SOIL PHYSICAL PROPERTIES AND SOIL ORGANIC CARBON AS AFFECTED BY LAND USE IN SELECTED LOCATIONS OF SOUTHWESTERN NIGERIA.

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ABSTRACT

The increase in anthropogenic activities on the land is a threat to soil sustainability and productivity. A study was conducted to investigate changes that may occur in the soil due to conversion of secondary forest land (SFR) to cocoa plantation (CPL), fallow (FA) and arable land (ARL). The four locations in Ekiti State, Southwestern Nigeria selected for this study were: Itapaji, Asin, Odo-Ayedun and and Odo-Ogo . The experiment was arranged as a 4 x 4 factorial in randomized complete block design (RCBD) replicated three times. The numbers represent four land use types and four locations. Soil parameters evaluated include some selected soil physical properties and micro-aggregate stability indices as well as the soil organic carbon (SOC) content. The SFR recorded lower sand(645 g/kg) and higher amounts of clay(217 g/kg) and silt(138 g/kg) compared to ARL, FA and CPL. The total porosity(47.2 %), bulk density (1.40 gcm^{-3}) and soil organic carbon (20.75 g/ kg) in SFR were more enhanced compared to ARL, FA and CPL. The higher clay flocculation index (83.7 %) and lower clay dispersion index (16.35 %) in the SFR compared to other land uses was not different with the CPL. The dispersion ratio recorded the lowest value in the SFR (0.35) compared to other land uses. The highest aggregated silt + clay in the SFR (231.6 g/kg) compared to FA (147.63 g/kg), ARL (151.6g/kg) and CPL (159.1) implied higher micro aggregate stability in SFR. The highest WDS depicted in CPL was not different with SFR and ARL and the order was CPL= SFR = ARL = NFA. There was no significant difference among the land use types in their WDC.

With respect to location and land use interaction, about 75 % of the locations across the four land uses showed statistically similar values in soil properties between SFR and CPL and the same were observed between NFA and ARL. A well managed CPL has economic advantage therefore may be adopted as an alternative land use to SFR. The study showed that land use affected soil properties and the degree and direction of influence was dependent on the location. Therefore, the result of the study may help soil managers to make rational decisions on best soil management practices.

Key words: Land use, particle size distribution, bulk density, total porosity, micro aggregate stability, soil organic carbon.

INTRODUCTION

Understanding and monitoring the effect of land use change on soil physical properties and soil organic carbon is crucial and critical for soil sustainability. There has been growing concern on the contribution of deforestation for other land uses on soil degradation in Nigeria. Reasons postulated for this anthropogenic activity are population increase, search for more fertile arable land, logging for economic gains and urbanization (Mba 2018). It was reported that there is decline in the growth rate of plantation crops such as cocoa in Nigeria (Folayan, *et al.*, 2006). In the past, cocoa contributed immensely to national economy and a well managed cocoa plantation replicates forest environment Aweto *et al.*, 1993; Akinyemi 2013). Decline in cocoa production could be attributed to competition of cocoa plantation areas for food crop production (Aweto 1988).

Variations in topsoil properties when natural forests are replaced by tree crops and fallow arising from cultivation of food crops are widely discussed. (Osakwe *et al*. 2017; Jirku *et al*., 2010; Jiang *et al.*, 2006). Some workers indicated that texture, bulk density and total porosity of soils under cocoa plantations were degraded when compared with soils under natural forest (Ekande *et al.*, 2012). High bulk density, lower porosity in arable land and lower bulk density and higher porosity in forest land were observed by some researchers (Osakwe *et al.*, 2013). Adejewon *et al.* (1988) indicated that soil organic matter, water holding capacity in fallow and cocoa plantations soils differ significantly from forest soils. Aweto *et al*. (1993) also noted that the organic matter and nutrient levels in soils under a 26-year old cocoa plantation and shifting cultivation farmlands cropped with cassava and maize in Nigeria were not substantially reduced in soils under plantations of cocoa. In contrast, organic matter and nutrient levels were much lower in shifting cultivation farmlands which was attributable to the fact that the crops such as cassava and maize have a low ground cover.

Land use was also shown to influence micro aggregate stability defined by aggregated silt plus clay, dispersion ratio, water dispersible clay, and clay dispersion index in some selected soils in south eastern Nigeria (Osakwe 2014; Osakwe *et al.*, 2017). Therefore,the knowledge of micro aggregate stability of soils under land use change is important for assessing and evaluating erodibility of the soil.

Ekiti state is in the cocoa belt of southwestern Nigeria where massive deforestation and abandonment of cocoa farms for other land uses abounds. Moreover work on soil physical properties and soil organic carbon under different land uses in the selected locations of the study is scarce. Knowledge of these variables is expected to help farmers and soil managers in proper decision on sustainable land use and where possible revive cocoa production. Therefore, the main objective of this research is to evaluate the effect of land use on soil physical properties and soil organic carbon in selected locations of south western Nigeria.

