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Geospatial differences in organic carbon stock, structural and hydraulic properties of a coarse-textured soil under oil palm plantation

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ABSTRACT

Cropping systems can impact changes in the physicochemical conditions of soils across a given landmass, thereby influencing decisions on management strategies for soils under such use. The research was carried out to ascertain the spatial variation of organic carbon stock, structural, and hydraulic properties of soil under oil palm plantation. The research was laid out in a randomized complete block design. Nine replicates each of disturbed and undisturbed soil samples were randomly collected from the area at a depth of 0 – 20 cm. Soil parameters were determined in a laboratory, and data obtained were analyzed for spatial variation using geographical information system software. Organic carbon stock varied from 40 – 65 tons/ha, bulk density varied from 1.15 – 1.35 mg/m^3, saturated hydraulic conductivity varied from 2.70 – 3.05 cm/min, clay flocculation index varied from 64 – 70%, clay dispersion index varied from 30 – 36%, dispersion ratio varied from 5 – 25%, aggregated silt + clay varied from 16.5 – 20.5%, and mean weight diameter varied from 1.10 – 1.50 mm. Oil palm plantation influences the spatial condition of organic carbon stock and structural-hydraulic properties of soils under its coverage. Consequently, soil management strategies for the land must be designed to address the unique qualities of the various regions of the landmass.

Contribution/Originality: There is gap of knowledge on extent of variation of organic carbon stock, structural indices and hydraulic properties of soils under monocropping system of cultivating and managing oil palm plant. This study fits into the gap by providing such information qualitatively and quantitatively using range of values and arch maps, respectively.

1. INTRODUCTION

Cropping systems are among the land-use and soil management systems which have notable impact on the productivity and quality of agricultural soils [1]. Cropping systems comprise of types of crop and pattern of cultivating them over expanded period of time, and they are developed to improve crop production and ensure food security [2]. Meanwhile, the current emphasis on sustainable agriculture focuses on the cropping systems that do not only ensure food security, but also maintain and sustain quality environment including soil health and water quality [2]. Maintaining optimum soil and water quality in crop production greatly depends on rational implementation of cropping systems suitable for a given soil type under a prevailing climatic condition [2]. Consequently, cropping systems can greatly influence the nature and properties of soils within their coverage in such a way that the soils under such use vary in physical, chemical, and biological properties [3]. A suitable cropping system is one that is capable of attaining a dynamic equilibrium with its natural ecosystem, such that, there exists a harmonious interaction or balance between the system and its external environment with time [2]. This is achievable when the cropping system can ensure effective groundcover to regulate raindrop impact, moderate soil temperature, and promote organic matter return to the soil [4].

Oil palm plantation is usually established under monocropping system especially when it is fully grown to cover canopies, in such case, the crop is solely produced over expanded piece of land at determined spacing, and over a prolonged period of time [5]. In a fully grown oil palm plantation, the crop provides effective groundcover together with the low growing plants which are periodically slashed or allowed to remain bushy [6]. Therefore, the microclimate created within the plantation impacts the physical, chemical and biological properties of soil under the plantation compared to the adjacent soils [6]. However, there is speculation that soils in different regions of the plantation could differ in properties due to possible variations in microclimates, the rate of organic residue returning to the soil, and the degree of ground cover by the plants across the landmass [6, 7].

Variations in soil properties across a landmass under same vegetation cover or land-use is inherent in soil and applies to the concept of soil [8]. Reports have shown that soil organic carbon storage, structural and hydraulic properties of soil [8, 9] as well as chemical compositions of soil [5] differ across soils under similar vegetation type. Amanze, et al. [9] reported increase in organic carbon storage at regions of increased biomass and organic matter return to the soil, reduced disturbance on the soil, and good groundcover with its associated decrease in bulk density, improved soil aggregation and water transmission properties compared to other regions under same vegetation but of lesser organic residue return to the soil, poor groundcover, and increased disturbance to the soil. The understanding of spatial variation of soil physicochemical properties is relevant for effective management of soils against undue generalization; hence, it promotes the adoption of efficient and rational strategies for maintaining soil quality and productivity [9]. Soil organic carbon and structural properties are among the significant soil quality indicators which determine the degree of soil susceptibility to physical and chemical degradation including proneness to erosion [9]. Therefore, this study aims at assessing the spatial differences in organic carbon stock, structural and hydraulic properties of course-textured soil under an oil palm plantation in southeastern Nigeria.

2. MATERIALS AND METHODS

2.1. Location and Description of the Study Area

The study was conducted at Ndume Ibeku in Umuahia North LGA, Abia State. The area is within the humid tropical rainforest zone of Nigeria and lies on latitude 05°31″ 38.3″N to 05°31″ 37.2″N and longitude 07° 30″ 27.9″E to 07°30″ 26.2″E, with characteristic average rainfall distribution of 2200 mm per annum, and average yearly temperature of 28 °C [10]. There occurs in the area two notable seasons of climatic conditions which are rainy and dry seasons, such that the rain occurs within the months of March to October which peaks in July and September, and drops in August. The dry season on the other hand occurs from late November to late February of the year [11]. The landscape is flat to gently undulating, while the parent material is Coastal Plain Sands, and according to the United State Department of Agriculture (USDA) soil Taxonomy, the soil was classified as "Hapludult" and approximately correlated to Haplc Acrisol according to the FAO-UNESCO Soil map of the world legend [12].

2.2. Background Information on the Oil Palm Plantation

Table 1 provides some information about the soil chemical properties of the soil, its particles size distribution and soil textural class, as well as a brief history of the plantation, which captures the age of the plantation and its management.

Table 1. Background information on the oil palm plantation.

Soil characterization	History
pH = 5.40, total nitrogen = 1.5 g / kg, avail. P = 39.63 mg / kg, sand = 756 g / kg, silt = 101 g / kg, clay = 143 g / kg, textural class – sandy loam, soil taxonomical class = Haplic Acrisol.	The oil palm plantation has mean altitude of 163 masl, and was established for over 20 years. The alleys are not cultivated to crops but are covered by weeds which are slashed periodically and the biomass left at the ground to decay.

Note: Amanze, et al. [10].

In Table 1 the mean value of soil pH shows that the soil is strongly acidic, the organic carbon content is moderate, and the available phosphorus is high, while the textural class is sandy loam with moderate content of clay.

