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## COMPARING METHODS OF LAND USE PRACTICES EFFECT ON CLAY DISPERSION IN COASTAL PLAIN SAND SOILS IN SOUTHEASTERN NIGER

*Essien, O. A.[1], Akpan, E. A. and Akata, O. R.[2]*
[1]**Department of Soil Science, Akwa Ibom State University, Obio Akpa Campus, Nigeria**
[2]**Department of Crop Science, Akwa Ibom State University, Obio Akpa Campus, Nigeria**

**Corresponding Author:** *Otobongessien@aksu.edu.ng*

## ABSTRACT

Soil management practices and conservation measures that enhance aggregation and resistance to erodibility strongly require understanding and is important for clay dispersion. The effect of land use practices on clay dispersion was examined in coastal plain sand in southeastern Nigeria. Soil samples were collected from the study areas and analysed in the laboratory for physical and chemical properties, while clay dispersion indices were computed, namely, dispersion ratio, silt clay ratio, Clay Flocculation index, Modified clay ratio, Clay ratio and Clay dispersion ratio. Data were fitted into the Randomised Block Design, variance and correlation analyses were used to examine the relationships among soil properties and land use practices. The results showed that sand, predominated other particle size fractions. Effect of land use practices on clay dispersion indices indicated that there was a variation in Rubber, Oil Palm plantation and Forest Plot (1.044, CV= 4.7%, 1.069, CV= 2.7% and 1.017, CV= 19.5%) in dispersion ratio. Silt clay ratio and Clay Flocculation index of 0.567, CV= 97.3%, 0.217, CV= 76.9%, 0.702, CV= 13.12 and 0.433, CV= 54.4%, 0.537, CV= 13.39, 0.454, CV= 46.4% in Rubber, Oil Palm and Forest Plot, respectively. Clay ratio and Clay dispersion ratio were 6.26 with CV of 38.1, 6.424 with CV of 25.1%; 5.061 with CV of 31.5 and 0.566 with CV of 41.6%, 0.462 with CV of 15.5, 0.546, CV of 38.4% in rubber, oil palm and forest plot, respectively. Forest plot was less susceptible to impact of erosion followed by oil palm plantation, because they recorded less value in dispersion ratio and high value in silt clay ratio and clay flocculation index, while rubber plantation among land use types was inappropriate land use practices due to decline in soil structure.

**Keywords:** Soil properties, clay dispersion, land use practices, soil management.

## Introduction

Clay particles as binding agent in soil aggregation are a key factor of soil resistivity to mechanical stress. Soil clay dispersion describes the behavior of clay particles separating from one another in a soil particularly under moist conditions. This can result in the breakdown of soil aggregate and sealing/clogging of soil pores by the dispersed clay particles. Clay dispersion result in structural instability and soil/ water quality problem including soil loses by water erosion, it is also considered as a soil quality indicator that provides information on the ability of the soil to withstand stress

Aggregate breakdown through clay dispersion is a fundamental process in soil erosion (Le bissonnais, Y. Singer, M. J. and Bredford, J. M. (1993). And it may untimely yield crusting, enhance runoff and reduces roughness. Hence, clay dispersion plays a paramount role in soil erosion and is extremely sensitive to global change. This break down or falling apart when struck by raindrops, releases individual soil particles and clog pores. Aggregate breakdown into finer particles create crusts that close pores and other pathways for water and air entry into a soil and also restricts emergence of seedlings from the soil. Oguike and Mbagwu (2009), demonstrated that clay dispersion index (CDI) was affected by land use, while Chiang, S. C., West, L. T. and Radcliff, D. E. (1994), in their assessment, revealed that soils that have high water dispersible clay are Many previous studies have shown that tropical soil are fragile and sensitive to land use management which lead to clay dispersion. Land use management is also a factor that influences clay dispersion of a particular soil; this involves changes, maintenance, arrangement, activities and inputs people undertake in certain land cover types to produce their major needs. Soil structure is affected by the intensity of land use and this has effect on the distribution of microbial biomass as well as microbial processes within the aggregates. Mbagwu and Averswald (1999) showed that land use influenced structural stability. Gochin and Asgan (2008) investigated the effect of land use (forest, pasture and cultivation) on soil quality, and reported a 41-89% less dispersible clay in the forest than in their cultivated counter parts.

According to Gochin and Asgan (2008), cited in Osakwe (2014), Clay dispersion is recognized as an irreversible phenomenon that resulting in soil degradation and fertility decline. Variables can affect the spontaneous clay dispersion in coastal plain sand and flooded soils. Osakwe (2014) asserted that in soil organic carbon (SOS) is an important soil property because of it hydro phobic characteristics that have the ability to reduce slaking which precedes dispersion. The most important binding is clay mineralogy, organic matter content and Fe/Al oxides (Igwe, C. A., Zarei, M. and Starh, K. (2009). Mbagwu and Bazzofi (1998) findings revealed that 70% of the variation in water dispersible particle was accounted for by organic matter while Brubaker *et al.*, (1992) indicated that clay dispersion in water had been found to significantly correlate with total content of clay. The study area is located in the humid tropical region of southern eastern Nigeria, where annual rain fall distribution is erratic and often in storm, with potential for soil water that lead to flooding and runoff erosion. Accelerated erosion in the area caused by clay dispersion in the area is severe, with many gullies identified in the study area.

Knowledge of clay dispersion is important for soil and water conservation and for irrigation schedule. Hence, there is need for good soil water conservation and management practice that will guide against clay dispersion in order to solve water related problems such as erosion control. Therefore, the major objective of this study was to assess the effect of land use practices on clay dispersion and quantify the physical changes that may occur in the soil when oil palm, forest and rubber are established on coastal plain sands in southeastern Nigeria. This would provide information on the status of the soils that will culminate in better soil management toward sustainable agriculture.

## MATERIALS AND METHODS

### Site Description

The study was conducted on soil formed on coastal plain sand in Akwa Ibom State, southeastern Nigeria. Akwa Ibom State is located between latitude 4°50'E and 5°15'N, and longitude 7°30' and 8°30'E, while the coastal plain sands is located between latitude 4°40'N and 5°15'N and longitude 7°30'E and 8°15'E (Essien and Ogban 2018). The southern part borders on the Atlantic Ocean with a coastline of 129 km.

The climate of the area is uniformly hot, and is divided into two seasons, the wet or rainy season which last from April to October, and the dry season which last from November to March. The annual total rain fall range from 1,875 to over 2,500 mm. Although total rain received can be adequate, the problem are it variability, distribution and irregularity. The rains have high spatial and temporal variability and therefore vary markedly from place to place and from year to year (Nwa, 1977). Mean annual temperature varies between 21 and 29$^0$C and relative humidity is between 60 and 85% (Peter *et al.*, 1986), while evaporation transpiration ranged from 4.11 to 4.95 mm, partly because of high value of isolation and temperature (Udosen, 2012).