MATERIALS AND METHODS

Description of the study area

This study was carried out in four different locations in Ikole- Ekiti, Ekiti state Nigeria. The locations are Itapaji and Asin in the rainforest region while Odo – Ogo and Odo – Ayedun are in the derived savannah agro ecological zone of the state. The locations lie in the humid tropics with two seasons (dry and rainy/wet), minimum and maximum ambient temperatures ranges between 21 and 28 ^{0}C respectively. The region has an annual rainfall of 1275 - 2030 mm. The soils are derived from Basement complex Southwestern (Shittu, 2014). In each location, four land uses were identified which include secondary forest (SFR), fallow (FA), cultivated (ARL) and cocoa plantation (CPL). The fallows are natural bush fallows, the plantations are all cocoa plantations (*Theobroma cacao*) while the land has been under cultivation for fifteen to eighteen years. Shifting cultivation is practiced in the arable land and common arable crops planted are yam, cocoyam, cassava, maize and vegetables. The forests are secondary forest. Details of the site description are shown in Table 1.

Table 1. Locations and site description

Land use	FA	ARL	SFR	CPL	GPS		Vegetation
Location		Age (years			Longitude	Latitude	
Itapaji	3-5	12	>70	20	005.27.444	07 45.183	Rain forest
Asin	3-5	15	>70	35	005.30. 072	07.47.376	Rainforest
Odo – Ogo	3-5	12	>70	25	005.31.217	07.48.190	Derived Savannah
OdoAyedun	3-5	11	>70	25	005.24.643	748.12	Derived Savannah

FA – Fallow; ARL – Arable land; SFR- Secondary forest; CPL – Cocoa plantation

Soil sampling and Sample preparation

A stratified random sampling method (Peterson and Calving, 1986) that involved dividing a land use area (21m by 21m) in each location into three replicates from which soil samples were taken. Soil samples from 0-20cm were collected randomly in each replicate and made composite. A total number of 12 composite samples were collected at each location. Core samples were collected in triplicates from each replicate. A total of forty-eight (48) core samples were taken in each location. The 48 samples were air dried and passed through a 2 mm sieve and < 2mm soil was used for the determination of physical and chemical properties.

Laboratory Analysis

Physical analysis

Particle size distribution of less than 2 mm fine earth fraction was measured by the hydrometer method using calgon as the dispersion agent (Gee and Bauder, 1986).

Measurement of micro aggregate stability involved the determination of the amounts clay in calgon-dispersed and water-dispersed samples using bouyoucos hydrometer method of particle size analysis described by Gee and Bauder (1986).

CDI = [% clay (water) / % clay (calgon)]

CFI = [% clay (calgon) - % clay (water)] / [% clay (calgon)].

WDC = % clay in water

WDS = % silt in water

ASC = [% clay + % silt (calgon)] – [% clay + % silt (water)]

DR = DR= [% clay + % silt (water)]/ [% clay + % silt (calgon)]

Where, CDI = Clay Dispersion Index, CFI i= Clay Flocculation Index, WDC = water dispersible clay, ASC = aggregated silt + clay, DR = dispersion ratio and WDS = water dispersible clay.

CHEMICAL ANALYSIS

The soil organic carbon was determined by Walkey and Black wet Oxidation method as modified by Nelson and Sommer (1996).

STATISTICAL ANALYSIS

The data generated for the different parameters were subjected to statistical analysis using Genstat Discovery software edition 7.22 by VSN International Ltd. A two way ANOVA was used to test significant differences between means and where the F - values were significant at P=0.05, the means were separated using the F LSD. Simple correlation analysis was used to determine relationships between soil properties.

RESULTS AND DISCUSSION

Selected soil physical properties

The main effect of land use on soil particle size distribution, bulk density (BD) and total porosity (TP) was evaluated and significant differences were observed at P≤ 0.05 (Table 2). The secondary forest land use (SFR) indicated the lowest sand fraction (644.9 g/kg) compared to other land use types. The highest value (738 g/kg) in arable land use (ARL) was not different from the sand content in the fallow land use (FA). Lal (1996) reported an increase in sand fraction with deforestation and replacement with cultivation. Silt ranged between 160 (ARL) and 217 g/kg (SFR). The amount of clay under SFR was significantly higher by 17.60, 18.98, and 26.15 % in cocoa plantation (CPL), FA and ARL respectively. The reason for higher clay in SFR compared to ARL and FA land use, could be due to amelioration effect of forest canopy and forest litter to impact of raindrop and soil detachability,. On the other hand, poor management of plantations, removal of vegetation, tillage may expose and loosen the soil, resulting to easier removal of clay particles. This result corroborates the result of Ufor (2016) who reported that clay fraction was significantly (P≤ 0.05) higher in forest and plantation soils. He ascribed it to vegetation cover, reduction in infiltration rate which reduces downward movement of clay to lower depths. Also, silt showed 40, 26 and 15 % lower silt in ARL, FA and CPL compared to SFR respectively.

