< 0.25 mm mesh and were oscillated vertically in water for twenty (20) minutes at the rate of one oscillation per second. After wet-sieving, the remaining soil materials on each sieve were emptied into beakers, dried for 48 hours in an oven and weighed (W2). The percentage of sand in each sieve fractions was corrected by washing the aggregates with sodium hexametaphosphate,oven dried and weighed (W3). Percentage water stable aggregates (%WSA) was then calculated using % WSA= $\frac{W2-W3}{W1-W3} X\ 100$............................Equ. 1

The same procedure apart from over drying the soil in each sieve was used to obtain soil samples for chemical analyses in soil aggregate sizes.

Bouyoucos hydrometer method documented by Gee and Or, (2002)was used in the determination of particle size.Core method of Grossman and Reinsch, (2002) was used in bulk density determination. The method documented by Hendershot et al.,(1993) was used in the measurement of soil pH in soil-water ratio of 1:2.5. Soil organic carbon in whole soil and in subsamples of aggregates sizes was measured by wet digestion mettod of Nelson and Sommers, (1996).Available phosphorus was measured by Olsen method(Emteryd, 1989).

The use of flame photometer according to Thomas (1982) aided exchangeable cations(potassium and sodium) determination while magnesium and calcium were determined using ethylene diamine tetra-acetic acid (EDTA) (Thomas, 1982). Effective cation exchange capacity was determined by summing the exchangeable cations as documented by Landon (1991) Brady and Weil (1999).

Data Analyses. Data were analysed with analysis of variance ANOVA. Significant means were separated using least significant difference (LSD) at 5% probability.

Results and Discussion

The results of the physical and chemical properties of the studied soils are presented in Table 1. Sand fraction ranged from 552.90 to 840.00 gkg^{-1} and is significantly higher ($p<0.05$) in Uzoakoli. Clay fraction ranged from 110.00 gkg^{-1} to 323.30 gkg^{-1}, while silt ranged from 40.00 gkg^{-1} to 123.80 kg^{-1}.These values were typical of soils of south eastern Nigeria (Igwe, 1995).Values of silt fraction which followed the order: ARG > FBS > CPS > BAG are low indicating high degree of weathering. Texturally, soil of Ishiagu was sandy clay loam, Obinze: sandy, Umuna and Uzoakoli were sandy loam and loamy sand respectively. The classification was in line with Esheth (1995), Akamigbo and Asadu (1983) who documented similar textures for surface horizon soils of humid tropics. Sandiness of texture could be attributed to landuse, climate and geology. Soils with high sand fraction witness leaching, of high infiltration and low water retention thus incapable of supporting most crops. Differences in clay fraction are attributed to soil structure, clay movement and parent material. Bulk density ranged from 1.20 gcm^{-3} in Uzuakoli to 1.40 gcm^{-3} in Obinze. Soils whose bulk densities were low are related to high porosity, lesser compaction and easier penetration of roots and movement of micro fauna in them. Higher bulk density of soils leads to low infiltration and high runoff. However these values were lower than 1.85 gcm^{-3} (SSS 2006) considered as very critical and will surely impair root growth and is tandem with those of tropical soils (Landon, 1991).

The stability of aggregates using percentage water stable aggregates greater 0.25 mm (WSA > 0.25) was significantly higher in soil of Umuna under FBS (59.18 %) and least at soils of Obinze (26.27 %) under Coastal Plain Sand.The trend in the stability with respect to studied parent material was FBS >ARG>BAG> CPS (Table 1). This trend is attributed to texture, type of clay (USDA 1996) and organic matter which has binding effects soil particles (Tisdall and Oades, 1982; Hayness and Swift, 1990; USDA, 1996) and their interactions (Le-Bissonnaise, 1996). Others include exchangeable sodium percentage (Kazman*et al.*, 1983), soil management (Iraj, 2009). Kay and Angers (1999) stated that aggregate stability declines rapidly as organic carbon decreases from 1.5- 1.2%. Among the list of other factors that affect structural stability include sesquioxides (Le-Bissonnaise and Singer 1993).This result showed that soil under False bedded sand stone is much more stable than others and will be able to resist erosion more than others. Soil pH in water though did not differ significantly ($p<0.05$) among parent materials ranged from 5.37 to 5.75 (Table1). Moderate acidic condition of the soils was credited to constant leaching by rainfall in the area. This leaves the soil saturated with more aluminium and hydrogen (Landon, 1991).