The study area is underlain by one major geological formation, the coastal plain sand, which comprises of largely poor consolidated sands. The sand which makes up a greater part of deposits possesses several characteristics such as deeply permeable and structurally unstable. The soils are rich in free iron but have low weathering potential and mineral reserved and therefore low properties and chemical fertility status, Due to prolonged deep weathering and cycles of erosion. They are described as acidic red and brown solid with good physical condition for crop production (Ofomata, 1975; Ojanuga *et al.*, 1981).

The vegetation of the study area is generally the rain forest which has been reduced in most places completely to farm land of short duration fallows less than 4 years and to secondary forests of oil palm (Ogban *et al.*, 2004). the farmer are practicing subsistence farming. A variety of tree and food crops includes cassava, coco yam, melon, maize, oil palm, cocoa, rubber; plantain/banana and assorted vegetable are cultivated in the study area.

A variety of geological formation occurs in Akwa Ibom State, the dominant parent materials are the quaternary Benin formation or unconsolidated coasted plain sands, the Tertiary Bende-Ameki (sand stone) formation and river Alluvium (Ojanuga *et al.*, 1981, Peter *et al.*, 1989). The soils are low in physical and chemical fertility status, due to prolonged deep weathering and cycles erosion. The soils are therefore inherently unstable due to the nature of the parent material and climatic conditions. The soils are loamy sand, sandy loam and sandy texture in the surface, and are acidic.

**Field Method**

Soil samples were collected from three (3) land used types that is not less than ten (10) years of establishment. (rubber plantation, oil palm plantation, and forest plot) in Akwa Ibom State University Teaching and Research Farm, Obio Akpa Campus in Oruk Anam Local Government area. The coordinates of the sampling location were taken with the use of GPS (geographical positioning system). Coordinates of the Study Area: Rubber Plantation: 4°57’52.3”N, 7°45’ 12.9”E; 4°57’42.3”N, 7°45’ 09.0”E; 4°57’37.4”N, 7°45’ 04.0”E; 4°57’32.3”N, 7°45’11.0”E4°57’27.5”N, 7°45’18.2”E. Oil Palm Plantation: 4°58’08.3”N, 7°45’14.9”E; 4°58’03.0”N, 7°45’ 19.1”E; 4°58’10.0”N, 7°45’ 23.0”E; 4°57’01.8”N, 7°45’17.1”E;4°58’57.9”N, 7°45’26.6”E.Forest Plot: 4°57’40.8”N, 7°45’20.4”E;4°57’35.0”N, 7°45’ 25.8”E; 4°57’30.5”N, 7°45’ 19.0”E; 4°57’25.9”N, 7°45’14.6”E;4°57’20.2”N, 7°45’09.7”E.

At each sampling location, three composite soil samples were collected with a spade from top, 20 cm soil depth in five (5) locations of the three (3) land use types given a total of fifteen (15) soil samples, and bulked for particle size distribution and chemical analysis. Core samples were collected at each sampling location with core cylinders measuring 7.2 cm long and 6.8 cm wide each.

**Laboratory Methods**

The bulk samples were air dried gently crushed and passed through a 2 mm sieve for the various laboratory analyses.

Particle size analysis was done using Bouyoucos method as described by Udo *et al.*, (2009). Saturated hydraulic conductivity (Ksat) was determined using the constant head parameter method (Dane and Topp, 2002), and was calculated using the equation.

$$Ksat = \frac{QL}{\Delta hAt}$$

Where

Ksat = Saturated hydraulic conductivity (cmhr$^{-1}$)

Q = discharge rate (cm$^3$ min$^{-1}$)

L = length of soil column (cm)

$\Delta h$ = Change in hydraulic head (cm)

A = cross sectional area through which the flow takes place (cm$^2$)

T = time (minutes)

Bulk density was determined using core samples as described by Dane and Topp (2002), and calculated using the equation.

$$\ell b = \frac{Ms}{Vt}$$

Where
$\ell b$ = bulk density ($Mgm^{-3}$)
Ms = mass of oven dry soil (mg)
Vt = Total volume of soil ($m^3$)
The total volume of soil was calculated from the internal dimension of the cylinder. Total porosity was calculated from particle and bulk density relationship as follows

$$f = \left(1 - \left(\frac{\ell b}{\ell s}\right)\right)$$

Where:
$f$ = total porosity ($m^3m^{-3}$)
$\ell b$ = bulk density (Mg $m^{-3}$)
$\ell s$ = particle density (Mg $m^{-3}$

Soil pH was determined using 1:2.5 soil and water suspension and the pH value read with a glass electrode pH meter. (Udo *et al.*, 2009).

**Exchangeable bases** (Ca, Mg, Na and K) were determined by extraction using ammonium acetate (in $NH_4OAC$) solution (Thomas, 1982). The available K and Na were determined by flame photometer and atomic absorption spectrophotometer.

Organic carbon content of the soil was determined using Walkley-Black oxidation method as modified by Nelson and Sommers (1996). Organic matter was calculated as follows: Organic matter = % carbon × 1.724
Available phosphorus was determined by the Bray p-1 method. The Phosphorus in the extraction was measured by the method of Murphy and Riley (1962). Exchangeable acidity was determined by titration using KCl extraction method (Peech *et al.*, 1962).
Total nitrogen was determined using macro-Kjedahl digestion method (Bremner, 1996). Effective cation exchange capacity was obtained by summation of the exchangeable bases and exchangeable acidity (Udo *et al.*, 2009). Base saturation was calculated as % BS = TEB x 100

Where
BS = Base Saturation
TEB = Total exchangeable bases
ECEC = Effective Cation Exchange Capacity

**Computation of Clay Dispersion Indices:** Dispersion ratio was obtained according to Middleton, 1930. Thus calculated as

$$DR = \frac{(\%\,silt + \%\,clay)(dispersed\,in\,calgon)}{(\%\,silt + \%clay)(dispersed\,in\,water)}$$

Silt clay ratio (SCR) was calculated by dividing the total percentage of silt with the total percentage of clay. This is expressed as

$$SCR = \frac{\%\ Silt}{\%\ Clay}$$

Clay flocculation index (CFI) was calculated by subtracting the total percentage of clay treated with Calgon from the total percentage of clay treated with water ($H_2O$) dividing it with the total percentage of clay treated with Calgon multiply by 100.
This is expressed as

$$CFI = \frac{\%\ clay\ (dispersed\ in\ calgon - \%\ clay\ (dispersed\ in\ water)}{\%\ clay\ (dispersed\ in\ calgon)}$$

Modified clay ratio (MCR) was determined by summing up the percent of sand with percent of silt divided with the sum of percent of clay and percent of organic matter. This was expressed as

$$MCR = \frac{\%\ silt + \%sand}{\%clay + \%organic\,matter}$$

ASC was expressed as
ASC = (% clay + % silt (calgon) - % clay + % silt ($H_2O$)
Clay ratio was calculated by dividing the percentage of sand and silt with the percentage of clay.
This is expressed as

$$CR = \frac{\%\ sand}{(\%silt + \%clay)}$$

Total free oxides were determined by the Diothionite Citrate Buffered (DCB) method. This was extracted with citrate buffer, amorphous form by ammonium NaOH solution, and the organic form by the pyrophosphate solution and the crystalline Fe and Al was equally determined (Holmogren's, 1967).

