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Effect of Land Use on Organic Matter Concentration of Aggregate Fractions of Fallow and Cultivated Soils

KEYWORDS Aggregate Sizes. Cultivated, Fallow, Organic matter,

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ABSTRACT *This study was undertaken to evaluate the effects of continuous cultivation on the organic matter concentration of the aggregate fractions of dry and wet sieved samples. Four soils collected from different locations in Nsukka area of southeastern Nigeria were used for the study. The land use types considered were fallow and cultivated. The soils collected from 0-25cm depth were separated into five aggregate fractions, 5-2mm, 2-1mm, 1-0.5mm, 0.5-0.25mm and 0.25mm and the organic matter (OM) concentration due to cultivation were determined for both dry and wet sieved fractions. The result of the study showed a decrease in the OM concentration for both dry and wet sieved fractions in all the soils following continuous cultivation. The OM concentrations in the aggregate of dry and wet-sieved fractions increased as aggregate sizes decreased in virtually all the soils studied and showed a trend of ENsk (Entisol at Nsukka) > UNsk (Ultisol at Nsukka) > IEh (Inceptisol at Eha-Amufu) > Iik (Inceptisol at Ikem), higher concentrations of OM was more observed in the aggregate size of the fallow than those of the cultivated soils of the dry sieved samples. From the result of this study it was found out that continuous cultivation depletes OM content of soil which invariable will affect their fertility and aggregation stability of the soils, which directly will affect the productivity of the soils studied. Hence appropriate fallow period and other management practices that will ensure more residues inputs on the soil to improve the OM content should be encouraged to ensure yield and soil sustainability.*

INTRODUCTION

Soil organic matter is the ‘seat' of the plant mineral nutrients in the soil, as it has the ability to hold cations from being leached or washed away through drainage water due to it is negatively charged, which enable it to attract and hold cations. The adsorbed cations are subject to be exchanged by other cations in a reversible process called cation exchange. Even heavy metals are subject to replacement as they exist as cations in the soil. From the exchange site the cations enter into soil liquid phase otherwise called soil water or solution where they can be picked up by the plant roots, hence referred to as readily available nutrients, the cations at this position can react with other soil constituents or be leached and or carried away by the drainage water. Carter (2002) reported that soil organic matter play important role in sustaining soil quality; it has a specific function in soil fertility, productivity or erodibility. It also influences soil compactibility and friability and soil water holding capacity. The aggregated soil organic matter has major implications for the functioning of soil in regulating air and water infiltration, conserving nutrients, influencing soil permeability and erodibility, while the dynamics of the sand- sized macro organic matter and the soil aggregate process are important factors in maintaining and regulating organic functioning in soil (Carter et al. 2002). Thus, organic matter content can be said to be the life wire of a soil, as its decline or changes due to agricultural practices adversely affect the productivity and structural stability of the soil. Traditional agriculture practices and land use change cause changes in soil structure and soil quality. This may be referred to as soil structure decline. In investigating the effect of land use changes on soil quality attributes Yousefifard et al. (2007), Hajabbasi et al. (2007) and Lemenin (2004) found out that deforestation and land use changes cause organic matter to be decreased.

Charman and Murphy (1998) proposed two categories of soil structures decline – cultivation and irrigation. Soil structure decline under irrigation is usually related to the breakdown of aggregates and dispersion of clay material as a result of rapid wetting. While in the case of cultivation, it has been found to be the most important factor that is very effective in accelerating soil organic matter reduction and degradation and various negative effects on the structural stability of the soil. Hence soil structure and soil organic matter content are considered important indicators of soil in agricultural soils (Lal and Kimble 1997). In many soils cultivation, cropping systems and climatic greatly influence structural stability of soil aggregates, organic matter in stable clay mineral fraction and soil organic carbon. Saha et al; (2010) observed that the soil organic matter content in clay mineral fraction was affected by intensive cultivation though it is the stable mineral fraction of soil. While Eynard et al; (2004) and Six et al; (2000a) reported decreased in soil organic carbon content, structural stability and changes in the distribution and stability of soil aggregates following cultivation. Guerrif et al; (2001) added that soil structure and aggregation are strongly influenced by processes such as tillage, cropping systems and climatic conditions. The conversion of virgin or native land into agricultural land or perennial crops into annual row crops has also been found to accelerate soil structure degradation and lose of organic matter content. Magdoff and Van Es (2000) and Karunatilake and Van Es (2002) observed that perennial crops generally improve soil structure and organic matter content while annual row cropping often results in structural degradation, mainly as a result of a loss of ground cover and organic matter losses from increased soil disturbance from tillage.