2.3. Soil Sampling and Sample Preparation

The collection of samples of soil was done through simple random sampling technic in which nine (9) representative auger and core soil samples were obtained at 0 – 20 cm depth. The auger soil samples were sent to the laboratory for processing and laboratory determinations, such as particle size distribution, mean weight diameter, and organic carbon content, while bulk density (BD) and saturated hydraulic conductivity were determined through the core soil samples. Table 2 provides some geographical information on the sampling points such as the elevation, as well as their latitude and longitudinal positions. Also, the geographical coordinates (latitude and longitude) provided in the Table 2 were used in producing the arch maps through geospatial analysis.

Table 2. Geographical position of the sampling points in the land area.

Cropping system	Sampling points	Elevation (masl)	Geographical locations
Monocropping (Oil palm plantation)	1	166	05°31' 37.6"N; 07°30' 26.7"E
	2	162	05°31' 38.1"N; 07°30' 26.2"E
	3	162	05°31' 38.3"N; 07°30' 26.6"E
	4	165	05°31' 38.5"N; 07°30' 27.1"E
	5	166	05°31' 38.2"N; 07°30' 27.6"E
	6	162	05°31' 37.8"N; 07°30' 27.2"E
	7	163	05°31' 37.7"N; 07° 30' 27.9"E
	8	162	05°31' 37.3"N; 07° 30' 27.1"E
	9	163	05°31' 37.2"N; 07° 30' 27.7"E

2.4. Laboratory Analysis

Particle size distribution was done using the hydrometer method under calgon and water dispersed soil conditions as explained in Gee and Or [13] and reported in Amanze, et al. [14] and the results were used to calculate for micro aggregate stability indices as shown below;

$$\text{\% Dispersion ratio} = \frac{\%[\text{Silt + Clay(H2O)}]}{\%[\text{Silt + Clay(calgon)}]} \text{ x } 100 \qquad (1)$$

Implications: increased value of dispersion ratio implies increased proneness of micro-aggregates to dispersion by water; hence, weak resistance to water erosion, vice versa.

$$\text{\% Aggregated Silt + Clay} = \%[\text{Silt + Clay(calgon)}] - \%[\text{Silt + Clay(H2O)}] \qquad (2)$$

Implications: Increased value of aggregated silt + clay is an indication of increased stability of micro-aggregates by water, hence, increased resistance to water erosion, vice versa.

$$\%\text{Clay flocculation index (CFI)} = \frac{\%\text{Clay(calgon)} - \%\text{ Clay(H2O)}}{\%\text{ Clay(calgon}} X\ 100 \qquad (3)$$

Implications: Increased value of clay flocculation index implies that the soil has increased stability of micro-aggregates against water dispersion; hence, increased resistance to water erosion, vice versa.

$$\%\text{Clay dispersion index (CDI} = \frac{\%\text{ Clay (H2O)}}{\%\text{Clay (calgon)}} X\ 100 \qquad (4)$$

Implications: Increased value of clay dispersion index implies increased possibility of breakdown of micro-aggregates by water; hence, weak resistance to water erosion and increased loss of clay particles, vice versa.

Mean weight diameter (MWD) of Water Stable Aggregates (WSA) was determined by the wet-sieving method of Kemper and Rosenau [15]. Here, the dry mass of the various sizes of water stable aggregates were determined from 25 g of wet-sieved soil. The water stable aggregates (WSA) were categorized into 4 – 2, 2 – 1, 1 – 0.5, 0.5 – 0.25 and <0.25 based on the sieve sizes. Then the proportion by dry mass of each group of water stable aggregates in each sieve was calculated as shown in Equation 5.

$$Water\ Stable\ Aggregates = \frac{dry\ mass\ of\ resistant\ aggregates}{total\ dry\ mass\ of\ the\ wet-sieved\ soil} \qquad (5)$$

Mean weight diameter (MWD) of the water stable aggregates was calculated as:

$$MWD = \sum_{i=1}^{n} XiWi \qquad (6)$$

Where Xi is the mean diameter of each of the ith sieve category, and Wi is the proportion of the dry mass of aggregates in the ith sieve.

Bulk density (BD) was determined using the core method explained in Anderson and Ingram [16] and reported in Amanze, et al. [9] here, the oven-dried mass of the soils were obtained, and BD was calculated as shown in Equation 6;

$$BD = \frac{\text{Mass of oven dried soil}}{\text{Bulk volume of the soil}} \qquad (6)$$

Bulk volume of the soil is the volume of cylindrical core sampler calculated from the $\pi r^2 h$ where $\pi = 3.142$, r is the inner radius of the base of the cylindrical core sampler and h is the height.

Total porosity (TP) was obtained by calculation using the values for the bulk density of the soils, given particle density of 2.65 mg/m^3 as shown in Equation 7;

$$\%\ Total\ porosity = 1 - \frac{bulk\ density}{particle\ density} X\ 100 \qquad (7)$$

Saturated hydraulic conductivity (K_{sat}) was determined by the constant head method of Klute [17]. In this method, the core sample of soil was trimmed at both ends. A piece of cheese cloth was tied at the base of the core soil with a rubber band. The core sample was allowed to saturate in water. To start the determination, an empty core with same diameter was placed on top of the soil core samples and held in place with masking tape and wax while ensuring no water leakage. A constant head of water was maintained above the sample. Water flow rate was observed and recorded when constant for three consecutive runs. Saturated hydraulic conductivity (K_{sat}) of the soil was calculated using Darcy's equation as explained by Youngs [18] shown below.

$$Ksat = \frac{QL}{AT\Delta H} \qquad (8)$$

Where Q, L, A, ΔH, and T in the equation represent quantity of water discharged (cm^3), length of soil column (cm), interior cross – sectional area of the soil column (cm^2), head pressure difference causing the flow or hydraulic gradient, and time of water flow (s), respectively.

Dichromate oxidation method explained in Nelson and Sommers [19] was employed to analyze for organic carbon content, then organic carbon pool of the soil was calculated using the formula provided in Amanze, et al. [11].

$$C_T = C_F \, x \, q \, x \, D \, x \, 1 \, ha \qquad (9)$$

Where C_T, C_F, q, and D in the formula are respectively, total organic carbon pool for the layer (metric ton), fraction of carbon (percentage carbon divided by 100), bulk density of the soil, and depth of the soil layer (m)

2.5. Data Analyses

Soil data obtained were analyzed for spatial variability using a GIS analytical software package in line with the geographical coordinates of the sampling points [14].