**Statistical Analysis**

The data generated were fitted into 3 x 5 factorial experiment of Completely Randomized Block Design. Descriptive statistical analysis of mean, standard deviation and co-efficient of variation were used to measure central tendency, while correlation analysis was used to establish the relationship between soil properties and clay dispersion indices.

**Results and Discussion**

**Effect of land use Practices on some Selected Soil Physical Properties.**

Physical Properties of soil under different land use types are presented on Table 1 Coarse sand ranges from 593-829gkg$^{-1}$ with mean value of 692± 9.54gkg$^{-1}$ (CV = 90.99%) at rubber plantation, mean value of 723±8.70gkg$^{-1}$ (CV = 75.67%) at oil palm plantation and with mean value of 648 ±5.19gkg$^{-1}$ (CV = 26.89%)in the forest plot. Find sand value ranges from 150-286gkg$^{-1}$ with mean value of 220±8.81gkg$^{-1}$ (CV = 77.61%) at rubber plantation, oil palm plantation ranges 69-219gkg$^{-1}$ with mean value of 127 ±5.66gkg$^{-1}$ (CV =31.99%), while forest plot ranges 133-260gkg$^{-1}$, with mean value177±5.07gk$^{-1}$ (CV = 25.69%). Total sand value ranges from 819-897gkg$^{-1}$ with mean value of 860±3.00 (CV = 9.01%) at rubber plantation. Oil palm plantation value ranges from 799-899gkg$^{-1}$ with mean value of 849± 4.72gkg$^{-1}$ (CV = 22.26%) while forest plot ranges from 755-877gkg$^{-1}$ with mean value of 825 ±4.82gkg$^{-1}$(CV= 23.24%). The highest sand fraction mean value was observed at the oil palm plantation and the lowest value was observed at the forest plot.

**Table 1: Variability in Soil Physical Properties in the Study Area**

| Land Use Type | CS | FS | TS | Silt | Cl | Bd | Tp | Ksat |
|---|---|---|---|---|---|---|---|---|
| | ← | | gkg$^{-1}$ | | → | mgm$^{-3}$ | m$^3$m$^{-3}$ | cmhr$^{-1}$ |
| **Rubber Plantation (RP)** | | | | | | | | |
| Mean | 692 | 220 | 860 | 25.2 | 115 | 1.31 | 0.51 | 0.32 |
| Std(±) | 9.54 | 8.81 | 3.0 | 2.05 | 1.91 | 0.21 | 7.76 | 0.27 |
| CV (%) | 90.99 | 77.61 | 9.01 | 1.19 | 3.67 | 0.04 | 60.25 | 0.07 |
| **Oil Palm Plantation (OPP)** | | | | | | | | |
| Mean | 723 | 127 | 849 | 49.2 | 100 | 1.69 | 0.36 | 0.08 |
| Std(±) | 8.70 | 5.66 | 4.72 | 4.17 | 3.52 | 0.25 | 9.38 | 0.04 |
| CV (%) | 75.67 | 31.99 | 22.26 | 17.39 | 12.37 | 0.06 | 88.07 | 0.00 |
| **Forest Plot (FP)** | | | | | | | | |
| Mean | 648 | 177 | 825 | 72.5 | 102 | 1.47 | 0.44 | 0.11 |
| Std(±) | 5.19 | 5.07 | 4.82 | 2.23 | 2.64 | 0.16 | 0.89 | 0.06 |
| CV (%) | 26.89 | 25.67 | 23.24 | 4.95 | 6.99 | 0.02 | 34.79 | 0.00 |

L = Location; Cs = Coarse sand; Fs= Fine sand; Ts = Total sand; Si = Silt; Cl = Clay; Bd – Bulk density, TP – Total Porosity, Ksat – Hydraulic conductivity.

The silt content value ranges between 10-60gkg-1 with mean value of 25.2+-2.05 (CV =1.19) at rubber plantation, at oil palm plantation, mean value ranges from 12-103gkg-1 with mean value of 49.2+-4.17 (CV =17.39), at Forest plot value ranges from 45-104gkg$^{-1}$ with mean value of 92.5+-2.23 (CV =4.95) The result of silt content in Table 1, were lower than the other particle size irrespective of the land use practices. Low silt content has been reported for many soil derived from the coastal plain sand in southeastern Nigeria (Essien *et al.*, 2019). The clay content recorded at rubber plantation ranged between

93-141gkg$^{-1}$ with mean value of 115± 1.91gkg$^{-1}$ (CV =3.67%) oil palm plantation, range between 79-161 gkg$^{-1}$ with mean value of 100± 3.52 (CV = 12.37%) Forest plot value ranges between 78-139, with mean value of 102-±2.64 (CV=6.99). Amusan *et al.*, (2001) reported that translocation of colloidal clay particle deep into the profile with percolating water, transport fine particles during heavy downpour, which seal pore space, thus reduces infiltration rate could have been one of the factors responsible. Bulk density in Table 1 shows that rubber plantation, location 1 and 2 (1.09 Mgm$^{-3}$) recorded lowest value, while oil palm plantation, location 5 recorded the highest value (2.10 Mgm$^{-3}$). Oil palm plantation, ranged between 1.44-2.10 Mgm$^{-3}$ with mean value of 1.69± 0.25 Mgm$^{-3}$ (CV =0.06%) > forest plot, range between 1.21-1.61Mgm$^{-3}$, of 1.147± 0.16 Mgm$^{-3}$ (CV = 0.02%) > rubber plantation range between 1.09-1.49 Mgm$^{-3}$ with mean value of 1.31± 0.21 Mgm$^{-3}$ (CV=0.04) (forest plot). As reported by Ijah, C. J., Umoh, F. O. Essien. O. A., Itakufok, U. G. and Moses, V. I. (2023), it may be due to soil being undisturbed and has consolidated for over a period of 10 years.