The SFR recorded significantly lowest BD (1.40gcm-^{3}) and highest TP (47.20 %). Furthermore, the highest BD (1.78 gcm-3), and lowest TP (32.83%) relative to other land uses was shown in the ARL. This result corroborates the report of Ufor (2016) of lower BD and higher porosity in forest and plantation land use compared with continuous cultivation.

Table2: The main effect of land use on selected soil physical properties

Parameter	Sand	Clay	Silt	BD	TP
Land use		(g/kg)		g/cm^3	
ARL	738	178	84	1.78	32.83
FA	727	160	102	1.64	38.02
SFR	645	217	138	1.40	47.20
CPL	708	175	118	1.59	40.09
Land use	20	18	16.9	0.10	3.67

The main effect location on sand, clay and silt content was significant at P≤ 0.05 (Table 3). The lowest sand fraction (653 g/kg) highest silt (133 g/kg) and clay (203 g/kg) were recorded in Asin compared to other locations except in Itapaji. The highest sand (750 g/kg), lowest silt (98 g/kg) and clay (157 g/kg) was indicated in Odo-Ogo compared to other locations except that the silt was at par with silt in Itapaji. Higher colloidal materials and lower sand content may improve aggregate stability, increase organo-mineral interaction and enhance nutrient and water storage. The variation in particle size distribution may be ascribed to differences in soil forming processes and vegetative cover that can affect the rate of soil erosion and loss of particle sizes. There was no significant effect of location on the BD and TP.

Table 3: The main effect of location on selected soil physical properties

Parameter	Sand	Clay	Silt	BD	TP
Location		(g/kg)		g/cm^3	
Itapaji	703	195	102	1.57	40.72
Asin	663	203	133	1.67	37.14
Odo-Ogo	745	157	98	1.58	40.38
Odo-Ayedun	707	176	118	1.59	39.91
LSD (0.05)	20	18	19	NS	5.96

The interaction of location and land use indicated that SFR in Asin registered significantly the lowest sand (503 g//kg) and highest clay content (297 g/kg) compared to other locations and land uses. The lowest clay in CPL of Odo-Ogo (143 g.kg) was not significantly different from other locations and land uses except SFR in Itapaji and Asin, CPL in Itapaji and FA in Odo- Ogo. It was observed that the highest sand content was registered in ARL of Itapaji (763 g/kg) buttressing that cultivation causes loss of fine materials thereby increasing the sand fraction. However, some land use types in other locations other than ARL showed increased sand content. The result may suggest that effect of land use is dependent on the location. There were variations in silt content and values ranged between 77 g/kg and 200 g/kg in ARL of Itapaji and SFR in Asin respectively. The result suggests about three times lower silt as a result of cultivation.

The similarities in parent material and differences in soil management may be implicated for the significant variations as suggested by Kiflu and Beyene (2013). Loss of clay in agricultural systems affects many crucial processes such as aggregation, carbon sequestration, infiltration, porosity, soil water and nutrient retention and availability among others. Olorunfemi *et.al.,* (2018) conducted a study on effect of land use on physico-chemical properties in 35 locations of Ekiti state southwestern Nigeria and reported non-significant difference in sand content between, plantation and arable land use. Abate *et al.*, (2016) indicated higher sand in forest soils compared

Table 4: The interaction effect of land use and location on selected soil physical properties

Location	Land use	Sand	Clay	Silt	BD	TP
Itapaji	ARL	763	170	77	1.94	26.92
	FA	753	144	93	1.66	37.23
	SFR	630	243	127	1.24	53.33
	CPL	667	223	110	1.45	45.40
Asin	ARL	763	177	80	1.83	31.07
	FA	723	157	100	1.68	36.48
	SFR	503	297	200	1.34	49.31
	CPL	663	183	153	1.81	31.70
Odo- Ogo	ARL	743	177	100	1.73	34.72
	FA	737	157	87	1.56	41.26
	SFR	750	150	100	1.54	41.89
	CPL	750	143	107	1.49	43.60
Odo-Ayedun	ARL	683	190	113	1.63	38.62
	FA	697	183	133	1.67	37.11
	SFR	697	177	127	1.48	44.30
	CPL	750	150	100	1.60	39.60
LSD (0.05)		41	38	36	0.20	7.35

to cultivated land use. The removal of vegetative cover may cause erosion leading to selective removal of fine particles and clay migration consequently increasing the sand content.. Increase in sand may be used to measure the extent of degradation under different land uses (Ayoubi et al., 2011). High sand content reduces water and nutrient holding capacity and may encourage loss of nutrients by leaching. Also microbial activities and soil structure may be adversely affected. Also, the loss of silt from agricultural fields may reduce water quality downstream and affect aquatic life due to siltation as opined by Zhai (2010). In addition, the clogging of soil pores and surface sealing increases runoff and impairs water infiltration, aeration, seed germination and seedling emergency.

