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Effect of land use type on organic C, physical properties and stability indices of soils in Nanka area, southeast Nigeria

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ABSTRACT

This study was conducted in Ifite-Nanka, Orumba North L.G.A. in Anambra state, Nigeria. The aim of the research was to evaluate the effect of three land use types on soil organic carbon (SOC) and physical properties and to determine the factors that contributed to the stability of the eroded sites. Horizon variability of these soil parameters was also determined. The result showed that Oil palm plantation had significantly ($p < 0.05$) highest SOC value (0.51 %) followed by arable cropping (0.46 %) and least in cashew plantation (0.28 %). Oil palm plantation had the highest value of water stable aggregate (WSA) (15.35) followed by arable farm land (11.67) and least was cashew plantation but aggregate stability (AS) was highest in arable cropping. Along the profile, SOC was highest in A horizon and so was the WSA and AS. Among SOC, clay and sand content used in determining the stability of the soil, SOC explained 64.9 % and 45.5 % variations in AS and WSA respectively. Collapsing the structural and stability indices, more of the structural indices were improved in arable land use while more of the stability indices were improved oil palm plantation plots.

1.0. Introduction

Soil organic carbon (C) is regarded as the most singular useful indicator of soil quality and plays significant roles in preservation and enhancement of soil processes and productivity of agricultural lands (Obalum et al., 2017). Soil organic C regulates diverse processes essential to nutrient supply, creates adequate environment for growth of plants, stabilizes the soil and controls several processes leading to the creation of soil-based ecosystem services (Vanlauwe, 2004). One of such ecosystem service is agricultural production. Most natural forests have been converted to use in arable and plantation crop production. Agriculture and managed forests according to Scialabba (2012) occupies 60% of the global lands. And in addition to providing food to the populace, provides 40% of livelihoods to humans.

Consequently, agricultural production is very essential to human survival and existence. The particular use to which these agricultural lands are utilized is also very essential in maintaining its quality. Akamigbo FOR (2010) defined land use as the type of activity to which man has put the land in order to generate some economic output or result. Land use type and change has significant impact on soil characteristics including SOC, chemical and physical properties (Okebalama et al., 2017). It influences soil C sequestration and concomitant carbon (IV) oxide emissions into the atmosphere. Continuous cultivation of crops leads to rapid decline in soil organic matter in West Africa (Bationo et al., 1995). Land clearing accelerates rapid mineralization with up to 30% reduction in SOC (Gregorich et al., 1998; Nandwa, 2001). Okebalama et al. (2017) in their research on soil organic C in southeastern Nigeria found that most cultivated lands had lower SOC stock over fallowed land. In an effort to determine the land use type most suitable in a particular location, effect of different land uses on SOC need to be evaluated. In this research, SOC of arable and plantation lands were evaluated. Soil organic C and land use type has implications on soil physical properties, which were also analysed.

Soil physical properties are like the bedrock on which soil fertility is expressed. They are affected by the overall organic carbon in the soil. Land use type determines the stability of soil aggregates. Most studies on land use on soil physical properties evaluated land use change from forest, pasture or fallow land to arable production (Haghighi et al., 2010; Kiakojori and Gorgi, 2014; Addis et al., 2016) but data on different land use types of an area are still limited. Obalum and Obi (2010) evaluated the impact of tillage mulch practices under different cropping systems on soil physical properties. They summarized that cropping systems (land use types) had more pronounced effect on the physical properties, thus having most measured parameters significantly improved under sole soybean, while bulk density and mean weight diameter were significantly improved by the intercrop.

Another dimension of this research was to determine the predictability of soil stability by SOC, clay and sand content. Soil aggregate stability is a fundamental in soil resistance to water erosion, which is a threat to soils of this location. Research on soil aggregate stability is an essential requirement considering the importance of water erosion damages (Keesstra et al., 2016; Montanarella et al., 2016).

This research evaluated the impact of different land use types on SOC and some soil physical properties (% clay, % total sand (TS), water stable aggregates (WSA), mean weight diameter (MWD), aggregate stability (AS), bulk density (BD), hydraulic conductivity (Q) and total porosity (TP) and the relationship between SOC and these soil stability properties.