3. RESULTS AND DISCUSSION

3.1. Variation of Organic Carbon Stock and Bulk Density of the Soils

Figure 1a shows that organic carbon stock of the soils varied from 40 – 65 tons / ha with its highest concentration observed at the Northeast, extreme Southeast, and border part of the Northwestern region of the land. On the contrary, the lowest concentration of organic carbon stock was observed within the central region of the land, and extended to the Southwest and part of Southeast, then to a portion of the Northwestern regions of the land. Figure 1b shows that bulk density varies from 1.15 – 1.35 mg / m^3, with the highest soil compaction observed at the Northeast, extreme portions of Northwest and Southeast regions of the land, while the regions of decreased soil compaction occurred at the central portion of the Southern region, and extended from the central part of the land to a localized portion of the Northwest and middle eastern regions of the land.

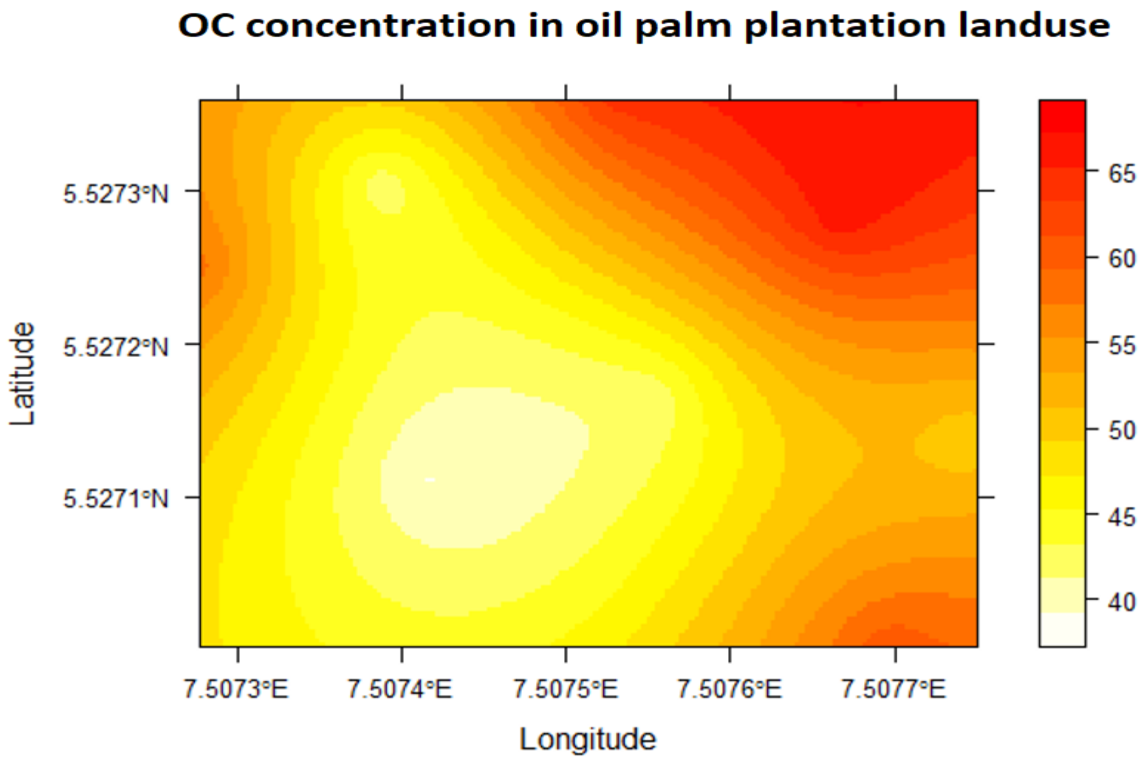

Figure 1a. Variation of Organic carbon stock (ton / ha).

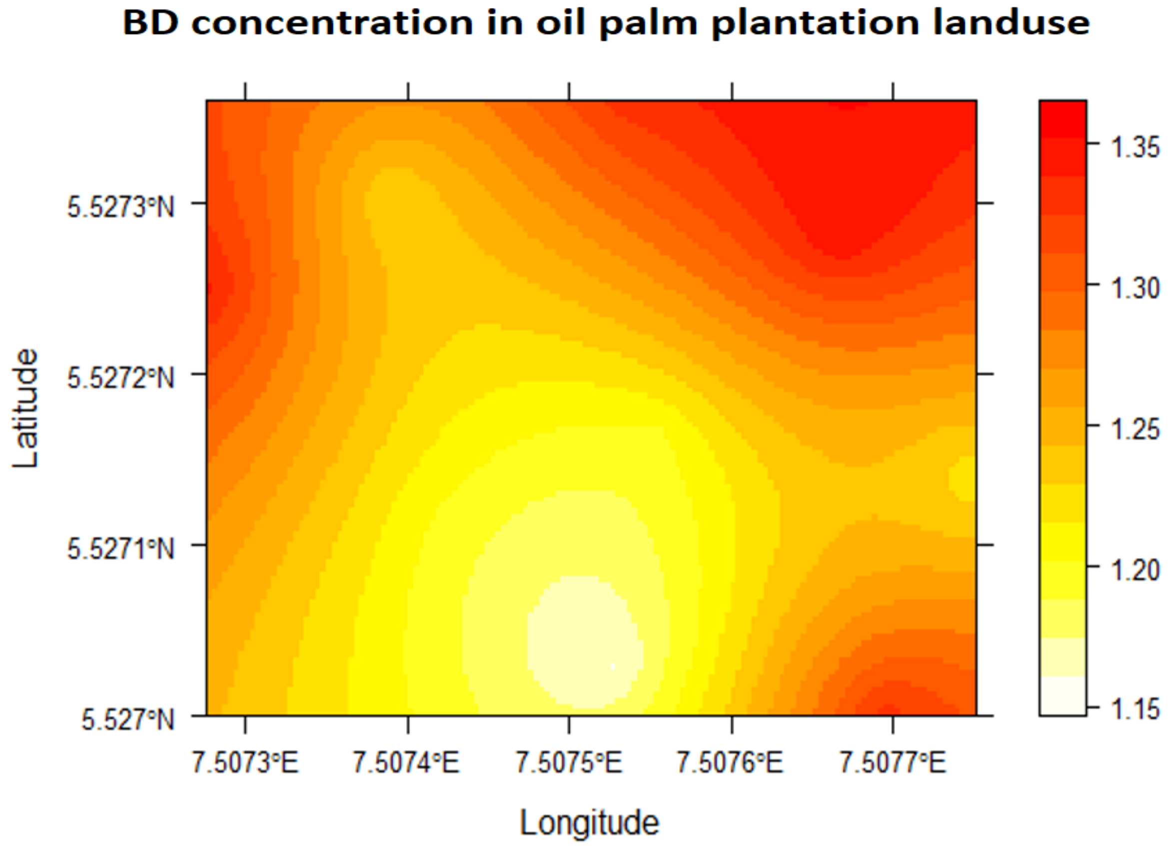

Figure 1b. Variation of Bulk density (mg / m³).