Furthermore, the interaction of location and land use on the BD and TP showed the lowest bulk density (1.24 gcm^{-3}) and the highest TP (53.3 %) in SFR of Itapaji compared to other land uses except in SFR of Asin (Table 4). The higher clay content (Table 4) and or SOC (Figure 3) in these locations and land use types may be suggested as factors that enhanced the TP and BD. Igwe (2001) reported that higher SOC and faunal activity in forest soil and less trafficking may contribute to lower BD and higher porosity The lowest TP (26.92 %) and highest BD (1.94 gcm^{-3}) recorded in ARL of Itapaji was not significantly different with TP and BD in ARL and CPL of Asin. This study showed that conversion of forest to other land use types increased the bulk density. In the ARL of Itapaji and Asin, the increase was above the critical limit that may impede root growth (1.55 – 1.75 gcm^{-3}) according to the table of critical limit for different textures by Morris and Lowery (1988). The combined effects of tillage, trafficking and loss of organic matter in cultivated land use can cause soil compaction leading to higher bulk density and destruction of pores. Bulk density above the critical limit; impede seedling emergence, root growth and reduction in total porosity. Lower bulk density and higher porosities in forests soil compared to other land uses has been reported by many researchers. Ekande *et al*., (2012) showed increase in bulk density in cocoa plantation with increase in age. Kizilkaya *et al.,* (2010) reported decrease in porosity and a corresponding increase in bulk density in cultivated soils compared to forest land.

Micro aggregate stability indices

The effect of land use on micro aggregate stability indices measured by clay dispersion index (CDI),clay flocculation index (CFI), water dispersible clay (WDC), aggregated silt plus clay (ASC),dispersion ratio (DR) and water dispersible silt (WDS) were evaluated and significant differences were observed at P≤ 0.05 (Table 5). The CDI, CFI and WDC indicated values that varied between 16.3 (SFR) and 26.6 % (ARL); 73.35 (ARL) and 83.75 % SFR); 36.68 (SFR) - 45.85 g/kg (NFA) respectively. The result showed significantly lowest CDI and highest CFI in SFR compared to NFA and ARL while land use did not significantly affect WDC. The ASC varied between 147.63 (ARL) and 231.68 g/kg (SFR). The result showed that SFR recorded significantly highest ASC compared to other land use which may be attributed to higher clay (Table 2) and SOC (Figure 1) content in SFR compared to other land uses. Enhanced aggregation is important for soil pore connectivity, aeration, root penetration and water infiltration. Decline in ASC may lead to soil dispersion, erosion, siltation, sedimentation and pollution of water bodies. The DR varied between 0.35 (SFR) – 0.45 (CPL). The lowest DR in the SFR significantly differed from DR in ARL, CPL and NFA. However, the three later land use types were not significantly different among themselves. No significant effect of land use was observed on the WDS. Agricultural activities destroy soil aggregation and increase dispersion leading to erosion and surface crusting (Fuller *et al*., 1991; Basaga *et al*., 2018). Almajmaie *et al.*, 2017 reported that clay dispersion is linked to quartz content, soil texture, sodium adsorption ratio, Na+ and soil pH while SOC did not influence dispersion. However, Parwada *et al.,* (2017) reported that SOC significantly influenced soil loss, CDR, CFI and DR (P < .05).

Table 5: The main effect of land use on micro aggregate stability indices

Parameter Land use	CDI %	CFI %	WDC g/kg	ASC g/kg	DR	WDS g/kg
ARL	26.6	73.3	44.18	147.6	0.44	70
FA	26.2	73.8	45.85	151.6	0.44	75
SFR	16.3	83.7	36.68	231.6	0.35	86.7
CPL	21.9	78.1	41.68	159.1	0.45	91.7
LSD (0.05)	5.83	5.83	NS	20.9	0.06	16.0

CDI, Clay Dispersion Index, CFI, Clay Flocculation Index, WDC, water dispersible clay, ASC, aggregated silt + clay, DR, dispersion ratio, WDS, water dispersible clay