2.0. Materials and methods

2.1. Site description

This research was done at Ifite-Nanka, Orumba North L.G.A. of Anambra state- longtime gully erosion site. Nanka is located within latitude 60 011 to 60 061 N and longitude 70 02E to 70 081E. Reconnaissance survey of the area was done with a topographic map (Fig 1) obtained from Department of Geology, University of Nigeria, Nsukka. During the reconnaissance survey, three major land use types were observed namely arable farmland, cashew and oil palm plantations adjacent to gully sites were identified. They constituted the specific area for this research.

2.2. Sample collection: Composite soil samples were collected from the top 0 – 10 cm soil depth of each of the location for textural and routine analyses. Then profile pits were dug in each of the land use types and soil samples collected from horizons A, B and C. All these were replicated thrice. The samples were used determination of aggregate stability parameters such as SOC, mean weight diameter, aggregate stability and water stable aggregates. In addition, undisturbed core samples were collected from top soils of each of the soil conditions for determination of structural indices namely: bulk density, field capacity, hydraulic conductivity and total porosity.

2.3. Laboratory analysis: Standard laboratory methods were undertaken in analyzing soil samples for chemical and physical properties.

2.4. Statistical analysis: The data obtained from the structural and stability measurements were subjected to analysis of variance (Anova) for factorial in completely randomized design (CRD) to detect significant ($p < 0.05$) treatment means using Genstat discovery edition 10 version 8.0 computer package. The differences in means were gotten by the F-LSD procedure. . Significant means were used in preparation of graphs. Regression analysis was also undertaken to determine contribution of SOC, sand and clay percentage to variation in soil stability.

3.0 Results and Discussions

3.1. Topsoil characteristics

Table 1 shows the physico-chemical characteristics of the soils of the different land use type. The soils were loamy sand, neutral in reaction (6.1), low in total nitrogen and moderate available P (Landon, 1991). In addition, all the soil had low exchangeable cations (Landon, 1991) dominated by Ca (1.0 cmol kg^{-1} - 1.6 cmol kg^{-1}) and Mg (0.4 cmol kg^{-1} - 1.2 cmol kg^{-1}). Among the three land uses, total N (0.24%), SOC (1.06%), avail P (10.26 mg kg^{-1}), exch Ca (1.6 cmol kg^{-1}) and CEC (40.4 cmol kg^{-1}) were highest in soil of arable cropping while oil palm had the least total N (0.14%), SOC (0.65%) and avail P (2.8 mg kg^{-1}) whereas cashew plots had least exch Ca (1.0 cmol kg^{-1}), exch K (0.11 cmol kg^{-1}) but highest exch acidity (2.02 cmol kg^{-1}). Considering the constituents of textural classes, sand particles dominates the soils of all the land use types. This is attributed to the genesis of the soils rather than the effect of land use. More so, soils of southeastern Nigeria have predominantly sandy textural classes (Udom and Ogunwole, 2015; Nwite and Alu, 2017; Okebalama *et al.*, 2017). Values for Clay content were highest in horizon B in all the treatments while total sand had highest value in horizon A. Research has shown that sand content is usually higher in the topsoils than subsoils (Obalum *et al.*, 2013). Oguike and Mbagwu (2009) found that clay content