The variation in organic carbon stock across the soils at the oil palm plantation could be attributed to the differences in the rate of residue return to the soil through litter fall, and the possible differences in the microclimate of various regions of the land with regards to sunlight penetration, temperature, and relative humidity, which are known to have direct and indirect influence on the rate of organic matter decomposition [20]. Regions of greater organic carbon stock may have been favoured by a microclimatic condition that helped to reduce the rate of organic matter decomposition, vice versa. Consequently, regions of the land with greater organic carbon stock will be characterized by increased microbial population and activities with resultant effect of increased nutrients transformation, improved soil health and quality, as well as optimum plant nutrients availability for effective and sustained crop production [21].

It could also be inferred that the variation in bulk density across soils of they may be associated with possible differences in degree of groundcover by the canopies of the oil palm trees across the land area. This variation in groundcover may have influenced the intensity of raindrop impacts on the soils at varying regions of the land which resulted to differences in bulk density across the soils of the land area. This finding corroborates the report of Bronick and Lal [22] that raindrop impacts on soils significantly influenced the bulk density of soils such that the greater the raindrop mass and velocity, the greater its momentum and impact when it strikes the soil, leading to increased bulk density resulting from the compaction effect produced by the raindrop. Therefore, regions of the land characterized with greater soil bulk density may have been exposed to increased raindrop impact, vice versa. Meanwhile, the greater soil bulk density observed at regions of the land with greater soil organic carbon stock against the known negative relationship that exist between organic carbon and bulk density [14] could be attributed to the possible increased dispersion and loss of clay through the dispersing action of increased concentration of organic carbon stock at such regions thereby leaving the soil with increased sand fraction. This agrees with the report of Mestdagh, et al. [23] that compacted coarse-textured soils of increased sand content are notable for their increased mass per unit volume. Consequently, regions of the land with increased soil bulk density will be prone to poor drainage, increased volume of water run-off, and its resulting condition of increased erosivity of water and erodibility of the soil [24] also, such regions will be characterized by decreased permeability to air and roots; hence, regions of reduced bulk density will portray better qualities with regards to water transmission down the solum, permeability of roots and air, water infiltration and reduced tendency of erosion [25].

3.2. Variation of Saturated Hydraulic Conductivity and Total Porosity of the Soils

Figure 2a shows that the saturated hydraulic conductivity of the soils varied from 2.70 – 3,05 cm / mins with the most rapid vertical water transmission across the soil column observed at part of the central region, and extended to a part of the Northeast and Southern regions, while the slowest vertical water transmission was observed at the extreme parts of Southeastern region, due North central region, and the borders of the Northwestern region of the land. Figure 2b reveals that the total porosity of the soils varied from 49 – 56 % with increased volume of pore spaces observed at the South-central region, and declined gradually towards the central part of the eastern region and a localized portion of the Northwestern region, while regions of decreased volume of pore spaces were the Northeastern region, localized part of the extreme Southeastern region, and the border region of the Northwestern part of the land.

The difference in saturated hydraulic conductivity across the soils of the area is probably a result of differences in organic carbon distribution and changes in bulk density across soils of the land area. Balesdent, et al. [25] and Amanze, et al. [9] reported that organic carbon had significant positive relationship saturated hydraulic conductivity, while bulk density had significant negative relationship with saturated hydraulic conductivity. This implies that regions of the land with greater organic carbon stock will be characterized by increased saturated hydraulic conductivity, vice versa. Consequently, such areas will have reduced volume of water run-off, reduced erosion, and greater water content. Meanwhile, considering the arch maps for organic carbon stock, bulk density and saturated hydraulic conductivity, it could be inferred that the observed greater saturated hydraulic conductivity at the regions of the land with reduced organic carbon stock, contrary to results in previous reports, but with reduced bulk density was possibly a result of the interaction effect of organic carbon stock and bulk density, such that the reduced bulk density may have aided the relatively little organic materials contained in the soil to bring about greater transmission of water down the profile. Therefore, the overall water transmission properties of soils depend not only on the organic matter content but its degree of compaction measured by the bulk density [9, 26].

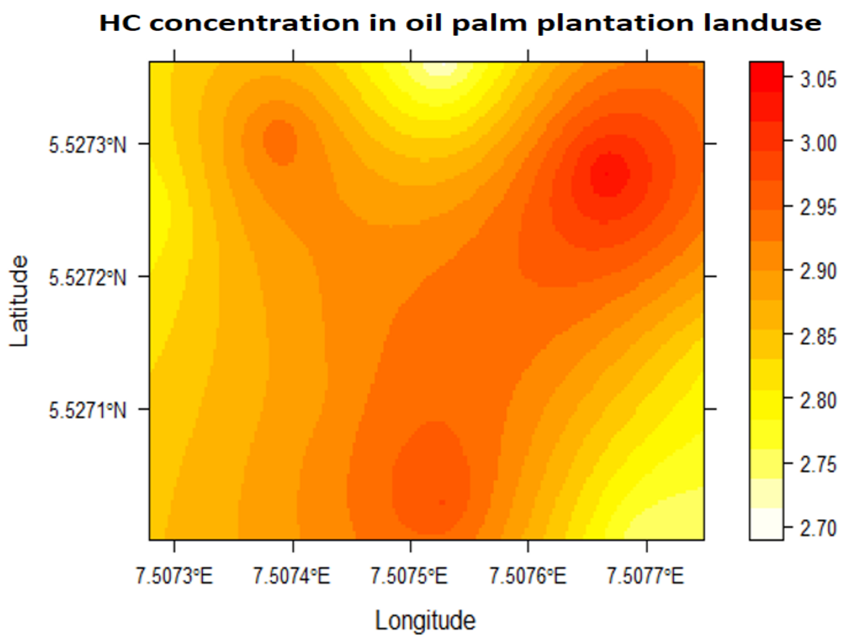

Figure 2a. Variation of Saturated hydraulic conductivity (cm / mins).