Total porosity in Table 1, indicated that rubber plantation ranged between 43.70-59.16 m$^3$m$^{-3}$, with mean value of 50.61 ± 7.76 m$^3$m$^{-3}$, (CV = 60.25%) > forest plot, ranged between 39.25-54.18m$^3$m$^{-3}$ with mean value of 44.39± 5.89 (CV = 34.79%) > oil palm plantation, range between 20.91-45.54 m$^3$m$^{-3}$, with mean value of 36.37± 9.38m$^3$m$^{-3}$ (CV = 88.07%). The result shows that on a volume weighted basis, rubber plantation have more total space than others. The variation in matrix pore space observed in bulk density, and is affected by particle – size distribution (Lal and Shukla, 2004). The result indicates that rubber plantation had moderate hydraulic conductivity, while forest and oil palm plantation had very slow hydraulic conductivity (FAO, 2006).

**Effect of Land Use Practices on Some Selected Soil Chemical Properties**

Soil chemical properties influenced by land use practice in Table 2, shows that in rubber plantation, pH ranges from 4.7-5.6 with mean value of 5.34 ± 0.38 (CV = 0.14%), for oil palm plantation; 5.0-5.5 with mean value of 5.28± 0.19 (CV = 0.04%) Highest value of pH mean was observed at rubber plantation and the least mean value was observed at forest plot. Soil P$^H$ of the area was slightly acidic in line with the findings of Essien and Ogban (2016).

**Table 2: Variability in Soil Chemical Properties in the Study Area**

| Land use type | pH (H20) | OC % | TN % | Av.P Mgkg-1 | K | Ca | Mg | Na Cmolkg-1 | EA | ECEC | Bsat % | AI Mgkg-1 | Fe Mgkg-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RUBBER PLANTATION | | | | | | | | | | | | | |
| Mean | **3.34** | **3.46** | **0.15** | **2.62** | **0.12** | **3.31** | **0.41** | **0.06** | **1.92** | **6.01** | **64.3** | **0.15** | **0.47** |
| Std(±) | **3.38** | **1.68** | **0.07** | **2.24** | **0.01** | **0.60** | **0.44** | **0.00** | **0.47** | **1.08** | **4.30** | **0.03** | **0.07** |
| CV(%) | **0.14** | **2.81** | **0.01** | **5.012** | **0.00** | **0.38** | **0.19** | **0.00** | **0.23** | **1.16** | **18.3** | **0.00** | **0.00** |
| OIL PALM PLANTATION (OPP) | | | | | | | | | | | | | |
| Mean | **5.28** | **3.45** | **0.15** | **0.15** | **30.48** | **4.0** | **1.15** | **0.06** | **1.73** | **7.03** | **79.18** | **0.19** | **0.22** |
| Std(±) | **0.19** | **0.39** | **0.28** | **0.28** | **5.73** | **0.97** | **0.87** | **0.01** | **0.23** | **0.97** | **3.46** | **0.04** | **0.05** |
| CV(%) | **0.04** | **0.35** | **0.001** | **0.001** | **32.86** | **0.94** | **0.76** | **0.00** | **0.05** | **0.93** | **14.83** | **0.00** | **0.04** |
| FOREST PLOT (FP) | | | | | | | | | | | | | |
| Mean | **5.2** | **4.10** | **0.18** | **27.92** | **0.12** | **2.83** | **1.68** | **0.06** | **1.98** | **6.67** | **70.26** | **0.17** | **0.19** |
| Std(±) | **0.44** | **0.73** | **0.03** | **4.40** | **0.01** | **0.94** | **0.56** | **0.00** | **0.43** | **1.04** | **5.01** | **0.03** | **0.03** |
| CV(%) | **0.19** | **0.53** | **0.00** | **19.39** | **0.00** | **0.88** | **0.32** | **0.00** | **0.19** | **1.08** | **25.11** | **0.00** | **0.00** |

**OC - Organic carbon, TN - Total nitrogen, Av.P – Available Phosphorus, K – Potassium, Ca -Calcium, Mg – Magnesium, Na – Sodium, EA – Exchangeable acidity, ECEC – Effective cation exchange capacity, Bsat – Base saturation, AI – Aluminum, Fe - Iron**

Organic carbon ranges from 2.49-6.44% with mean value of 3.46 ± 1.68% (CV = 2.81%) at rubber plantation; 3.09 -4.49% with mean value of 3.45±0.59% (CV = 0.35%) at oil palm plantation and 3.19 – 5.15% with mean value of 4.10± 0.73% (CV = 0.53%) at forest plot. Organic carbon content on forest plot was low. This disparity and low content of organic carbon could be caused by localized variation and low supply of organic matter across the land use types. Available Phosphorus content in the soil ranges from 2.35-2.83 $mgkg^{-1}$ with mean value of 2.62± 2.24 $mgk^{g-1}$ (CV = 5.012%) at rubber plantation; 2.61-0.20 $mgkg^{-1}$ with mean value of 0.15± 0.28$mgk^{g-1}$ (CV = 0.001%) at oil palm plantation and 22.38-33.57 $mgkg^{-1}$ with mean value of 27.92 ± 4.40 $mgkg^{-1}$ (CV = 19.39%) at forest plot. Highest value of mean was observed at oil palm plantation, followed by forest plot and rubber plantation.

Exchangeable potassium (K) content in the soil ranges from 0.11-0.12 cmol $kg^{-1}$ with mean value of 0.12±0.01 (CV = 0.00%) at rubber plantation; 26.11 – 40.50 cmol kg-1 with mean value of 30.48±5.73 (CV =32.86%) in oil palm plantation and 0.12 – 0.12 cmol $kg^{-1}$ with mean value of 0.12±0.01 (CV = 0.00%) in forest plot. The highest mean value was the same in the three land use types and forest plot.

Exchangeable calcium (Ca) content in the soil ranges from 2.4-3.8 4$cmolkg^{-1}$ with mean value of 3.31±0.60 (CV = 0.38%) in rubber plantation; 2.9-5.5 cmol $k^{g-1}$ with mean value of 4.0±0.97 (CV =0.94%) in oil palm plantation and 1.92-3.84 cmol $kg^{-1}$ with mean value of 2.83±0.94(CV =0.88%) in forest plot. Highest value was observed in oil palm plantation while the lowest value was observed in forest plot. Exchangeable magnesium (Mg) content in the soil ranges from 0.24-1.20 cmol $kg^{-1}$ with mean value of 0.62±0.44 cmol $kg^{-1}$ (CV 0.19%) in rubber plantation; 0.24-3.40 cmol kg-

$^{1}$ with mean value of 1.15±0-87 cmol kg$^{-1}$ (CV = 0.76%) in oil palm plantation and 0.72-2.16cmol kg$^{-1}$ with mean value of 1.68±0.56 cmol kg$^{-1}$ (CV = 0.32%) in forest plot. Forest plot recorded the highest mean value, while rubber plantation recorded the lowest mean value and same with oil palm plantation.