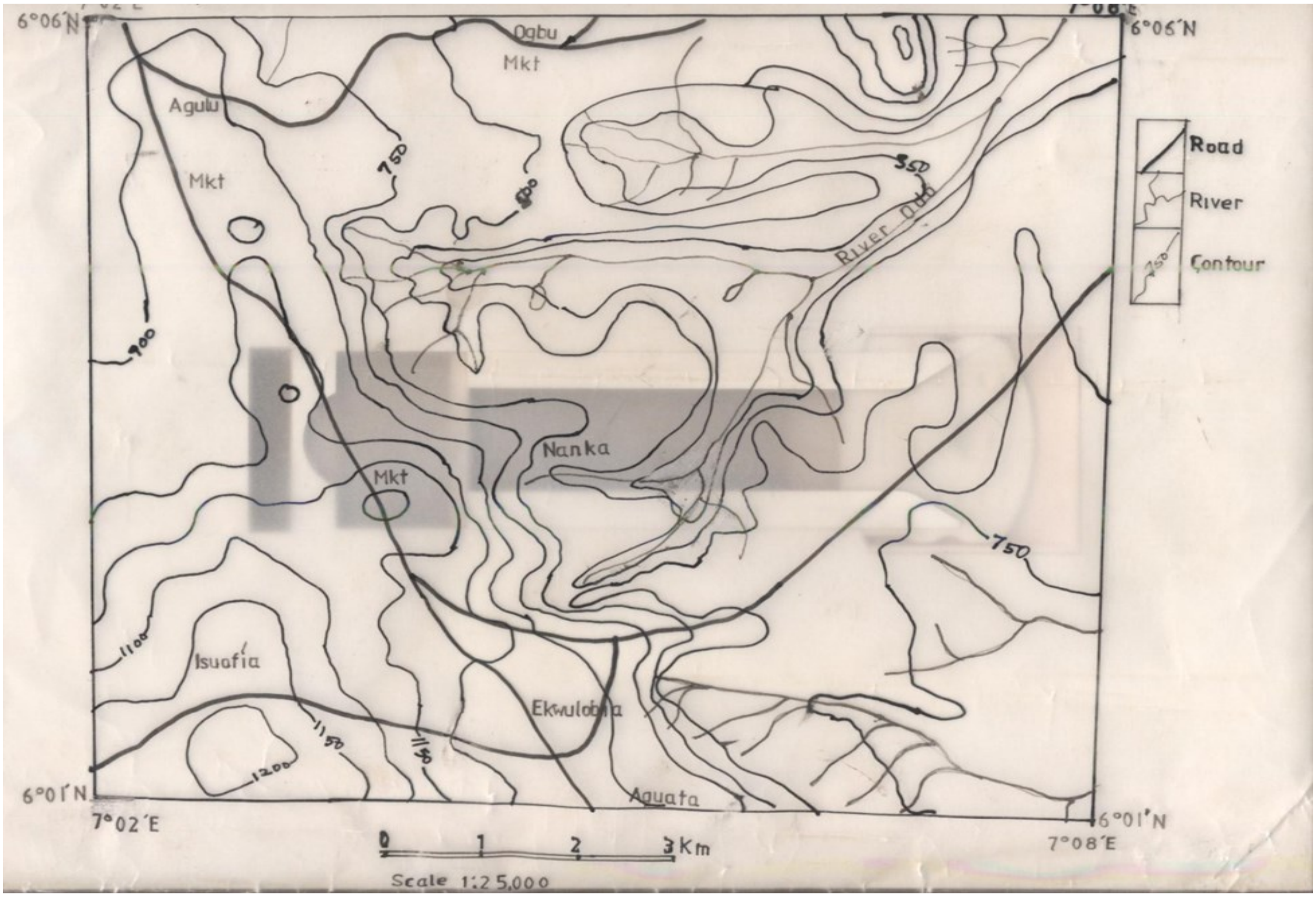

Fig. 1: Topographic map of the study area

increased with depth while sand decreased. This shows the extent of illuviations/eluviations that had occurred in such a place that had leached most of clay minerals to horizon B.

3.2. Land use effects on soil structural parameters

Structure of the soil has serious implications for agricultural productivity with respect to seed emergence, nutrient acquisition, water infiltration and uptake and root development. All the structural parameters measured were significantly ($p<0.05$) affected by the land use except bulk density (Table 2 and fig 2) and all these parameters had low