Table 6: The main effect of location on micro-aggregate stability indices

Parameter Location	CDI %	CFI %	WDC g/kg	ASC g/kg	DR	WDS g/kg
Itapaji	22.8	77.3	48.35	173.4	0.40	75.11
Asin	31.7	68.3	58.35	183.3	0.49	95.00
Odo-Ogo	18.7	81.3	30.00	145.0	0.43	80.03
Odo-Ayedun	17.8	82.2	31.68	188.3	0.36	73.30
LSD (0.05)	5.83	5.83	10.6	20.89	0.06	16.0

The average values of CDI, CFI and WDC in the locations ranged between 17.76 (Odo-Ayedu) - 31.66 % (Asin), 68.32 (Asin) – 82.23 % (Oda-Ayedu), 30.0 (Odo-Ogo) – 58.35 g/kg (Asin). The result showed consistently highest dispersion indices in Asin. The WDC followed this order among the four locations: Asin=Itapaji > Odo- Ogo=Odo- Ayedun which suggests that WDC within the same agro ecological zone did not differ from each other (Table 1). This probably may be ascribed to similarity in clay mineralogy or soil forming process.

The average amount of ASC in the various locations ranged between 145(Odo- Ogo) and 188.3 g/kg (Odo- Ayedun). It was obvious that ASC was influenced by SOC (Table 7) because the two locations with higher SOC had the highest ASC. The DR in the various locations ranged between 0.35 (ODA) and 0.49 (Asin). It was noted that DR was neither associated with SOC (Figure 2) nor clay/silt content (Table 3). The understanding of the clay mineralogy of these locations or other aggregating agents may be useful for explanation of observed variations and also in land use management decisions.

The interaction effect of land use and location on micro-aggregate stability indices was significant at

P≤ 0.05(Table 7). The lowest CDI (9.7 %) and the highest CFI (90.3%) compared to other land use types across the various locations was indicated in the FA of Itapaji. However it was not significantly different from SFR and CPL in Asin, Odo-Ayedun, as well as ARL in Itapaji and Oda-Ayedun and FA (Odo-Ogo). On the other hand the highest CDI (51.05%) and the lowest CFI (48.95%) registered in FA of Asin significantly differed from all land use types in all locations except non- significant difference with ARL in Asin and CPL in Itapaji. Similarly the ARL and FA in Itapaji indicated lowest amount of WDC (16.7 g/kg) compared to other land uses in the various locations except for non significant difference with ARL(Odo- Ogo), FA (Odo-Ayedun) SFR (Odo-Ogo and Odo-Ayedun) and CPL (Asin and Odo-Ogo). The results showed that the effect of land use on the micro-aggregate stability was dependent on the location.

Table 7: Interaction of land use and location on and micro-aggregate stability indices

Parameter		CDI	CFI	WDC	ASC	DR	WDS
Location	Land use	%	%	g/kg	g/kg		g/kg
Itapaji	ARL	9.7	90.20	16.7	153.9	0.34	66.7
	FA	11.7	88.4	16.7	163.3	0.33	66.72
	SFR	24.7	75.3	60.0	230.0	0.38	80.0
	CPL	44.8	55.2	100.0	146.6	0.55	86.8
Asin	ARL	51.1	48.95	80.0	96.7	0.59	60.0
	FA	49.1	50.93	86.7	110.0	0.60	80.0
	SFR	15.7	84.3	46.7	330.0	0.34	120
	CPL	10.9	89.1	20.0	196.60	0.42	95 .0
Odo-Ogo	ARL	21.3	78.8	33.3	136.7	0.47	80.0
	FA	26.4	73.6	46.7	136.7	0.48	86.7
	SFR	13.3	86.7	20.0	163.3	0.35	66.7
	CPL	14.0	86	20.0	143.3	0.43	80.63
Oda-Ayedun	ARL	24.50	75.5	46.7	203.2	0.36	73.3
	FA	17.50	82.5	33.3	196.7	0.35	66.7
	SFR	11.3	88.7	20.0	203.4	0.33	80.0
	CPL	17.8	82.2	26.7	159.1	0.40	73.3
	LSD (0.05)	11.67	11.67	21.2	40.52	0.13	32.2

The SFR in Asin registered the highest ASC compared to all the other land use types across all locations. The lowest value of ASC (96.7 g/kg) in FA of Asin was not significantly different from ARL in Asin as well as FA and ARL in Odo- Ogo. Activities that deplete SOC, indirectly affect aggregate stability of soils. Opara (2009) also recorded lowest ASC in cultivated and plantation land use compared to forest soils in some soils of southeastern Nigeria. Osakwe *et al*., (2014) reported that ASC was dependent on soil characteristics such as clay and organic matter content. They reported that some locations in southeastern Nigeria with higher clay and SOC in cultivated land recorded higher ASC in arable land compared to forest soils. Enhanced aggregation is important for soil pore connectivity, aeration, root penetration and water infiltration while decline in ASC may lead to soil dispersion, erosion, siltation, sedimentation and pollution of water bodies.