Exchangeable sodium (Na) content in the soil ranges from 0.06-0.06 cmol kg$^{-1}$ with mean value of 0.06±0.00 cmol kg$^{-1}$ (CV = 0.00%) in rubber plantation; 0.06 to 0.07 cmol kg$^{-1}$ with mean value of 0.06±0.00 (CV = 0.00%) in oil palm plantation and 0.06-0.06 cmol kg$^{-1}$ with mean value of 0.06±0.00 cmol kg$^{-1}$ (CV = 0.00%) in forest plot. The highest mean value was observed in oil palm plantation and the three land used types recorded the same lowest mean value. Exchangeable Acidity (EA) had values ranging from 1.26-2.52 cmol kg$^{-1}$ with a mean of 1.92±0.47 cmol kg$^{-1}$ (CV = 0.23%) in rubber plantation; 1.44-2.04 cmol kg$^{-1}$ with a mean value of 1.73±0.22 cmol kg$^{-1}$ (CV = 0.05%) in oil palm plantation and 1.26-2.40 cmol kg-1 with mean value of 1.98±0.43 cmol kg-1 (CV = 0.19%) in forest plot. The highest mean value was observed in rubber plantation followed by forest plot and followed by oil palm plantation, while the lowest was observed in rubber plantation. Effective cations exchangeable capacity (ECEC) ranges from 4.80-7.73 cmol kg$^{-1}$ with a mean value of 6.03±1.08 cmol kg$^{-1}$ (CV = 1.16%) in rubber plantation; 6.18-8.35 cmol kg$^{-1}$ with a mean of 6.03±1.98 cmol kg$^{-1}$ (CV = 1.16%) in rubber plantation; 5.52-8.04 cmol kg$^{-1}$ with a mean value of 6.67±1.04 cmol kg$^{-1}$ (CV =1.08%) in forest plot. The highest mean was observed at oil palm plantation and the lowest mean value was obtained at rubber plantation. ECEC did not follow a specific trend as a result of difference in soil properties other land use type that affected ECEC. All land use types had low values of ECEC (Udo *et al.*, 2009). This could be as a result of the continuous cropping and environmental deterioration in the coastal plain sand.

Base saturation ranges from 63.3-73.7 with a mean value of 68.3±4.30 (CV = 18.5%) in rubber plantation; 69.90–79.80 with a mean value of 75.18±3.86% (CV = 18.5%) in oil palm plantation; 65.5-77.1% with a mean value of 70.26±5.01% (CV = 25.11%) at forest plot. Highest mean value was observed at oil palm plantation and the lowest value was obtained in rubber plantation. Exchangeable Aluminum (Al) ranges from 0.10-1.17% mgkg$^{-1}$ with a mean value of 0.15±0.03 mgkg$^{-1}$ (CV=0.00%) in rubber plantation; 0.14-0.24 mgkg$^{-1}$ with a mean value of 0.19±0.04 mgkg$^{-1}$ (CV = 0.00%) in oil palm plantation and 0.13-0.19 mgkg$^{-1}$ with a mean value of 0.17±0.03 mgkg$^{-1}$ (CV =0.00%) in forest plot. Highest mean value was observed a t rubber plantation while the lowest mean value was obtained at forest plot. Iron (Fe) content in the soil ranges from 0.11-0.18 mgkg$^{-1}$ with a mean value of 0.47±0.09 mgkg$^{-1}$ (CV = 0.00%) at rubber plantation; 0.16-0.27 mgkg$^{-1}$ with a mean value of 0.22±0.05 mgkg$^{-1}$ (CV = 0.00%) at oil palm plantation and 0.15-0.22 mgkg$^{-1}$ with a mean value of 0.19± 0.03 mgkg$^{-1}$ (CV = 0.00%) at forest plot.

**Effect of Land Use Practices on Clay Dispersion Indices**

Clay dispersion indices are shown in Table 4.3 Figure 4.1, 4.2 and 4.3 The dispersion ratio (DR) indicated that rubber plantation varied between 0.994 – 1.115 with mean value of 1.044 ± 0.050 (CV= 4.7%) > 1.030 – 1.109 with mean value of 1.069 ± 0.029 (CV = 2.7%) and 1.006 – 1.051 with mean value of 1.017 ± 0.199 (CV = 19.5%) in forest and oil palm plantation, respectively. There was a variation in dispersion ratio among the three land use practices. This may be due to the weakening of bond and cementing agent that bind aggregate together, that rendered the soils the of the area susceptible to rain splash and scouring effect of water erosion. Hillel (1998) indicated that dispersion depends on the clay mineralogy and chemical composition of the soils in the study area.

Silt clay ratio (SCR): Another index of clay dispersion ratio. Result presented in Table 4.3 showed that forest plot varied between 0.575 – 0.824 with mean value of o.702 ± 0.092 (CV = 13.1%) > 0.020 -1.302 with mean value of 0.567 ± 0.553 (CV = 97.3%) and 0.087-0.497 with mean value of 0.217 ± 0.167 (CV= 76.9%), respectively. The result in figure 2 and 3 shows that location 1 and5 in rubber and oil palm plantation (0.02, 0.087 and 0.099) respectively, recorded the least value of SCR. The dispersion of fine materials had negative and undesirable effect in hindering infiltration and retention of water, porosity and fertility of the soil in study area. Evaluation of the effect of land use practices on clay flocculation index (CFI) in table revealed that oil palm plantation varied between 0.486-0.656 with mean value of 0.537 ± 0.072 (CV = 13.3%) > 0.125-0.646 with mean value of 0.454 ± 0.211 (CV = 46.4%) and 0.160 – 0.720

with mean value of 0.433 ± 0.236 (CV = 54.4%). The high CFI in rubber plantation location 1 and 5 (Figure 3) and oil palm plantation in location 4 (Figure 2) implies that soils of those locations are structurally stable. This is because the resistance in breaking down of aggregate into individual particles decreases with increase in clay flocculation index of the soil.

Modified clay ratio (MCR) index (Figure 3) shows that forest plot varied between 0.960 – 0.985 with mean value of 0.967 ± 0.010 (CV = 1.0%) > 0.875 – 1.027 with mean value of 0.949 ± 0.064 (CV = 6.7%) and 0.870 – 0.935 with mean value of 0.908 ± 0.025 (CV = 2.7%) in rubber and oil palm plantations respectively. Clay ratio (CR) in Table 4.3 is one of the clay dispersion indices that can be used to infer soil erodibility. The values in oil palm plantation ranged between 4.530 – 8.746, with mean value of 6.424 ± 1.617 (CV = 25.1%) > 3.972 – 8.900 with mean value of 6.26 ± 2.39 (CV = 38.1%) in rubber plantation > 3.116 – 7.128 with mean value of 5.061 ± 1.596 (CV =31.5%) in forest plot. The high CR recorded in rubber plantation L 1 and 2 (Figure 1), oil palm plantation L 4 and 5 (Figure 4) and forest plot Locations 2 and 3 (Figure 3), the variability in values obtained could be due to textural characteristics or different composition of the organic matter.