Table 1: Top soil properties of the land use types

Soil properties	**Land use types**		
	Arable	Cashew	Oil palm
Clay (%)	13.2	9.2	9.2
Silt (%)	3.28	3.28	5.28
Sand (%)	83.52	87.52	85.52
Textural class	Loamy sand	Loamy sand	Loamy sand
pH in water	6.1	6.1	6.2
TN (%)	0.24	0.15	0.14
OC (%)	1.06	0.71	0.65
AVP (mg kg^{-1})	10.26	3.73	2.8
Ca(cmol kg^{-1})	1.6	1	1.2
Mg(cmolkg^{-1})	0.4	1	1.2
K(cmolkg^{-1})	0.13	0.11	0.14
Na(cmolkg^{-1})	0.04	0.04	0.06
EA(cmolkg^{-1})	0.6	2.02	0.6
ECEC(cmolkg^{-1})	2.77	4.17	3.2
CEC (cmolkg^{-1})	40.4	32	35.6

coefficient of variation. Arable land use had highest field capacity (29.19%) and total porosity (33%) than other land use types. This was followed by oil palm plantation soil having field capacity of 26.19% and total porosity of 32.7% while cashew plantation had the least values for field capacity (20.34%) and total porosity (30%) but its bulk density was highest (1.85 g cm^{-3}). Hydraulic conductivity was significantly ($p<0.05$) the same in arable and cashew plots but lowest in oil palm. The variation in the soil properties shows the respective influence of the different land use types on measured soil structural properties. This could be as a result of organic residues from the leaf fall which affected these soil parameters or the rooting patterns. Arable land use type improved the structural properties better than other land use types. It had highest field capacity, total porosity and least bulk density. This was also followed by oil palm plantation having higher field capacity and total porosity though least hydraulic conductivity but lower bulk density than cashew plantation fields.

From the top soil characterization, clay content and FC were highest in arable land while cashew plantation soil had highest values of total sand and bulk density. This goes in line with research findings that high sand content causes poor aggregation and this leads to high bulk density (Salako *et al.*, 2002). The difference in texture could not have resulted directly from the land use but from the level of illuviations and erosive forces predominant in each land use type. The insignificant effect on bulk density was usual and it had the lowest coefficient of variation. Bulk density have been reported to have low variability across soil types (Abu and Malgwi, 2011; Ghartey *et al.*, 2012). Also, Jiao *et al.* (2011) found that land use had no significant effect on soil bulk density. Lowest bulk density was from arable land, which has significance in terms of ease of root proliferation and development and nutrient acquisition (Hoyle *et al.*, 2011). It is likely that residue turnover was more in arable cropland because it was a mixed cropping with cassava, vegetables and legumes. Oil palm plantation had lower bulk density than cashew plantation, which could be as a result of the rooting structure and level of recovery from land degradation and compaction caused by erosion (Anikwe, 2010), since that area was just recovering from erosion menace.

Soil porosity is the total number of pores between soil particles and it depicts the aeration and water movement within the soil. Arable land-use had highest porosity and field capacity, showing the relationship between the two. Field capacity depends on the pore spaces in the soil, so the higher the porosity, the higher the field capacity. Also, porosity and bulk density are inversely related. According to Houston (2010), soils with lower porosity usually have higher bulk densities ranging from 1.6 to 1.7gcm-3. They also noted that bulk densities ranges from 1.0 to 2.0gcm-3 in most soils.

3.3. Interaction of land use type and soil horizon on stability parameters

The stability parameters referred to are SOC, mean weight diameter (MWD), aggregate stability (AS) and water stable aggregates (WSA) and they were significantly affected by land use, horizon and their interaction as shown in

Table 2: Structural indices of the cropping systems

Soil properties	**Land use types**				**CV**
	Arable	Cashew	Oilpalm	Flsd (0.05)	%
Field Capacity (%)	26.19[a]	20.34[c]	21.90[b]	1.25	3.7
Bulk Density (gcm^{-3})	1.67	1.85	1.78	ns	2.4
Hyd conductivity (cm h^{-1})	21.1[a]	21.5[a]	10.5[b]	1.41	3.5
Total Porosity (%)	33[a]	30.0[b]	32.7[a]	2.07	2.9