The result of soil organic carbon presented in Table 1 significantly differed ($p<0.05$) with parent material and followed similar trend with that of aggregate stability (FBS >ARG>BAG> CPS). Soil organic carbon (SOC) ranged from 9.60 in Obinze - 14.80 gkg^{-1} in soils under Uzuakoli. Generally, the result of soil organic matter are rated low (Landon 1991; Igwe and Stahr 2004, Opara - Nadi (1988), typical of tropical soils, a factor that predisposes the soil to dispersion making it prone to erosion (Agim et al., 2012).

Table 1. *Physical properties of studied soil.*

P.M	Location	Sand	Silt	Clay	T.C	B.D	WSA	pH	SOC	Av, P	T.N	ECEC
			gkg^{-1}			gcm^{-3}	%	(H_20)	gkg^{-1}	mgkg^{-1}	gkg^{-1}	cmolkg^{-1}
ARG	Ishiagu	552.90	123.80	323.30	SCL	1.25	47.16	5.37	12.40	10.94	1.20	7.41
CPS	Obinze	809.60	80.40	110.00	S	1.40	26.27	5.75	9.60	**11.26**	1.02	3.97
FBS	Umuna	622.90	90.40	286.70	SL	1.30	59.18	5.75	10.90	**11.57**	1.30	12.00
BAG	Uzoakoli	840.00	40.00	120.00	LS	1.20	31.15	5.42	14.80	11.86	1.20	3.21
LSD ($P<0.05$)		22.10*	7.31*	10.42*		0.21*	2.23*	NS	**0.39****	NS	NS	0.95*

P.M=parent material, ARG=Asu River Group, CPS=Coastal plain sand, FBS=False bedded sand, BAG=Bende Ameki Group, WSA=water stable aggregates.BD=Bulk density.*=Significant,**=highly significant, ECEC=effective cation exchange capacity, SOC=Soil organic carbon=probability level, Av. P=Available phosphorus, T.C=Testural class.

The distribution of selected soil nutrients in aggregate sizes of studied soil

The distribution of selected soil properties in aggregate sizes of studied soils are presented in Table 2. Soil organic carbon ranged from 10.31 gkg^{-1}-12.20 gkg^{-1} in aggregate diameters of 2 and 0.5 mm in Ishiagu (ARG),5.30 - 9.30gkg^{-1} in 2 and< 0.25 mm in Obinze (CPS). Similarly, values of 8.80 –10.60 and 8. 40 – 14.30 gkg^{-1} were obtained in Umuna (FBS) and Uzoakoli (BAG) under sieve sizes of 2,< 0.25and 0.5 - < 0.25 mm respectively. Generally, these values were lower than that contained in whole soil(Figures 1:a-d). This confirms that breakdown of aggregates leads to loss of organic matter. In all cases however, organic matter were low, highest values were obtained in the 0.5 mm sieve at Ishiagu, where as they occurred at the <0.25 mm for others. Result obtained in Ishiagu is similar to that of Igwe 2001, Green et al.,(2005) where as those of others followed the trend of Razalfimbelo et al., (2008) who reported high SOC in micro aggregates (<0.02 mm).Inconsistent values are attributed to parent materials. The high values of soil organic matter at this level of aggregation are also attributed to slaking which occur when bigger aggregates are not able to survive inner pressure as a result of fast water absorption or tillage. Such process releases heat that makes the aggregate to collapse. Igwe (2003) observed that soils whose aggregates occur more on the < 0.25 mm sizes correlate with inter rill and rill erosion in the field. Le Bissoinnaise (1996) posited that aggregates at these sizes are very unstable and undesirable. This implies that the organic matter contained in the above soils are very much prone to erosion loses .This also supports Mbagwu et al., (1993),Obi (1982), who found significant positive association between micro aggregate stability and organic matter concentration in tropical soils.