Furthermore, the lowest DR (0.32) in SFR of Odo-Ayedun was not different from the DR in SFR of Asin and Odo-Ayedu, FA and ARL of Itapaji and Odo-Ayedun while the highest DR (0.60) in ARL of Asin was not different from FA of Asin, ARL and FA of Odo- Ogo as well as CPL of Itapaji. It may be deduced that direction of influence may be dependent on the characteristics of the location and not actually determined by land use alone. Hence the lowest DR were observed not only SFR but also in ARL and FA in other locations. Soils with high DR are known to be weak structurally and can easily erode (Igwe *et al.,* 2008). The interaction of location and land use on WDS was significant with the highest value (120 g/kg) recorded in the SFR compared to other land uses in other locations except CPL of Asin. The lowest value (60 g/kg) in ARL of Asin was at par with ARL and FA in Itaji, SFR in Odo-Ogo and also ARL and CPL in Odo- Ayedun. The variation seems to be controlled by silt content at each location and land use because the higher the silt the higher the yield of silt in water (Table 4). Igwe *et al.,* (2008) showed SOC, the clay and silt contents as factors that influence the water-dispersible properties of the soils. Dispersibility of silt in water is undesirable because of the propensity of such soils to erosion leading to loss of plant nutrients, decline of water quality, impairment to aquatic life and environmental pollution. Heathwaite *et al.,* (2005) noted that silt dispersion when soils are submerged in water affect a lot of soil physical and chemical properties such as water-retention characteristics and hydraulic conductivity, water pollution, including crusting and sealing. High dispersibility of silt in water is an indication of high soil erodibility consequently leading to soil degradation. Maintaining adequate soil cover can minimize loss of silt in agricultural fields.

Soil organic carbon

The main effect of land use on SOC was assessed and significant differences were observed at $P \leq 0.05$ (Figure 1).There was 23.72, 36.4 and 38 % lower SOC in CPL, ARL and FA respectively compared to SFR while no significant difference was observed among CPL, FA and ARL(Figure 1). The higher soil organic carbon in the forest may be ascribed to accumulation of litter on forest floor. Bossuyt *et al.*, (2002) postulated that plant residue addition in forests can contribute to increase in soil organic carbon. Dawoe *et al.*, (2014) studied the effect of conversion of natural forest to cocoa agro-forestry in a lixisol in Ghana reported lower SOC stock in cocoa land use compared to natural forest. Cultivation may expose the soil to faster mineralization of soil organic carbon while short duration of the FA may not allow enough time for accumulation of SOC. Some researchers have demonstrated that depletion of humus or level of SOC under fallow land use is related to age of fallow (Kio, 2002, Szott *et al.*, 1999).

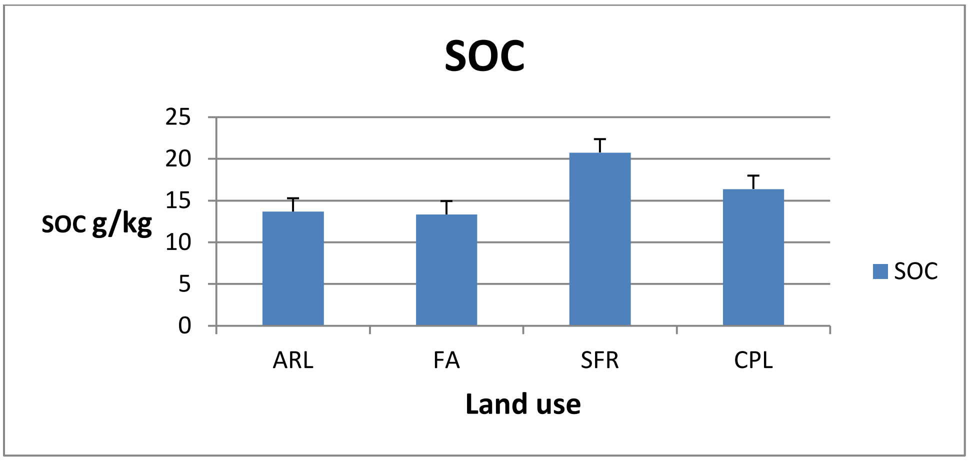

Figure 1: The effect of Land use on SOC
ARL, Cultivated land, FA, Fallow, SFR, Secondary forest, CPL, Cocoa plantation, SOC, Soil organic carbon.

The main effect of location indicated that the SOC in Asin (20.15 g/kg) was significantly higher than Itapaji and Odo-Ogo by 27.30 and 44.17 % respectively while maintaining a non significant difference with Odo-Ayedun (Figure 2). The variations in different locations may be ascribed to type and amount of organic matter input in the locations.