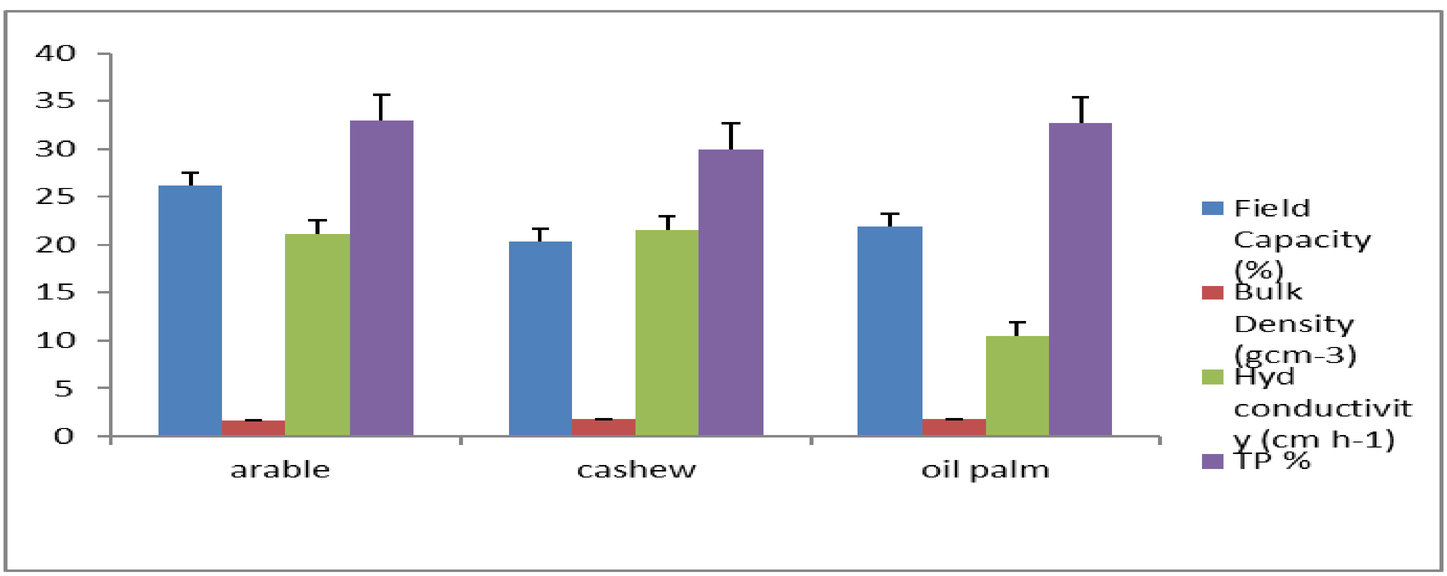

Fig. 2 Effect of land use on soil structural parameters

Table 3. Generally, most of the measured parameters in spite of the land use type, followed chronological order, highest value was in horizon A, followed by horizon B and least was horizon C except for MWD (fig 3). Horizon A had the highest SOC (0.77%), AS (26.38) and WSA (14.6), horizon B had the second highest SOC (0.26) and AS (15.04) but least MWD (0.75 mm) and WSA (10.84), while horizon C had the highest MWD (1.18 mm), but least SOC (0.22%) and aggregate stability (14.40%). WSA and AS followed similar trend except for AS in oil palm land use where horizon B had the highest value .of oil palm had the highest SOC (1.01%), followed by horizon A of the arable land. Considering the land use types, oil palm had the highest SOC (0.51%), MWD (1.45 mm) and WSA (15.35) while arable cropland had the highest AS (24.19), second highest SOC (0.46%), MWD (0.89 mm) and WSA (11.67). Cashew plantation soil had the least values for stability parameters. Looking at the interactions, horizon A of arable land had significantly overall highest AS (35.77) followed by its horizon B (23.12). Oil palm had the highest overall SOC (1.01%) and second highest WSA (17.03) in horizon A. It also had overall highest MWD (1.77%) and WSA (17.34) in horizon C. Cashew plantation soils along the horizons had the least values in most of the parameters.