Total nitrogen followed the same order with organic carbon. Higher values were noted in 0.5 and in < 0.25 mm sieve sizes. Wright and Inglett (2009) found similar trends in organic nitrogen distribution in aggregates of Everglades Histosols. Guan et al., (2018) also found similar result in an alpine meadow at the Damxung GrasslandTibetan Autonomous Region, northwest China. Increase in values of nitrogen at this level of aggregation is an indication of high preservability of soil nutrient micro aggregates or clay sized fractions.

Available phosphorus was significantly ($p<0.05$) higher in aggregates size of 1mm in all studied soils except in Uzuakoli. It ranged from 2.90 – 5.70 mgkg^{-1} in sieve size of 2mm and 1mm in Ishiagu, 3.84 -6.64 mgkg^{-1} in 0.5 and 2 mm sieves in Obinze, 6.60 -9.60 mgkg^{-1}in sieve size of 0.25 and 2mm in Umuna and 0.10 to 9.40mgkg^{-1} in aggregates sizes of 0.5 and 0.25mm in Uzoakoli respectively. Available phosphorus decreased as sieve sizes tends to < 0.25mm though not in all cases (Figures 2a and b). Aguilar and Heil (1988) observed that variations in phosphorus content along a toposequence reflected differences in parent material or geology. These values were low (Landon, 1991, Enwezor 1977) and typical of soils of the eastern Nigeria. Uzoho and Oti (2005) recorded similar trend in similar soil. Igwe (2001) attributed low phosphorus availability in soils of the area to high fixation associated with the studied soils. Low phosphorus availability in tropical soil is also attributed to intense weathering and partly to the low availability of phosphorus in the aluminium and iron combination which were the dominant sources in these soils (Brady and Weil 1999). It has also been documented that low phosphorus values inhibit effective nodulation and leads to biological nitrogen fixation process of leguminous plants (Brady and Weil 1999).

Effective cation exchange capacity (ECEC) ranged from 5.77 to 9.03 cmolkg^{-1} in sieves of 2mm and 1mm in Ishiagu (ARG), from 2.20 to 2.93cmolkg^{-1} in sieves of < 0.25 mm and 1mm, Obinze (CPS); from 5.22 to 11.13 cmolkg^{-1} in sieves of 2mm and 0.5 mm in Umuna(FBS) and from 3.04 to 3.44 cmolkg^{-1} in sieves of< 0.25and 2 mm in Uzoakoli (BAG) respectively Table 2. Trends in effective cation exchange capacity differed significantly among parent materials suggesting that the breakdown of macro aggregates to smaller fractions during cultivation may lead to significant loss of cations. Generally higher values were obtained macro aggregates 2-0.5 mm than in micro aggregates <0.25. This accounts for higher stability of aggregates at macro levels a fit attributed to the binding actions of cations. Moreover, cations especially divalent ones are tightly held at the exchange complexes of macro aggregates (Jiang et al., 2011) found higher calcium and magnesium at the macro levels of stability in their work. They however obtained high levels of sodium at <0.25 mm confirming high level of dispersbility thus favouring erosion in the soils. ECEC like soil organic carbon in all soils are low. These values are below the critical limits for soils of South-eastern Nigeria (Enwezor et al., 1990), suggesting poor fertility status of the soil (Igwe, 2000). Ojanuga and Awojuola (1981) attributed low ECEC to the type of clay minerals prominent in the study area and differences in parent materials.