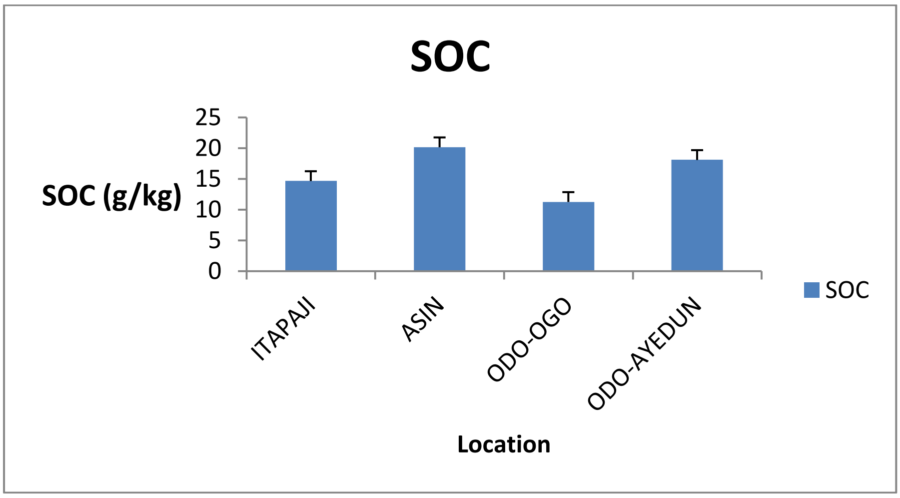

Figure 2: The effect of location on SOC

The interaction of land use and location effect on SOC was assessed and result presented in Figure 3. Soil organic carbon varied between 9.0 g/kg in ARL of Odo- Ogo and 35.6g/kg in SFR of Asin. The highest amount of SOC (35.6g/kg) was about 1.5 - 4 times higher compared to SOC observed in all the locations across all land uses. Akinde *et al.*, (2020) studied the effect of land use on selected soil physical and chemical properties in Nigeria, reported that SOC in secondary forest was higher than in other land uses but added that cocoa plantation had statistically similar values with the secondary forest.The result agreed with the report of other researchers of higher accumulation of SOC in forests compared to other land uses (Lal 2003; Lal 2004; Osakwe 2014; Spaccini *et al.*, 2001). Jamala and Oke (2013) reported 8% and 15% higher SOC under natural forest compared with

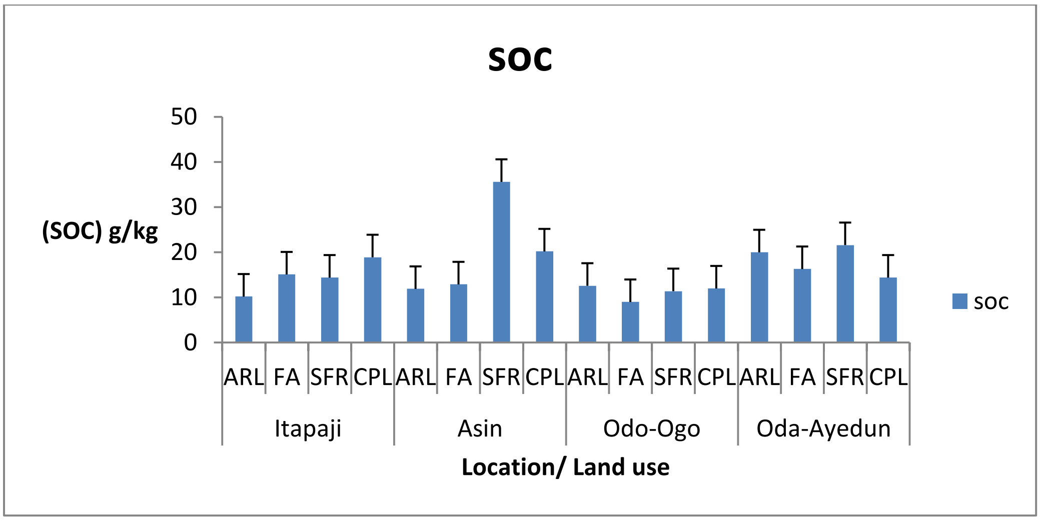

Figure 3: Interaction of location and land use on SOC
FA – Fallow; ARL – Arable land; SFR- Secondary forest; CPL – Cocoa plantation

cropped land and fallow land respectively. Furthermore, 60% of the experimental plots which included SFR, FA, ARL CPL in the various locations were statistically at par with the lowest (9.0 g/kg) SOC in the ARL of Odo-Ogo inferring that amount of SOC was dependent on location.. It is noteworthy that the recurrent annual forest fires during the dry season and logging which hinders the build-up of soil organic matter may explain the reason for this deviation.