The predominance of SOC in horizon A is in agreement with research and natural occurrence because organic matter is deposited on the top soil, so is usually higher at the top soil than down the profile. The variability of these parameters with depth is also observed by other researchers. Obalum *et al.* (2013) suggests that soil depth could also be a factor in soil spatial variability. As erosion occurs, the runoff water deposits soil particles down the profile, thus becomes source of variability in soil composition (Okon and Babalola, 2006). Soil aggregate stability represents an important characteristic of the soil structure, which is closely connected with the soil water regime, soil erodibility, and soil nutrient availability. An improved aggregate stability reduces the losses of soil with the nutrients it contains (Kasper (Kasper *et al.*, 2009), and increases the amount of macro-aggregates and the total and effective porosity (Shaver *et al.*, 2002). The aggregate (structure) stability influences water flow and contaminants transport in soils (Kodešová *et al.*, 2009).

3.4. Prediction of soil stability by soil OC, total sand and total clay

From the regression analysis shown on Table 4, OC predicted soil stability more than total sand and clay. Organic C explained 64.6 % and 45.5 % of aggregate stability and

Table 3: Interaction of land uses and horizon on Stability indices

Land use type	Horizons	Stability indices			
		SOC (%)	Mean Weight Diameter	Aggregate stability	Water stable aggregate
Arable	A	0.85	0.95	35.77	14.62
	B	0.37	0.58	23.12	10.47
	C	0.16	1.14	13.68	9.92
Mean	Arable	0.46	0.89	24.19	11.67
Cashew	A	0.45	0.64	22.36	12.15
	B	0.16	0.64	9.52	10.37
	C	0.24	0.64	12.51	10.66
Mean	Cashew	0.28	0.64	14.80	11.06
Oil palm	A	1.01	1.53	21.00	17.03
	B	0.25	1.04	12.50	11.68
	C	0.27	1.77	17.00	17.34
Mean	Oil palm	0.51	1.45	16.83	15.35
Mean	A	0.77	1.04	26.38	14.6
Mean	B	0.26	0.75	15.04	10.84
Mean	C	0.22	1.18	14.40	12.64
LSD(0.05)	Land use	0.017	0.038	0.14	0.08
LSD (0.05)	Horizon	0.016	0.038	0.14	0.08
LSD (0.05)	Interaction	0.029	0.065	0.24	0.14

water stable aggregates respectively while total sand explained 15.9% and 10.5 % and total clay explained 5.6 % and 7.0 % of the same parameters respectively. In addition, only OC had positive correlation with stability indexes whereas total sand and clay had negative correlation. Soil aggregate stability is a key factor in soil resistance to water erosion (Annabi *et al.*, 2017), which is a threat to soils in Nanka and its environs. Those areas including Uga, Achina and other towns in Aguata Local government area of Anambra state are highly prone to erosion. Using easily and frequently measured soil attributes to estimate aggregate stability is an easy way to build data on stability of soils. Soil organic matter is known to have a profound positive influence on aggregate formation and stabilization (Tisdall and Oades, 1982; Six *et al.*, 2002). The relationship is also seen to be reciprocal. Soil organic matter con-