The high clay ratio in oil palm plantation thus suggested that the soils might resist slaking and dispersion in water. Clay dispersion ratio (CDR) in Table 3 revealed that rubber plantation ranged between 0.280 – 0.840 with mean value of 0.566 ± 0.236 (CV= 41.6%) > 0.357 – 0.875 with mean value of 0.546 ± 0.210 (CV= 38.4%) in forest plot > 0.344 – 0.514 with mean value of 0.462 ± 0.072 (CV= 15.5%). The high CDR is detrimental to the soil depending on the infiltration capacity and structural stability of the soil surface layers. Consequently, fine soil particles are dislodged and clog soil pores reducing rain water infiltration and enhancing soil erosion especially in unstable soils (Ogban, P. I., Ibotto, M. I., Utin, U. E., Essien, O. A. and Arthur, G. J., 2022).

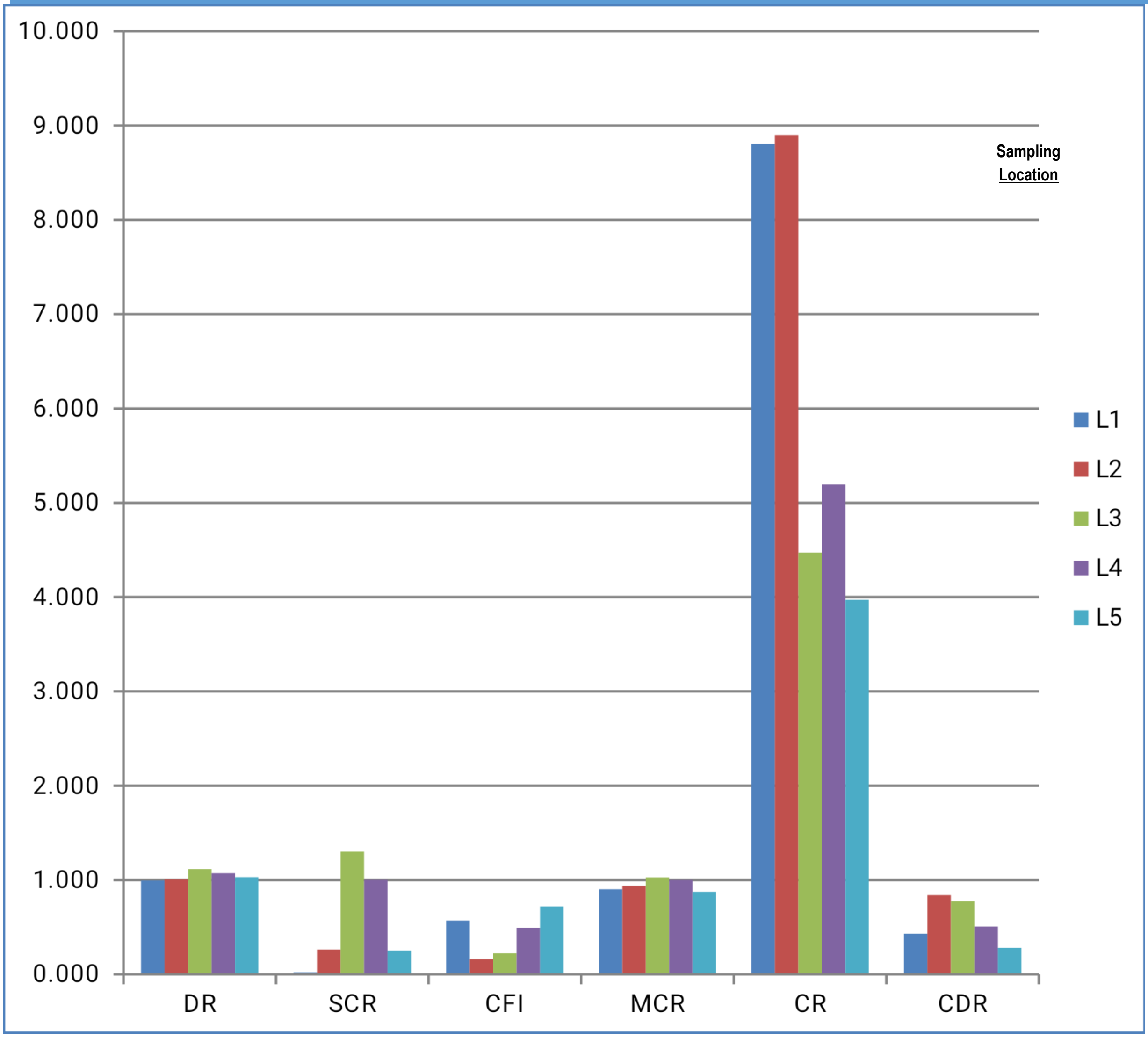


**Figure 1: Clay dispersion indices in Rubber Plantation**

DR-dispersion ratio, SCR- silt clay ratio, CFI- clay flocculation index, MCR- modified clay ratio, CR- clay ratio, CDR- clay dispersion ratio.