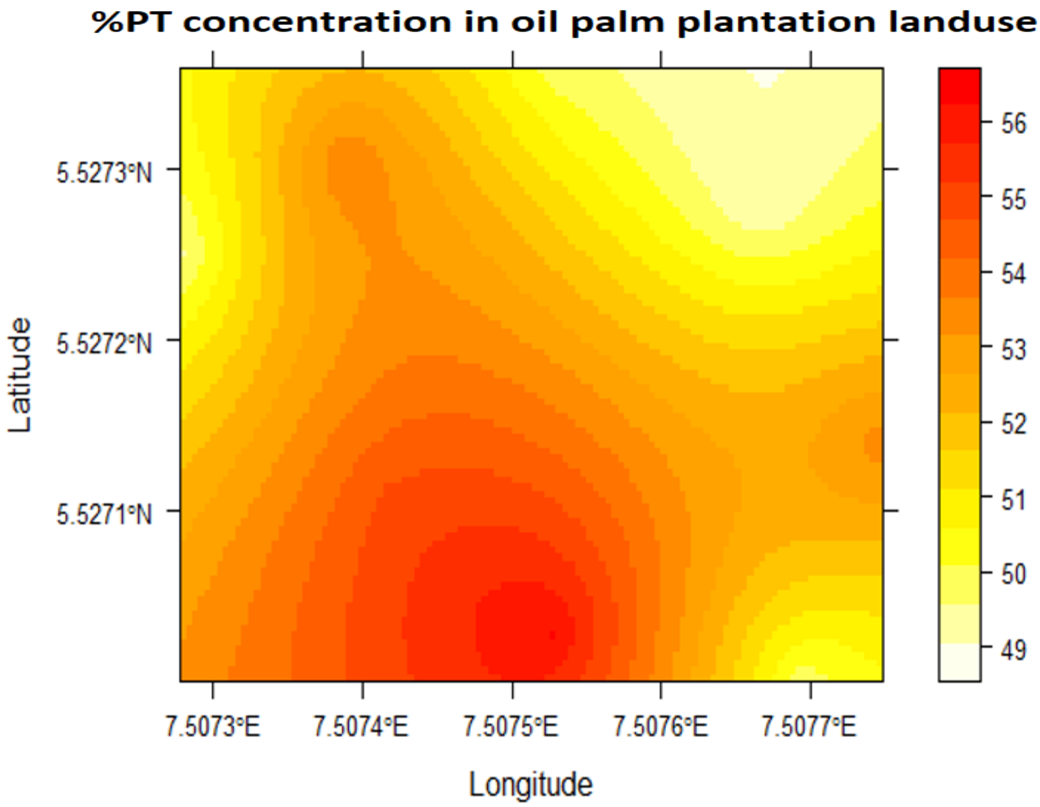

Figure 2b. Variation of total porosity (%).

The differences in total porosity is predictable on the observed differences in organic carbon stock and bulk density of the soils across the land area. However, the arch maps showed that soil bulk density had considerable negative relationship with total porosity, such that regions of greater bulk density had reduced total porosity, while regions of decreased bulk density had greater total porosity. This observation is in consonance with the report of Balesdent, et al. [25] that increased bulk density resulting from soil compaction decreased the number and volume of pore spaces in the soil. Significantly, the soils across the oil palm plantation will vary in soil aeration, degree of root permeability and density, moisture content, soil temperature, microbial activities and population, as well as biochemical and physical processes in the soil. This inference is based on the report that size, volume and continuity of pore spaces in soils are important indicators of soil quality due to the influence the bear on the physicochemical and biological processes of the soil [25]. Notwithstanding, regions of the land with very high or very low total porosity may pose challenges on the overall structural and hydraulic conditions of the soils, and will require appropriate soil management decisions.

3.3. Variation of Clay Flocculation Index and Aggregated Silt + Clay of the Soils

Figure 3a reveals that the clay flocculation index of the soils varied from 64 – 70 %, with regions of increased clay flocculation occupying the central portion of the land and extended to the central eastward portion of the land, while regions of decreased clay flocculation occupied the extreme Northeast, entire Westward, and extreme Southern parts of the land. Figure 3b indicates that aggregated silt + clay of the soils varied from 16.5 – 20.5 %, with regions of greatest aggregation of silt and clay observed at the central portion of the land, and this extends to the Northwestern area and middle Eastward parts of the land. Conversely, the region of least silt and clay aggregation was observed at the extreme Northeastern portion, extreme part of Southeastern region, and the extreme borders of the Western region.

The variation in degree of clay flocculation across soils of the area may be associated with differences in organic carbon stock across the soils, and possibly due to variations in clay content across the soils of the land area. Regions of the land characterized by decreased clay flocculation index may have been negatively influenced by an increase in organic carbon concentration as may be observed in comparing the arch maps of organic carbon stock and clay flocculation index. The increase in organic carbon concentration of such regions of relatively weaker flocculation of clay particles may have significantly contributed to the dispersion and subsequent loss of clay particles of soils in those regions. The dispersion and loss of the clay particles by the dispersing action of the organic materials possibly decreased the clay flocculation potentials of the soils, which agrees with the findings of Amanze, et al. [9] that considerable loss in clay content significantly weakens the clay flocculation potentials of soils because, the more the clay content of soils, the higher the cohesion force between the particles; hence the greater the possibility of flocculation processes to occur, vice versa. Also, the possible presence of polyanionic humic substances of the organic carbon content of the soils may have increased the critical flocculation concentration (a measure of the minimum amount of exchangeable cations required to bind the clay particles into floccules) of the soils in such areas of decreased clay flocculation index thereby limiting the possibility of clay flocculation and micro-aggregation [9, 27]. On the contrary, regions of the land characterized by increased clay flocculation index may have been favoured by increased concentration of clay particles in association with reduced organic carbon stock. Consequently, such regions of lesser clay flocculation index will be notable for increased structural instability at micro level, while areas of greater clay flocculation index will likely have greater stability of micro-aggregates with associated better structural quality in terms of resistance to water erosion, stability against the impact intensive tillage operations, and cushioning effect against pressure from trafficking of heavy machineries [28].

