g kg ⁻¹)	MWD (mm)	Permeability index ^a	Permeability class ^a
Site A: forested	76.8a	36.91a	1.02a	7	Very rapid
Site B: cultivated	31.5b	24.82b	0.96a	5	Moderately rapid
Site C: SSR	19.7c	12.3c	0.49b	4	Slow

Means followed by the same letter in each column for each parameter are not significant at $p < 0.05$. K_{sat} -saturated hydraulic conductivity, OM-organic matter, MWD-mean weight diameter.

^a Soil Survey Staff (1993) classification.

Table 3

Soil water parameters of 0–30 cm depth as influenced by cultivation and topsoil removal.

Location	Water content (% dry wt)		AW (%) dry wt)	UAW (mm)	EAW (mm)	BD (g cm ⁻³)
	– 10 kPa	– 1500 kPa				
Site A: forested	9.8a	6.1a	3.7a	14.5a	9.70a	1.31b
Site B: cultivated	7.3b	5.1a	2.2b	6.4b	6.3b	1.42a
Site C: SSR	5.9c	4.7b	1.2b	5.5b	3.65c	1.52a

Means followed by the same letter in each parameter within column are not significantly different at $p > 0.05$. AW – available water, UAW – useful available water, EAW – easily available water, BD – bulk density.

cultivation did not differ on their effects on AW and UAW, but showed significant difference ($p < 0.05$) in EAW capacity. Bulk densities varied from 1.31 g cm⁻³ in forested soils to 1.52 g cm⁻³ in SSR soils, indicating significant increase in bulk density due to topsoil removal. Although bulk density was higher in SSR soils, the non-significant difference effect between the cultivated and topsoil removal soils was indication that cultivation increased the soil bulk density.

Topsoil removal and cultivation showed similar effects on soil water retention characteristic curves at – 10 kPa and – 1500 kPa (Fig. 2). At saturation water content (0 kPa), and near field capacity (– 6 kPa), significant differences in water retention were found among forested, cultivated and SSR soils. Water retention was significantly higher ($p < 0.05$) in forested soils at all pressure potentials. On the other hand, cultivation and SSR induced very low water retention capacity at FC and PWP, creating a narrow range of soil water retention similar to that between UAW and EAW.

3.5. Relationships among soil water retention properties and some physical properties

Water content at saturation showed significant positive relationships with organic matter content ($r = 0.427$, $p < 0.05$), and micro-porosity ($r = 0.764$, $p < 0.01$) (Table 4). Increase in bulk density showed negative effect with saturation water content ($r = -0.501$, $p < 0.05$). There was significant negative relationship between sand and saturation water content ($r = -0.411$, $p < 0.05$), showing reducing saturation with increasing sand content due to cultivation. On the other hand, significant negative relationships were found between water content at FC and BD, OM, and silt + clay content. Silt + clay content showed highly positive linear relationship with water content at PWP ($r = 0.621$, $p < 0.01$), and negative relationship with EAW ($r = -0.614$, $p < 0.01$). Useful available water and EAW showed positive relationship with OM ($r = 0.416$ and $r = 0.421$ respectively, $p < 0.05$). The negative coefficient of correlation (R) between EAW and silt + clay and micro-porosity and between PWP and OM is important in assessing the effects of topsoil removal and cultivation on water retention characteristics of the fine soils after 10-years.

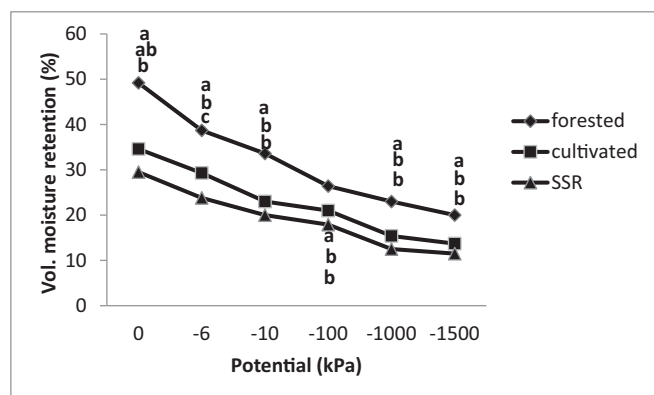


Fig. 2. Soil water retention characteristics curves for 0–30 cm depth of the forested, cultivated and surface soil removal. Different letters indicate significant differences at $p < 0.05$. SSR- surface soil removal.

4. Discussion

The results of this study clearly showed that topsoil removal and 10-year cultivation changed the hydrological and structural properties of the fine-sandy loam soil studied, consistent with findings from other authors conducted on soils dominated with kaolinite and oxides of Fe and Al (e.g. Woodland, 1996; Leonard et al., 2004; Udom and Adesodun, 2016). Topsoil removal and 10-year cultivation were similar in altering steady state infiltration rate and some structural properties of the soil. A large proportion of changes in, textural profile, infiltration rate, air-filled porosity, K_{sat} , MWD of water stable aggregates and water retention characteristics are attributable to loss of topsoil.