Table 2. *Distribution of selected properties in different aggregate sizes*

Parent material	Location	Sieve Sizes mm	pH (H2O)	SOC gkg^{-1}	Av.P mgkg^{-1}	Total nitrogen gkg^{-1}	ECEC cmolkg^{-1}
Asu River Group	Ishiagu	2.00		10.31		0.99	
			5.49		2.90		5.77
		1.00	5.67	11.39	5.70	0.98	9.03
		0.50	5.56	12.20	5.20	1.11	7.37
		<0.25	5.51	11.00	4.50	1.18	5.79
LSD(P< 0.05)			NS	0.08*	0.21*	0.02*	1.18*
PMX Ss			NS	0.16*	0.05*	0.01*	NS
Coastal plain sand							
	Obinze	2.00	5.63	5.30	6.64	0.98	2.55
		1.00	5.83	7.30	4.06	1.01	2.93
		0.50	5.58	8.30	3.84	1.02	2.43
		<0.25	5.85	9.30	4.01	1.02	2.20
LSD (P <0.05)			0.23*	0.12*	1.00*	NS	0.32*
PM X Ss			0.05*	0.32*	NS	NS	1.22*
Falsebedded sand	Umuna	2.00		8.80		1.20	
			5.41		8.60		5.22
		1.00	5.26	9.10	9.60	1.10	8.59
		0.50	5.32	10.50	9.00	1.28	11.13
		<0.25	5.48	10.60	6.60	1.29	9.18
LSD (P< 0.05)			0.27*	NS	0.03*	NS	2.14*
PM X Ss			1.23*	1.23*	1.10*	NS	2.16*
	Uzuakoli						
Bende Ameki Group		2.00		14.00		1.15	
			5.54		0.20		3.44
		1.00	5.71	9.80	3.90	1.10	3.15
		0.50	5.09	8.40	0.10	1.10	3.16
		<0.25	5.04	14.30	9.40	0.09	3.04
LSD (P <0.05)			1.32*	0.17*	0.31*	NS	NS
PM X Ss			1.20*	1.76*	1.77*	NS	NS

ARG=Asu River Group,CPS=Coastal plain sand, FBS=Falsebedded sand,BAG=Bende Ameki Group,SOC= Soil organic carbon, ECEC =Effective cation exchange capacity *=Significant,**=highly significant, P= probability level, LSD=Least significant difference. PM x Ss= Interaction between parent material and sieve sizes, Av.P=Available phosphorus

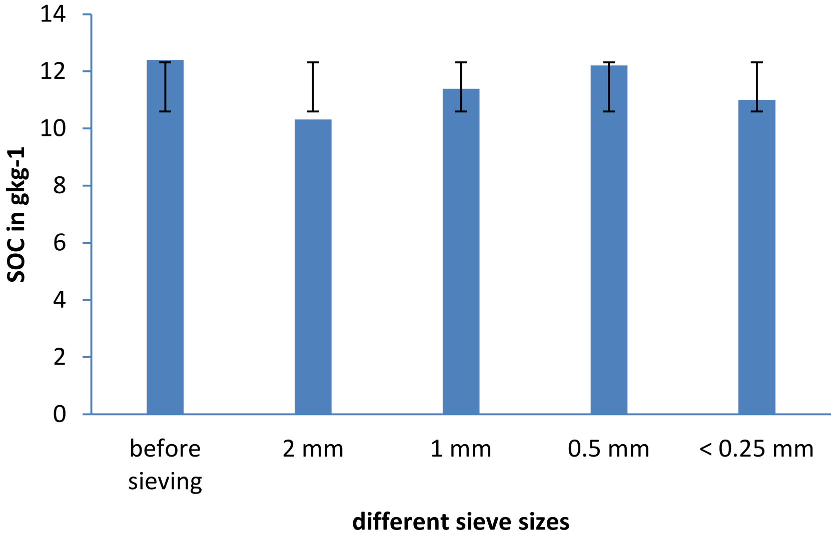

Figure 1a. *Soil organic carbon in whole soil before sieving and in sieve sizes under the Asu River Group formation.*