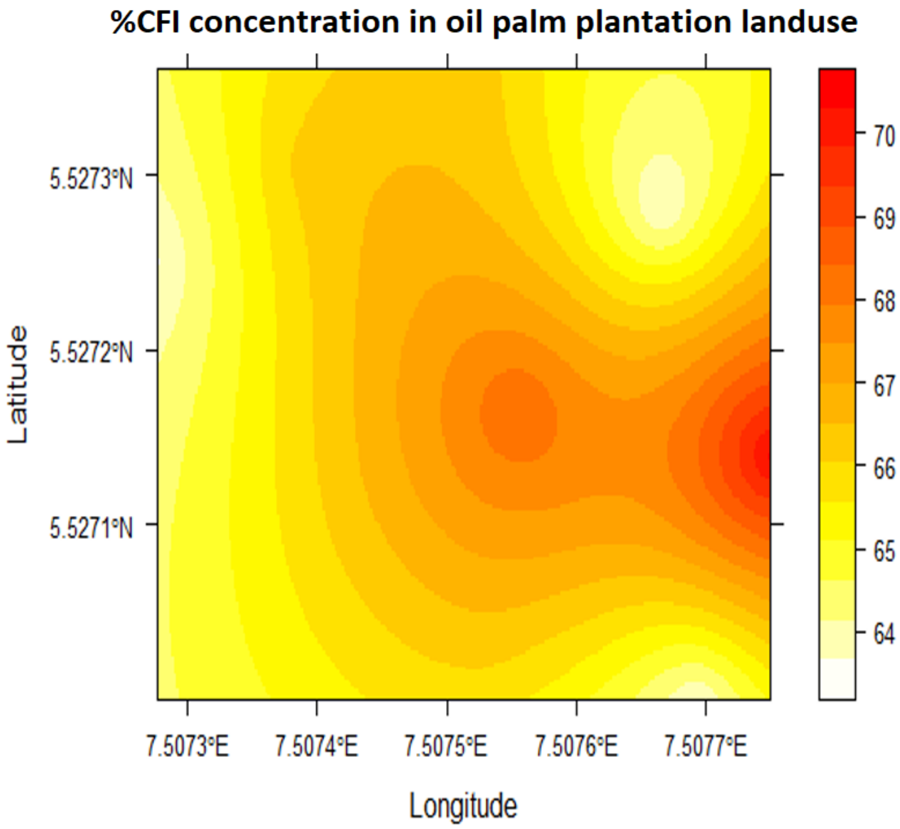

Figure 3a. Variation of clay flocculation index (%).

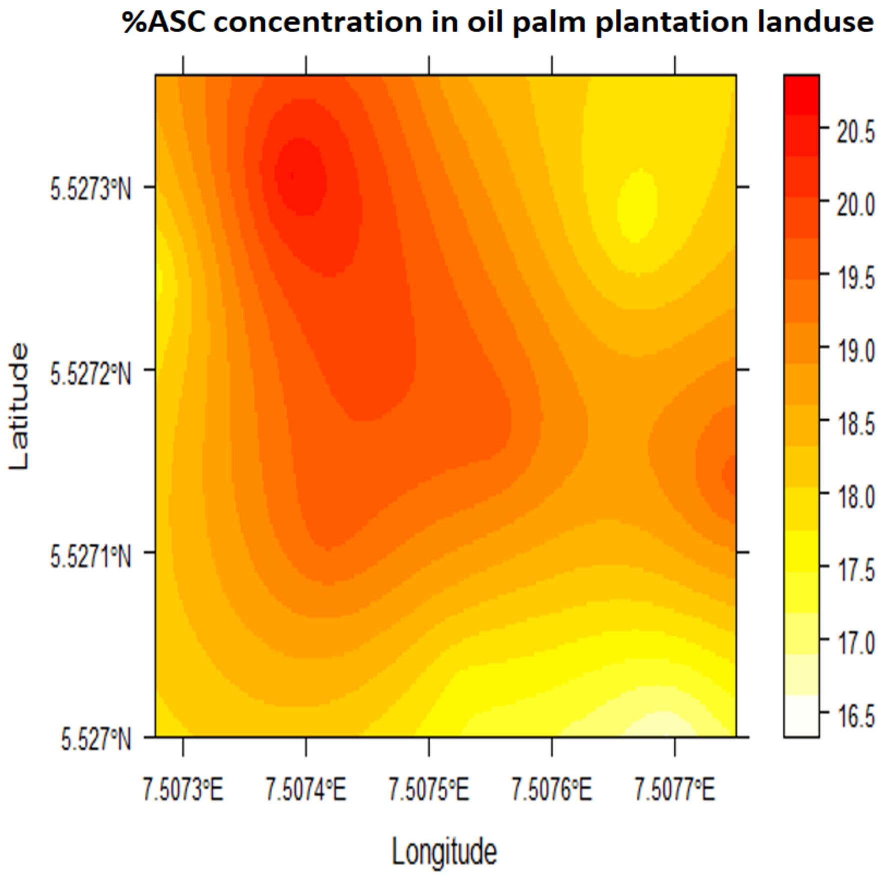

Figure 3b. Variation of aggregated silt + clay (%).

Similarly, the variation of degree of aggregated silt + clay across the land area could be predicated on the possible variations in the content of clay, and silt. Clay is also known for its significant impact on the aggregation of the fine particles of soil including silt; hence, regions of the land noted for greater percentage of aggregated silt + clay may be regions of greater concentration of clay particles, vice versa. Moreover, the changes in the concentration and distribution of organic carbon across the soil may have also contributed to the variation in the percentage aggregated silt + clay across the land area. This claim is based on the influence of organic carbon on clay particles, such that areas of stronger aggregated silt + clay may be areas of lesser stock of organic carbon, while regions of weaker aggregated silt + clay may have been influenced by possible increased concentration of organic carbon. This agrees with the report that organic carbon was responsible for the dispersion of soil micro-aggregates; hence, the greater the amount of organic carbon contents in such soils, the greater the disaggregation of aggregated silt + clay, vice versa [9]. Furthermore, comparison among the arch maps for clay flocculation index, aggregated silt + clay, and organic carbon stock shows that organic carbon concentration and distribution across the soils was of great relevance in bringing about negative impact on micro-aggregation and stability of micro-aggregates resulting from its dispersing effect on clay particles as well as its contribution in increasing the critical flocculation concentration of the soils by increasing the net negative charge within the soil colloidal complex, which resulted in increased repulsive force within the soil fine mineral particles; hence limiting flocculation and micro-aggregation potentials in the soils [29].

3.4. Variation of Clay Dispersion Index and Dispersion Ratio of the Soils

Figure 4a reveals that clay dispersion index varied from 30 – 36 % with the greatest clay dispersion observed at the extreme Northeast, entire Westward, and extreme Southern parts of the land, while regions of least clay dispersion were noted at the central portion of the land, and extended to the central Eastward region of the land. In

Figure 4b, the arch map reveals that dispersion ratio varied from 5 – 25 % with the dominance of regions of greatest dispersion, which covered almost every portion of the land except at localized portion within the central part of the land noted for the least dispersion of the micro-aggregates.