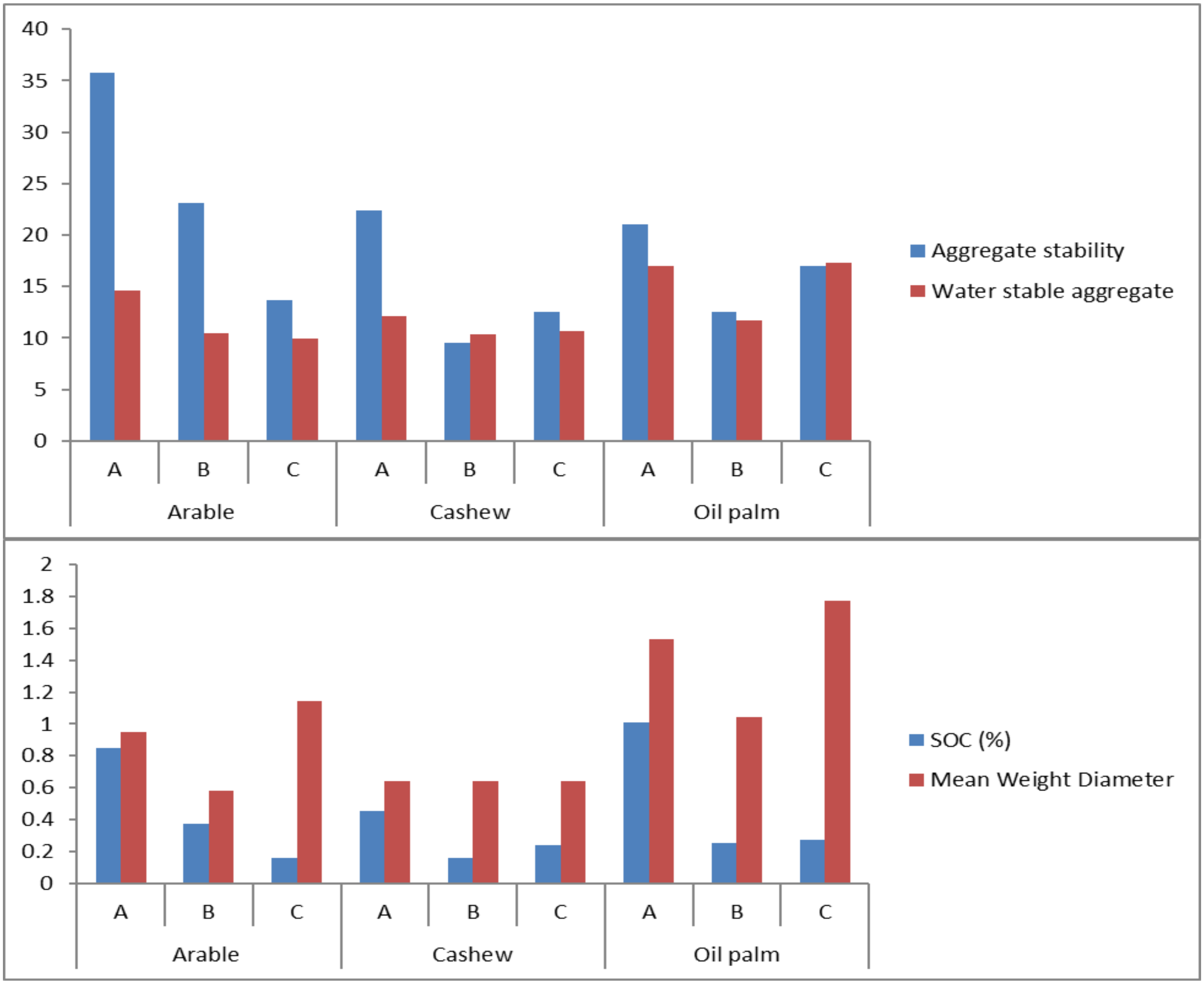

Fig 3: Interaction of land use type and horizon on soil stability properties

tent is vital for formation of aggregate and stabilization; nevertheless aggregates containing soil organic matter do physically protect it from decomposition (Six *et al.*, 2002). Unlike most reported research, Annabi *et al.* (2017) reported that SOC was not a major indicator of aggregate stability. They explained that this could be as a result of low organic carbon in those soils.

4.0. Conclusions

This research shows that arable crop land and oil palm plantation are more suitable for controlling erosion in the research area because the aggregate stability and water

Table 4: Total variation in soil stability explained by soil OC, total sand and total clay

Dependent variable	Explanatory variable (%)	Total variable (%)	Probability level
Aggregate stability	OC	64.6	<0.0001
	Clay	5.6	0.0032
	Sand	15.9	<0.0001
Total		86.1	
Water stable aggregate	OC	45.5	<0.0001
	Clay	7.0	0.0084
	Sand	10.5	0.0004
Total		63.0	

stable aggregates were high in these two crop land use types whereas cashew plantation had high bulk density and low aggregate stability. So, it is recommended that cashew plantation should not be established in such location if erosion is to be controlled. More so, there is need to increase organic matter in such area since organic matter controlled over 60 % variation in aggregate stability and has positive correlation with it. This means the more the organic matter, the better the stability of the studied soil.

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