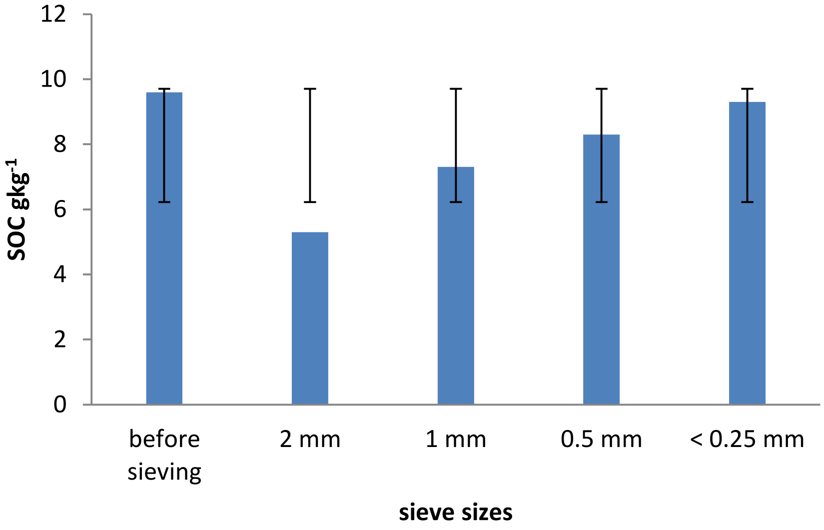

Figure 1b. *Soil organic carbon in whole soil before sieving and in sieve sizes under Coastal Plain Sand.*

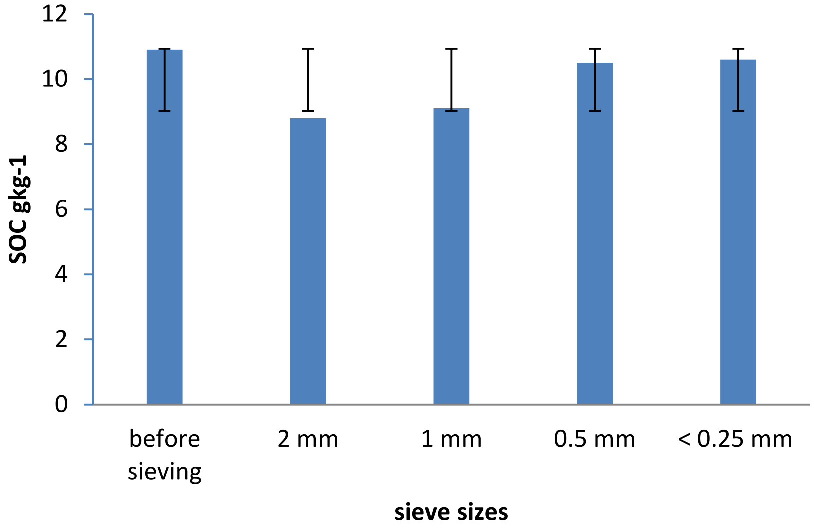

Figure 1c. *Soil organic carbon in whole soil before sieving and in sieve sizes under the Falsebedded Sand Stone*

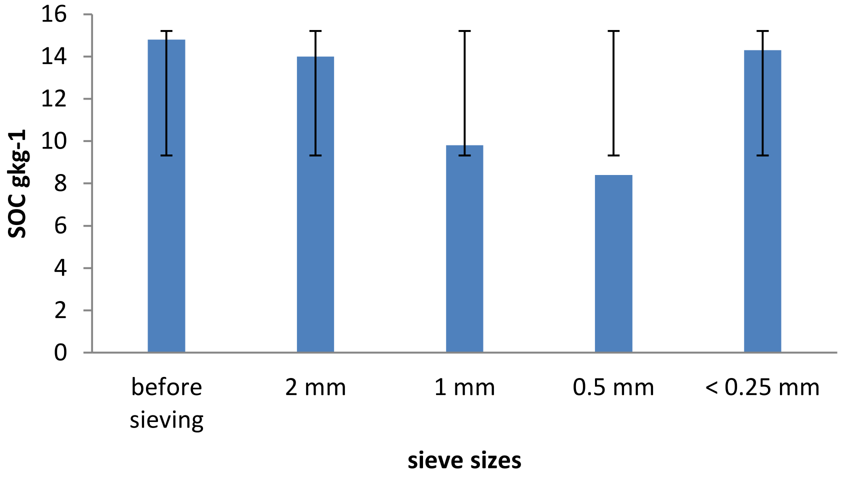

Figure 1d. *Soil organic carbon in whole soil before sieving and in sieve sizes under Bende Ameki Group.*