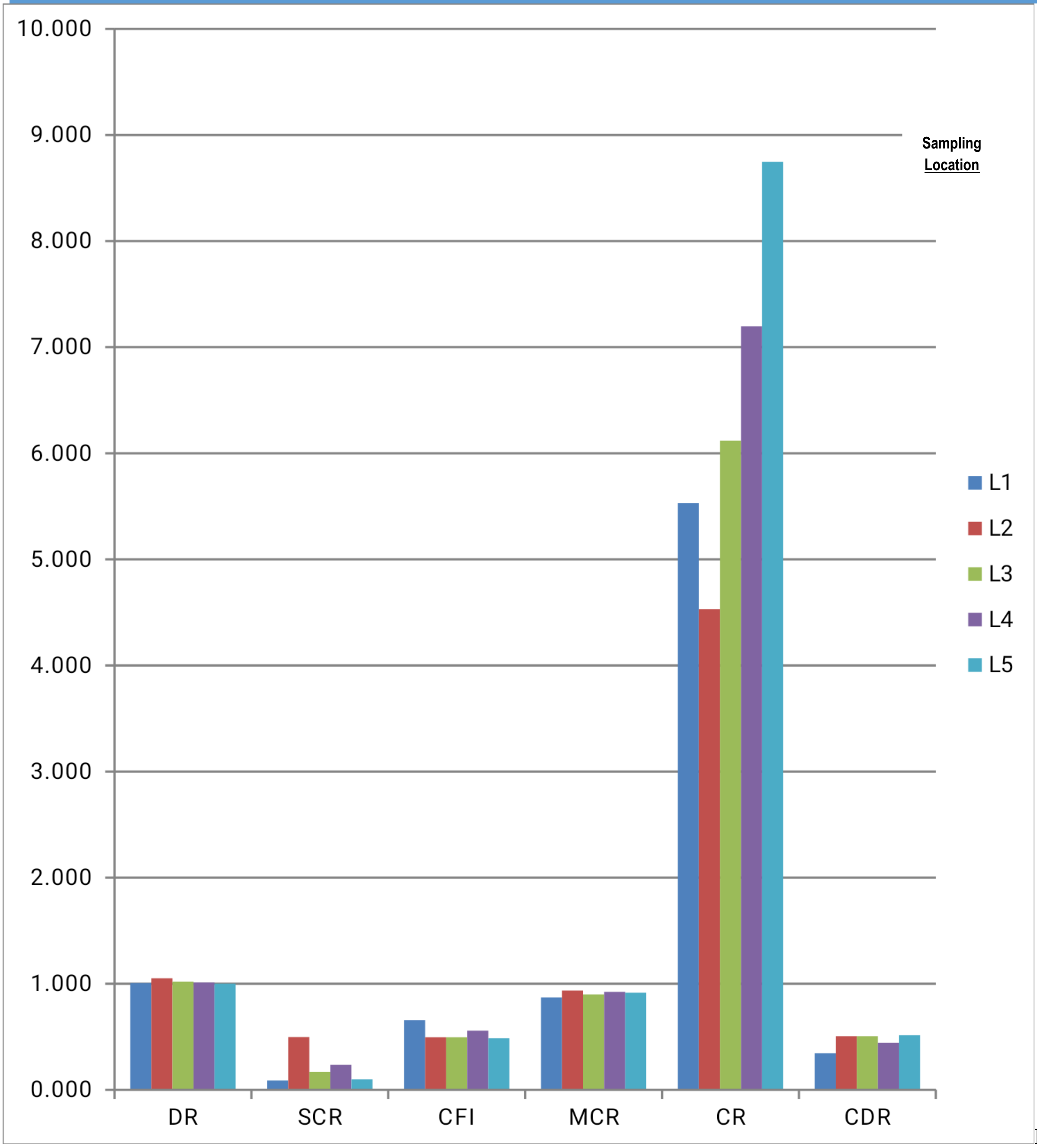


**Figure 2: Clay dispersion indices in Oil Palm Plantation plots.**

L- location, DR-dispersion ratio, SCR- silt clay ratio, CFI- clay flocculation index, MCR- modified clay ratio, CR- clay ratio, CDR- clay dispersion ratio.

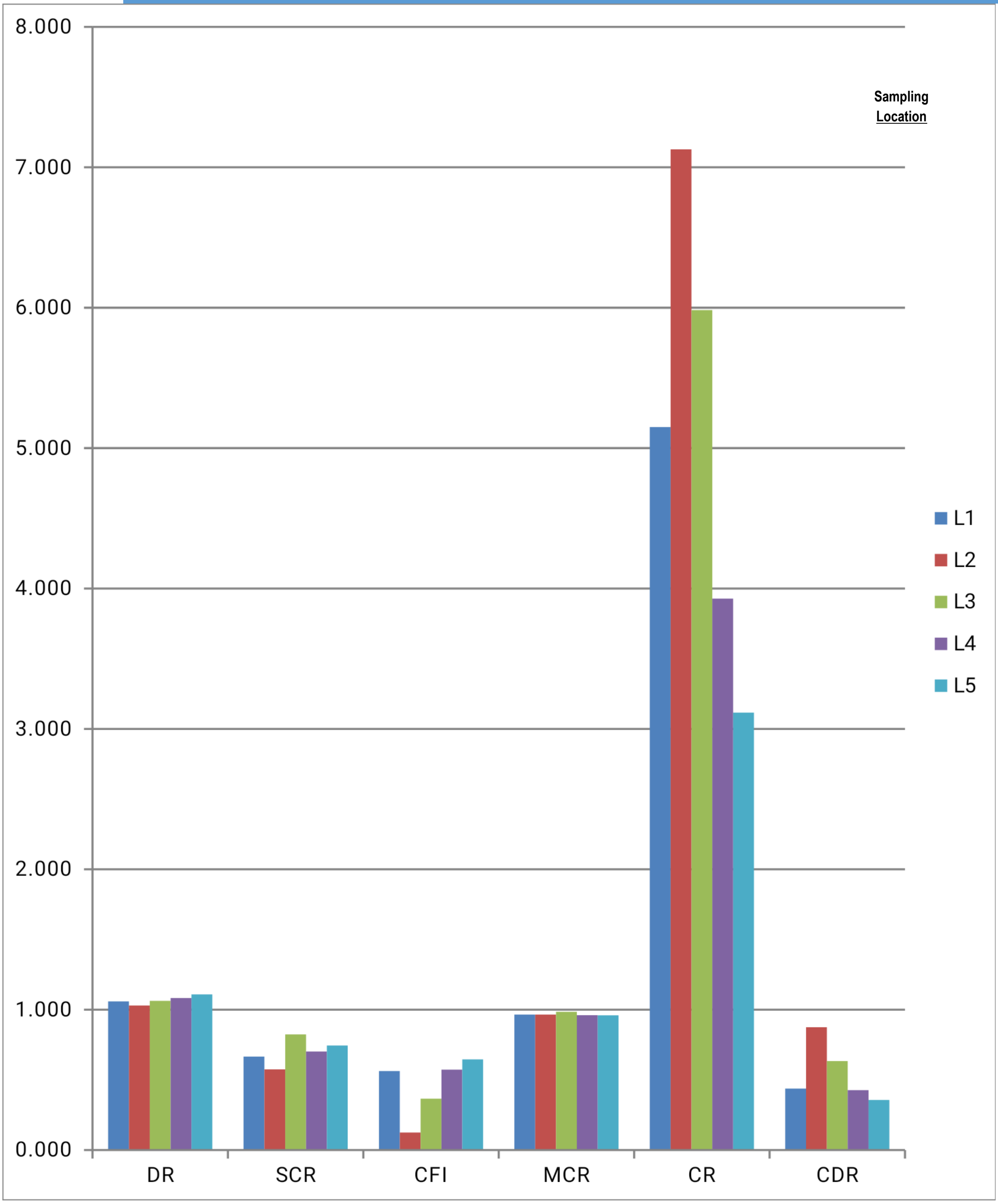


**Figure 3: Clay dispersion indices in Forest plots.**

L- location, DR-dispersion ratio, SCR- silt clay ratio, CFI- clay flocculation index, MCR- modified clay ratio, CR- clay ratio, CDR- clay dispersion ratio.