The results so far show that the soils in the land area are less dispersed [30] and this may be a result of the nature of the clay mineral, kaolinite, a 1:1 clay mineral which is dominant in the soils of the area, and is known for reduced dispersivity due to the ability of its interlayer space to resistance expansion [31]. Variation in the degree of dispersion of clay particles and soil micro-aggregates is also attributable to the variations in organic carbon stock and possible differences in clay and silt contents of the soils across the land area. Regions of greater clay dispersion possibly had greater content of clay particles relative to the other regions of the land that had lesser clay dispersion; hence, increased clay content of soils that are prone to clay dispersion could be the reason for increased percentage of dispersed clay particles observed in such soils.

The notable influence of organic carbon in dispersing soil micro-aggregates or decreasing flocculation and aggregation potentials of soils at micro level may have also contributed to the variation in the percentage dispersion ratio and clay dispersion index of the soils, such that regions of greater organic carbon stock had increased dispersion of micro-aggregates resulting from the dispersing action of organic carbon on soil micro-aggregates, vice versa [9, 32] Consequently, regions of the land area with increased dispersion of micro-aggregates will be more susceptible to erosion and have increased sensitivity to the negative impact of intensive tillage operation [24].

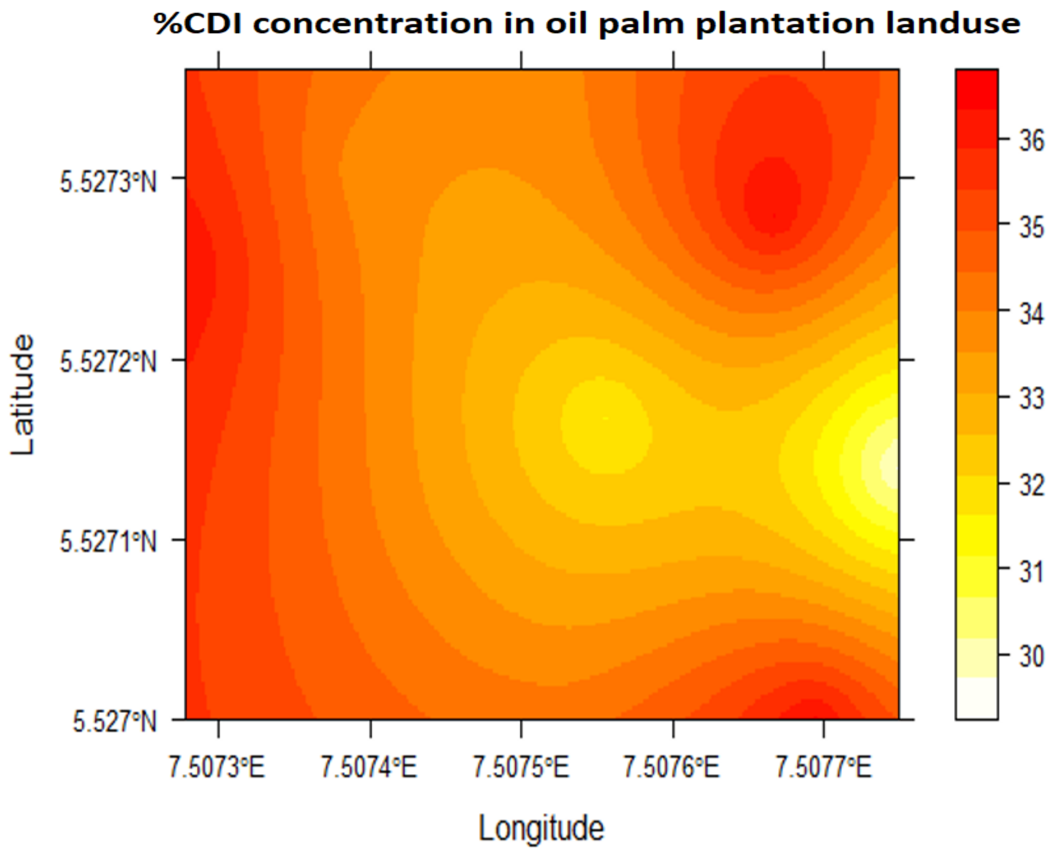

Figure 4a. Variation of clay dispersion index (%).