Cultivation increased the coarse-particle size fractions and bulk density, reduces soil organic matter and available water holding capacities of the soil. These changes control multiple factors that may interact to have negative effects on soil use and management. Higher infiltration in forested soils (Fig. 1) was in response to high SOM content found in these soils, which may have been responsible for the formation of macro-aggregates which created more macro-pores.

Although high organic litter on the forest floor usually lead to the formation of biological mat which may reduce initial infiltration rates (Leonard et al., 2004), in this study, high organic matter content help in creating large aggregates which, in turn formed more macro-pores which enhanced infiltration rate (Table 2). This result is consistent with the findings of Mapa (1995); Udom and Adesodun (2016), and Li et al. (2016) who found higher infiltration rate in forest than cultivated soils and attributed it to the presence of high organic matter. Soil disturbance due to cultivation destroyed soil organic matter and weakened the natural stability of the soil aggregates, while loss of topsoil increased micro-porosity (Table 1). The increase in silt + clay content in SSR soils may interact with high bulk density and low OM to control water storage and distribution in the soil which may have deleterious effects on plant growth. Changes in infiltration and water holding capacity at FC and PWP is in disagreement with studies of Hubbard et al.

(2013), and indicates that infiltration decreased when forested land is converted to arable cropping. This further agreed with earlier report by Smith et al. (2000), Munoz-Carpena et al. (2008) and Udom and Ogunwole (2015) who reported changes in physical properties of soils after forest clearing for agricultural purposes and recognized cultivation as a major driver in determining the hydraulic properties of soils.

The Low AW, UAW and EAW and slow to moderately rapid K_{sat} indicate high risk of water stress in SSR and cultivated soils with tendency of quicker drying of the soil surface immediately after heavy rainfall. This explained that topsoil removal and cultivation reduced air-filled porosity, leading to low saturated hydraulic conductivity, aggregate stability and increase in bulk density through deformation of soil structure (Elleckbrock et al., 2005; Udom et al., 2016). This way, roots of most arable crops may be restricted (Romanyà et al., 2000). Low water retention at high 10 kPa and 1000 kPa in SSR and cultivated soils compared with forested soils can be used as soil quality indices to explain the negative impact of these activities on soil structure. This is consistent with the findings of Korodjouma et al. (2006) and Gao et al. (2014) that soil water content corresponding to any pressure potential value depended strongly on soil structure, SOM, macro-to micro-porosity ratio, and specific surface area of the soil particles.

The highly positive relationship between saturation moisture content and micro-porosity defined the relationship between the capillary pressure and soil water content at low potential, which according to Saxton (2003) is especially measured by the pore distribution and the hysteresis of the matrix potential-water content relationship. Disruption of soil aggregates during cultivation, and creation of fine particles on unprotected subsoil may have caused the re-distribution of pore sizes to a more micro pores. Similarly, the negative correlation coefficient between BD and AW, FC and saturation water content confirmed the general knowledge that loss of topsoil and cultivation increase bulk density and reduce pore volume, with negative impact on soil moisture characteristics at these potentials.

The effect of topsoil removal on organization of soil texture defined particularly, the positive relationship between the fine particle-size fractions and available water holding capacities. Saxton (2003) and Korodjouma et al. (2006) had reported increased in water stress and draught index of soils due to increase in silt + clay fractions which have negative effect on available water holding capacities.

5. Conclusions

The following significant conclusions could be drawn from this study: (i) Topsoil removal and associated loss of organic matter have greater negatively effects on structural and hydraulic properties of the soil. Steady state infiltration rates and soil water status measurements were adversely affected due cultivation and topsoil removal. (ii) Available water measurements in SSR soils showed greater tendency of water stress, faster soil warming and quicker soil drying after heavy rainfall. (iii) Soil quality functions defined by saturated hydraulic conductivity, aggregate stability, soil organic matter and bulk density were adversely affected by cultivation topsoil removal. (iv) A shift in pore-size distribution towards greater micro porosity decreased UAW,

Table 4

Correlation coefficients (R) between water retention properties and soil properties ($N = 32$).

Parameters	BD (g cm^{-3})	OM (g kg^{-1})	MWD (mm)	Silt + clay (g kg^{-1})	Sand (g kg^{-1})	Micro-porosity (%)
Saturation (%)	−0.501*	0.427*	0.385	−0.401*	−0.411*	0.764**
FC (%)	−0.483*	−0.371	0.412*	−0.532*	0.480*	0.473*
PWP (%)	0.517*	−0.468*	0.311	0.621**	−0.352	0.342
AW (%)	−0.413*	−0.312	0.357	0.513*	−0.364	−0.441*
UAW (mm)	−0.364	0.416*	0.301	0.416*	−0.385	−0.373
EAW (mm)	−0.313	0.421*	0.362	−0.614**	0.531*	−0.458*

* Significant at $p < 0.05$.

** Significant at $p < 0.01$.

EAW and water content at field capacity; indicating high risk of water loss through runoff (vi) Negative effects of topsoil removal and cultivation discussed herein may be surmounted by minimizing excessive cultivation of low activity kaolinite clay-dominated soils and avoiding topsoil removal whenever possible.

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