Soil organic carbon is a crucial soil quality indicator that controls physical, chemical and biological processes in the soil. Increase in soil cover, external addition of organic matter, proper management of cocoa plantations and improved fallow system may be recommended to enhance SOC build up.

Correlation of selected soil properties with soil particle sizes and SOC

The correlation of some soil properties with soil particle sizes and soil organic carbon was assessed and the result presented in Table 8. It was shown that sand significantly and negatively correlated with WDS, ASC, WDC, TP and SOC with r = -0.64, -0.63, -0.36, -0.41, -0.71 and -.0.70 respectively. The result implied that increase in sand caused decline in WDS, ASC, WDC, TP and SOC while reduction in sand, increased the content of the mentioned parameters Also, the highly significant and positive correlation (r = 0.41) of sand with BD suggests that increase in sand content increases BD. Therefore, any land use that increases sand because of selective removal of colloidal materials may be viewed as an agent of soil degradation. Furthermore, clay had significant and moderate negative correlation (r = -0.42) with BD which infers that increase in clay reduces the soil BD and vice versa. There was weak to moderate positive correlation of clay with ASC, DR, WDC and TP with r = 0.49, 0 34, 0 35 and 0 42 respectively. It infers that loss of clay as a result of land use may reduce ASC, TP and SOC. Increase in clay may enhance aggregation, increase porosity and improve organo-mineral interaction. The correlation of silt with the micro aggregate stability indices presented negative (r =.-0.39) relationship with CDI, and positive relationship (r = 0.40, 0.45, 0.37) with CFI DR and WDS respectively. This result suggests that increase in silt reduces dispersion of clay and enhances flocculation of clay. This implied that loss of silt as a result of land use may increase the dispersibility of clay and soil erodibility. Also the result indicates that WDS is dependent on the silt content of the soil inferring that the higher the silt content, the higher the recovery of silt in water .On the other hand, the positive correlation with DR means that as silt increase, DR increases and vice versa.

Table 8: Correlation of soil properties with particle sizes and soil organic carbon

	SAND	CLAY	SILT	SOC
WDS	-0.64**	0.28	.37**	0.40**
WDC	-0.36*	0.35*	-0.17	0.02
CDI	-0.1	0.04	-0.39**	-0.17
CFI	0.10	-0.03	.40**	0.17
ASC	-0.63**	0.49**	0.24	042**
DR	-0.26	0.34*	0.45**	0.20
BD	0.41**	-.42**	-0.26	-0.36*
TP	-0.41**	0.42**	0.26	0.36*

Correlation of SOC with soil properties showed significant, moderate to weak positive relationship with WDS (r = 0.40), ASC (r = 0.42) and TP (r = 0.36). The results suggest that land use type that improves SOC status of the soil will have a positive influence on these soil properties and vise versa. The negative relationship with BD buttresses the importance of SOC in aggregation and other related properties hence land use option that contributes to soil organic carbon buildup should be recommended.
However, the observed relationships were not strong (except sand and SMC) which may need further investigation to find out other factors that may have stronger influence on the soil properties studied. The understanding of the clay mineralogy of this area may also be needed as it was noted that CFI and CDI were not related to either clay or SOC.

Summary and Conclusion

A study was conducted in selected locations of Ekiti state southwestern Nigeria to investigate changes in soil physical properties and soil organic carbon with land use change. The result indicated that conversion of secondary forest to ARL, FA and CPL caused decline in amount of colloidal particles and increase in sand. The bulk density equally increased with corresponding decline in TP. The micro aggregate stability declined while dispersive indices increased. This suggests increase in soil erodilbility which is not desirable because of the tendency of accelerated erosion. Also, the lower amounts of SOC observed in other land uses compared to the SFR is an indication of decline in soil quality. Furthermore the relationship of soil properties with soil particle sizes and soil organic carbon showed that that increase in sand negatively affected the micro-aggregates stability indices, the soil BD and porosity. On the contrary increase in the colloidal particles enhanced the micro-aggregates stability indices, the soil BD and porosity. Soil organic carbon correlated positively with all the studied soil properties except non significant effect of clay with clay dispersion index and clay flocculation index.
The result of the study supported other research findings that conversion of forests to other land use degrades the soil. However, the effect was less on cocoa plantations and in some locations, there was no difference between CPL and SFR in the studied soil parameters. Improvement in management of cocoa plantation may enhance soil quality and with the added advantage of being an economic crop can serve as an alternative land use to secondary forest. Furthermore, practices that can increase soil organic carbon and also reduce loss of fine soil particles in ARL and FA may restore soil physical properties and soil organic carbon build up.

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