**Table 3: Variability in Clay Dispersion Indices in the Study Area**

| Land Use Practice | DR | SCR | CFI | MCR | CR | CDR |
|---|---|---|---|---|---|---|
| **Rubber** | **Plantation** | | | | | |
| Mean | 1.044 | 0.567 | 0.433 | 0.949 | 6.26 | 0.566 |
| Std (t)(±) | 0.050 | 0.553 | 0.236 | 0.064 | 2.39 | 0.236 |
| CV (%) | 4.7 | 97.3 | 54.4 | 6.7 | 38.1 | 41.6 |
| **Oil Palm** | **Plantation** | | | | | |
| Mean | 1.017 | 0.217 | 0.537 | 0.908 | 6.424 | 0.462 |
| Std (t) (±) | 0.199 | 0.167 | 0.072 | 0.025 | 1.617 | 0.072 |
| CV (%) | 19.5 | 76.9 | 13.3 | 2.7 | 25.1 | 15.5 |
| **Forest Plot** | | | | | | |
| Mean | 1.069 | 0.702 | 0.454 | 0.967 | 5.061 | 0.546 |
| Std (t)(±) | 0.029 | 0.092 | 0.211 | 0.010 | 1.596 | 0.210 |
| CV (%) | 2.7 | 13.1 | 46.4 | 1.0 | 31.5 | 38.4 |

**DR:** Dispersion Ratio; **SCR:** Silt Clay Ratio; **CFI:** Clay Flocculation Index; **MCR:** Modified Clay Ratio; **CR:** Clay Ratio; **CDR:** Clay Dispersion Ratio.

**Table 4: Pearson Correlation Matrix of Soil Physical Properties and Clay Dispersion Indices of the Soils in the Study Area**

| | Ts | Si | Cl | Tp | Bd | Ksat | DR | SCR | CFI | MCR | CR | CDR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ts | 1.000 | | | | | | | | | | | |
| Si | -0.779* | 1.000 | | | | | | | | | | |
| Cl | -0.436 | -0.143 | 1.000 | | | | | | | | | |
| Tp | 0.084 | -0.054 | -0.190 | 1.000 | | | | | | | | |
| Bd | -0.084 | 0.054 | 0.190 | -1.000* | 1.000 | | | | | | | |
| Ksat | 0.009 | 0.020 | -0.057 | 0.759* | -0.759 | 1.000 | | | | | | |
| DR | -0.214 | -0.104 | -0.616 | -0.034 | 0.034 | -0.018 | 1.000 | | | | | |
| SCR | -0.196 | 0.068 | -0.432 | -0.025 | 0.025 | -0.007 | 0.939* | 1.000 | | | | |
| CFI | -0.034 | -0.313 | 0.892* | -0.336 | 0.336 | -0.136 | -0.070 | -0.318 | 1.000 | | | |
| MCR | -0.134 | 0.163 | 0.726* | -0.086 | -0.086 | 0.074 | 0.761* | 0.906* | -0.564* | 1.000 | | |
| CR | -0.150 | 0.189 | -0.436 | 0.084 | -0.084 | 0.009 | -0.782* | -0.571* | -0.484 | -0.245 | 1.000 | |
| CDR | 0.034 | 0.313 | -0.892* | 0.336 | -0.336 | 0.136 | 0.070 | 0.318 | -1.000* | 0.564* | 0.484 | 1.000 |

Ts – Total sand, Si – Silt, Cl - Clay, Tp – Total porosity, Bd – Bulk density, Ksat – Saturated hydraulic conductivity, DR – Dispersion ratio, SCR – Silt clay ratio, CFI – Clay flocculation index, CR – Clay ratio, CDR – Clay dispersion

**Relationship Between Soil Physical Properties and Clay Dispersion Indices**

Table 4 shows the relationship between soil physical properties and indices of clay dispersion. Clay dispersion is a sign of soil instability (Ogban and Essien, 2016). Soil stability against dispersion is an important phenomenon that checks soil degradation. The results show that Silt was negatively correlated with Sand (-0.779*). Bulk density negatively correlated with Sand and total porosity (-0.084* and -1.000*). The relationship is critical because high Sand and total porosity increases the rate of infiltration that wash away soil nutrient down the profile, thus rendering the top soil infertile and porous, as such the soil of the area cannot retain water and plant nutrient.

Ksat correlated positively with TP (0.759*) and negatively with bulk density (-0.759*). The positively relationship with total porosity, signify easily penetration of water, while high bulk density impede water and plant root penetration, thereby retard growth and development of plant. Also the relationship implies that Ksat increases with increase in total porosity and decreases with high bulk density, depending on the severity of erosion, this may lead to increase in erosivity. Silt clay ratio significantly correlated with DR (0.939*). The relationship shows that silt clay ratio brings about stability of aggregate, also is an index of aggregation. The susceptibility of soil to erosion reduces with increase in silt clay ratio.

Clay flocculation index positively significantly correlated with clay ratio (0.892*). The positive relationship introduced bond that bind aggregates and are resistance to clay dispersion and may be effective in bringing inter-particles force in the Tropical soil (Ogban and Essien, 2016). Modified clay ratio positively significantly correlated with dispersion ratio and silt clay ratio (0.761* and 0.906*) and negatively significantly released with clay ratio and clay flocculation index (-0.726* and -0.564*). Clay ratio negatively significantly correlated with clay ratio, dispersion ratio and silt clay ratio (-0.436*, - 0.732* and - 0.571*). The negative relationship shows colloidal instability. Clay dispersion ratio positively significantly correlated with MCR (0.564*) and negatively significantly related with clay ratio and clay flocculation index (-0.892* and -1.000*). Clay dispersion ratio positively relationship with modified clay ratio, this implies that there is low resistance to the shearing force of water with modifies clay ratio.

**Conclusion and Recommendation**

The effect of land use practices, namely, Rubber Plantation (RP), Oil Palm Plantation (OPP) and Forest Plot (FP) on clay dispersion was examined on coastal plain sand, Southeastern Nigeria. Result indicated that clay dispersion indices (DR – dispersion ratio, SCR –silt clay ratio, CFI –clay flocculation index, MCR – modified clay ratio, CR- clay ratio and CDR – clay dispersion ratio) were at increase and soils in three land use practices shows colloidal instability. Rubber plantation recorded high clay dispersion than forest and oil palm plantation. The indices could be used to predict dispersion and the best method of soil management practices on the coastal plain sand in southeastern, Nigeria.

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