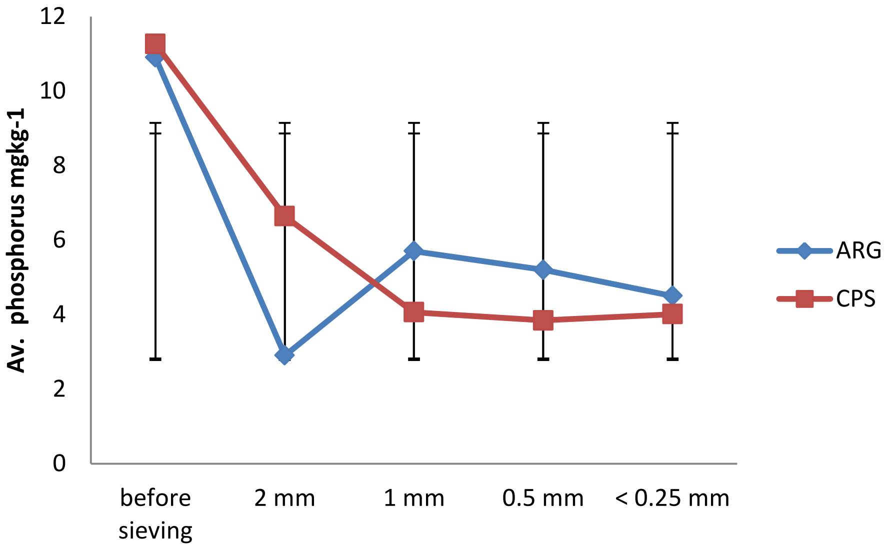

Figure 2a. *Available phosphorus in whole soil before sieving and in sieve sizes under Asu River Group and Coastal Plain Sand.*

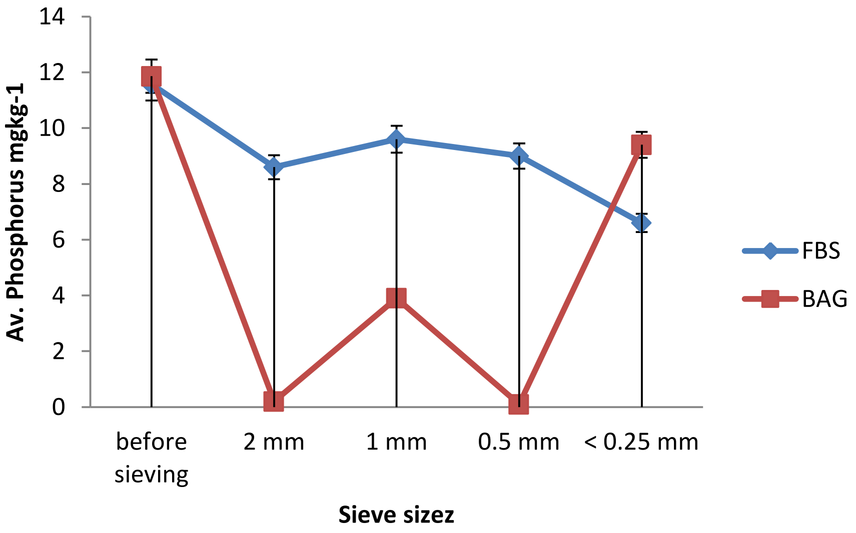

Figure 2b. *Available phosphorus in whole soil before sieving and in sieve sizes under Falsbedded sand and Bende Ameki Group*

Relationships among selected soil properties of studied soil.