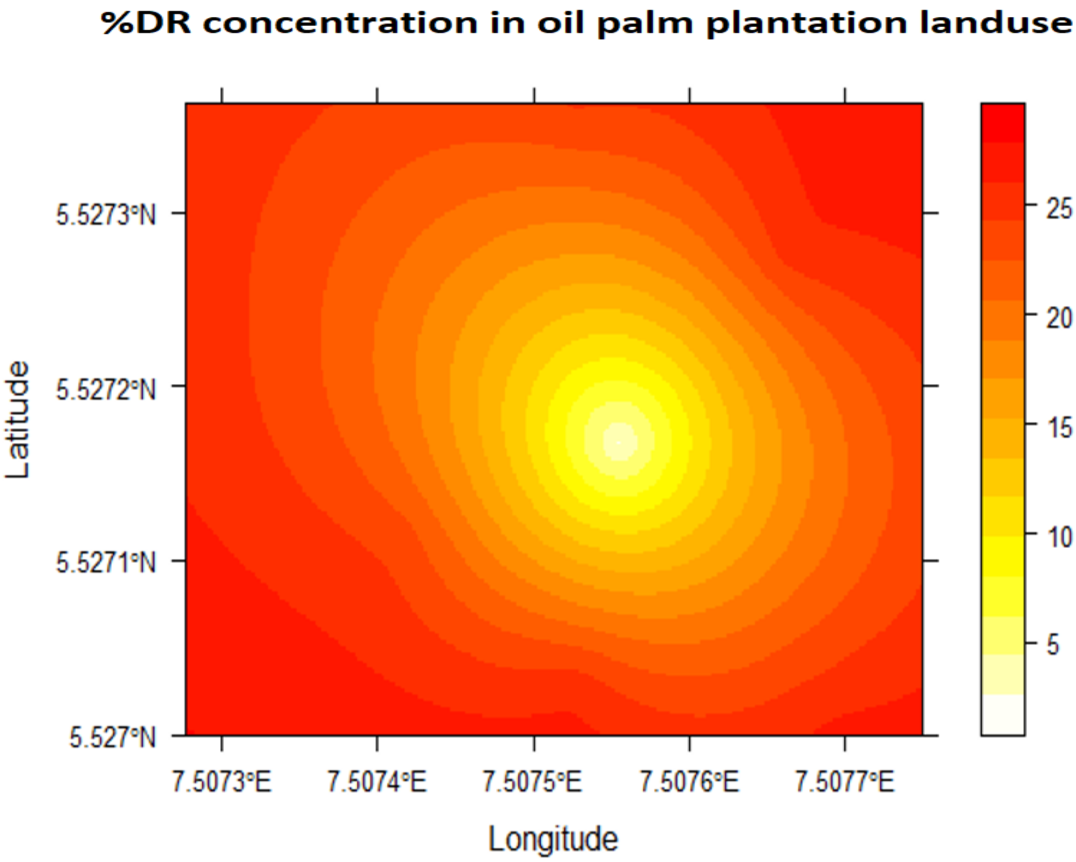

Figure 4b. Variation of dispersion ratio (%).

3.5. Variation of Mean Weight Diameter of the Soils

Figure 5 shows that mean weight diameter varied across the soils from 1.10 – 1.50 mm with the greatest stability of macro-aggregates observed at the Northwestern region of the land, while from the Southwestern region through the central region to a localized portion at the Northeastern region were noted for the least stability of macro-aggregate.

The differences in the stability of macro-aggregates across soils of the land area was possibly a resultant effect of the variations in organic carbon stock, clay content and bulk density of the soils, as well as differences in their interaction across the soils of the oil palm plantation. This explanation is in consonance with the report of Six, et al. [33] that macro-aggregate stability of soils measured by the mean weight diameter was significantly influenced by organic matter, clay content, and bulk density. Therefore, regions of the soil noted for greater mean weight diameter were possibly regions of greater storage of organic carbon, increased clay content, and greater compaction of soil particles. On the contrary, regions of the land characterized by lesser stability of soil macro-aggregates may be regions of decreased organic carbon stock, lesser clay content, and reduced bulk density. This report corroborates the findings of Wuddivira and Camps-Roach [34] that soil organic carbon and clay particles play significant roles as binding agents in uniting micro-aggregates and soil fine particles, respectively, into macro-aggregates, while increased soil bulk density (a measure of increased degree of soil compaction) increased the degree of adhesion of the aggregated particles by impacting high pressure which further decreased the inter-particular and inter-aggregate spaces thereby reducing the possible lines of weaknesses within and between the macro-aggregates. The implication is that regions of the land with lesser macro-aggregation would be very sensitive to tillage operations and water erosion; also, such regions of the soils will be faced with increased macro-aggregate dispersion by raindrop impact with its resultant effect of surface slaking and crusting.

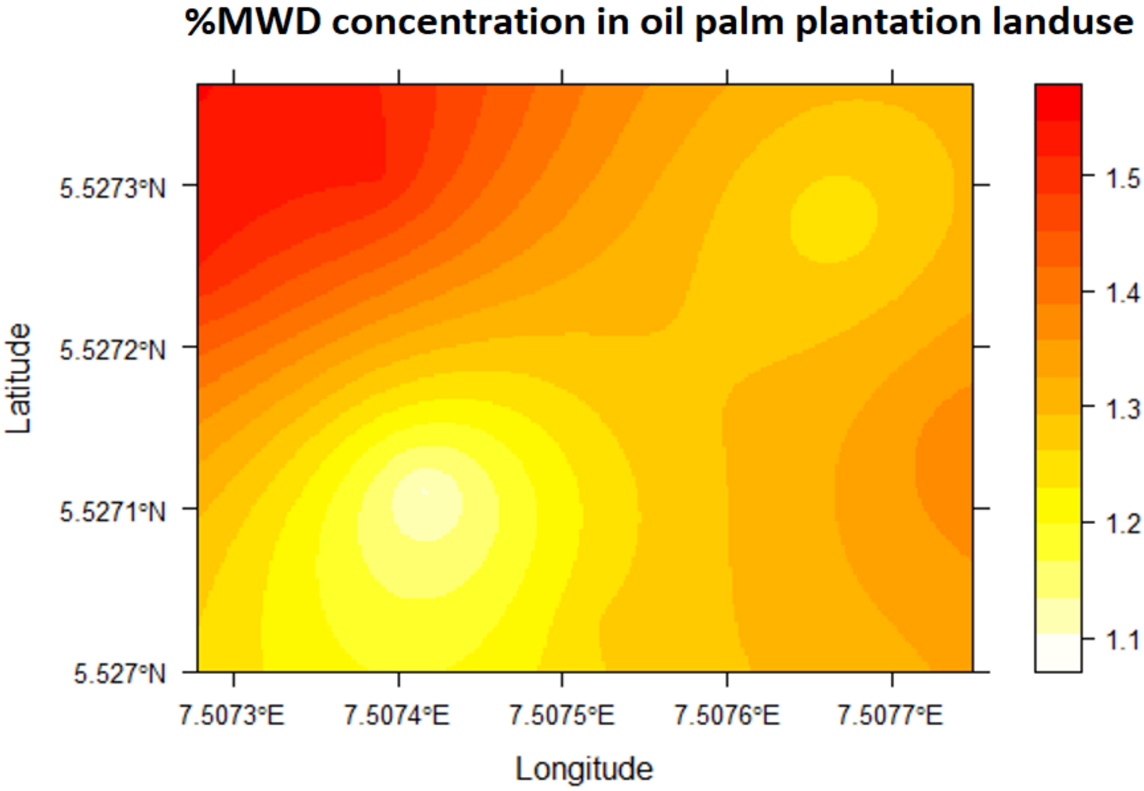

Figure 5. Variation of mean weight diameter (mm).

4. CONCLUSION

The findings from this research establish that there is spatial variation in the structural-hydraulic properties and organic carbon stock of soils under oil palm plantations; hence, the monocropping system of crop production and land-use management affects soil quality in varying regions of a land. Assessment of the arch maps establishes that the degree of variation of each soil parameter is greatly influenced by the degree of ground cover and disturbance of soil. Increased vegetation and ground cover with minimal disturbance to the soil encourage carbon sequestration, leading to increased organic carbon stock. Soils with increased organic carbon stock are likely to have increased clay dispersion and weak micro-aggregation, while soils with increased bulk density and organic carbon stock will likely have increased stability of macro-aggregates. Increased organic carbon and reduced bulk density enhance the water transmission properties of soils, including total porosity.

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