In the result, soil organic carbon had significant ($P< 0.05$) positive relation with water stable aggregates WSA ($r= 0.50$), pH water ($r= 0.53$), total nitrogen ($r=0.79$), effective cation exchange capacity ($r = 0.51$)and negatively related with bulk density ($r= - 0.58$) Table 3. This implies that increase in organic matter content of the soil increases soil stability, soil pH, total nitrogen and effective cation exchange capacity by 50, 53 and 79 and 51 percents respectively. These results were similar to Agim et al., (2012) Sakin (2012) and confirm that of Unamba – Opara, (1982) on selected Nigerian soils. Increase in the structural stability of the soil was as the result of binding effects of organic matter on soil properties. While organic matter gives flesh to the sand content remain the skeleton (Brady and Weil, 1999). The content of organic matter and nitrogen in soils are interwoven hence the positive relationship among them (Sakin, 2012;Unamba-Opara, 1982). This is because microbial decomposition of organic matter leads to nitrogen availability in soils. This assertion is not ignorant of the fact that nitrogen availability in soil is also achieved via synthetic fertilizer application and atmospheric fixation. Result of the relationship between organic carbon and effective cation exchange capacity supports the fact that it is a reservoir of soil cations and therefore availability of micronutrients in the soil are imminent. Onwudike et al., (2016) attributed positive relations between soil organic matter, micronutrients and soil pH to chelating characteristics of organic matter which helps to hold nutrients in the soil. In his own Verma et al., (2005) attributed such positive correlation to complexing agents that are generated by organic matter which promotes nutrient availability in soil. Negative relationship between soil organic matter and bulk density confirms is in order. This is because microbial decomposition of organic matter increases soil pores, thus low bulk density.

Total nitrogen related positively with moisture content and aggregate stability ($r = 0.38$, and 0.50, $P<0.05$). This goes further to buttress the important of organic matter in soil.

Table 3. *Correlation matrix among selected properties of studied soil.*

	Units	Sand	Silt	Clay	MC	BD	WSA	PH	SOC	TN	Av.p	ECEC
Sand	gkg^{-1}	*										
Silt	gkg^{-1}	0.29^{ns}	*									
Clay	gkg^{-1}	0.98**	0.15^{ns}	*								
MC	gkg^{-1}	0.48*	0.01^{ns}	0.57*	*							
BD	gcm^{-3}	0.46*	0.01^{ns}	0.52*	0.53*	*						
WSA	%	0.53*	0.05^{ns}	0.59*	0.89*	0.74*	*					
pH		-0.29^{ns}	0.11^{ns}	0.29^{ns}	0.01^{ns}	0.06^{ns}	0.16^{ns}	*				
SOC	%	0.22^{ns}	0.06^{ns}	0.30*	0.76*	-0.58^{**}	0.73^{ns}	0.53^{ns}	*			
TN	%	0.15^{ns}	0.06^{ns}	0.20^{ns}	0.38*	0.10^{ns}	0.50*	0.03^{ns}	0.79*	*		
Av.P	$mgkg^{-1}$	0.07^{ns}	0.07^{ns}	0.07^{ns}	0.03^{ns}	0.11^{ns}	0.34*	0.04^{ns}	0.02^{ns}	0.02^{ns}	*	
ECEC	$cmolkg^{-1}$	0.66*	0.37^{ns}	0.60*	0.11^{ns}	0.28^{ns}	0.08^{ns}	0.31^{ns}	0.51^{*}	0.09^{ns}	0.08^{ns}	1

Conclusion

In conclusion results showed that variations occur in soil nutrients among geologic formations and aggregates. Organic carbon, available phosphorus and effective cation exchange capacity of soil varied with sieve sizes. Soil organic carbon was lesser in the aggregate sizes in comparison to that of the whole soil at the beginning of the study. The stability of aggregates using percentage water stable aggregates greater 0.25 mm (WSA > 0.25) was followed the trend: FBS>ARG>BAG>CPS. Effective cation exchange capacity followed the trend ARG>FBS>CPS>BAG. Significant positive relations were noted between soil organic carbon and selected properties. Soil organic carbon is very important in the protection of aggregates from deformation, therefore efforts including cover cropping, mulching application of organic amendment etc that improve organic matter content of the soil should be adopted. Again since soil erosion is a function of rainfall, measures such as afforestation, mulching etc that will dissipate the kinetic energy of falling rain drops before it strikes the soil surface and those that would be able to trap sediments on site are recommended.

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