Organic matter act as a binder between soil aggregates that ensure their stability and food source for many soil organisms, its depletion will ultimately make the soil fragile and inability to withstand the agents of degradation. Hence it is generally accepted that aggregate stability is largely dependent upon organic matter (OM), clay, Fe and Al oxides contents (Kemper and Koch, 1966, Miguel and

Norton, 1994). Organic matter was found to promote soil aggregation through the linkage, clay – poly cat ion – organic matter – poly cautions – clay (Edwards and Bremner, 1967) and different kinds of organic matter stabilize aggregates of different sizes (Tisdall and Oades, 1982). Though not all organic compounds in soils are responsible for aggregation (Oades, 1984) and they may have no effect on swelling soils (Coughlan et al 1973). Organic material may retard stabilization owing to its ability to restrict age-hardening processes (Kemper et al, 1987). Also an increase in clay does not always result to an increased stability, since clay mineralogy is an important factor in aggregation and stability of high clay soils depends on the physical-chemical properties of the clay (Warkentin, 1982). There is a decrease in organic matter content in macro – aggregates following cultivation and the content in micro – aggregate was small and less labile compared to macro – aggregates (Tisdall and Oades, 1980a, b, Dormaar, 1973, Elliot, 1986, Gupta and Germida, 1988). Kaolinitic soils, characterized by high dispersibility, can increase the susceptibility of cultivated soils to aggregate disruption, surface rousting, reduced infiltration, sand erosion (miller and Baharuddin, 1986; Summer, 1992), contribute to rapid losses of soil organic matter and to a decline in the productivity of agricultural soils in warm humid climates (Giddens 1957, Sanchez et al, 1989; Bruce et al, 1990). The magnitude of losses of soil organic matter following cultivation, however, depends on the duration (short term or Long term) and intensity of cultivation, in particular the type and frequency of tillage and the quantity and quality of fertilizers and organic residues returned to soil (Jenkinson and Rayer, 1977, Dalal and Mayer 1986; Rasmussen and Collins, 1991).

Reduced – tillage practices compared with conventional tillage practices can result in greater aggregation and higher standing stocks of soil organic matter (Doran, 1980, Lamb et al, 1985, Bruce et al, 1990, Halvin et al 1990, Carter 1992). Some reported little or no effects of reduced tillage practices on these properties (Hamblin, 1980, Carter and Rennie, 1982), especially if the crop residues were burnt (Carter and Mele, 1982). Where differences between tillage practices are recognized, the mechanisms that regulate the accumulation or loss of soil organic matter are poorly known (Beare et al; 1994). Studies have shown that no-tillage management can improve soil aggregation and reduce losses of soil OM that result from cultivation if residues are not removed (Weill et al, 1989, Havlin et al 1990, Carter 1992). Hamblin (1980) reported few changes in soil aggregation, while Carter and Rennie, (1982) and Angers et al; (1992) observed no effect on soil OM content other than changes in the depth distribution of soil OM with plowing. Conventional tillage practices disrupt soil aggregates, exposing more OM to microbial attack (Beare et al, 1994). Organic matter, however, maybe protected from microbial attack by adsorption to clay minerals (Oades, 1984, Ladd et al, 1985) and the formation of micro aggregates (Edwards and Bremner, 1967; Gregorich et al, 1989), by isolation in micro pores (Adu and Oades, 1978, Foster, 1981) and by physical protection within stable macro-aggregates (Elliot, 1986, Gupta and Germida, 1988).

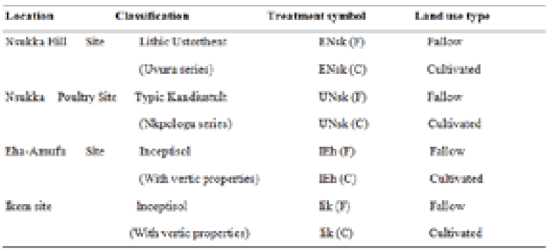
The soil OM lost during cultivation of grassland soils can be attributed to the mineralization of soil OM binding micro-aggregates into macro-aggregates (Elliot, 1986, Gupta and Germida, 1988). Macro-aggregates are much less stable than micro-aggregates, probably because of the nature of the binding agents involved (Edwards and Bremner, 1967, Oades 1984, Beare et al 1994). Tisdall and Oades, (1980), (1982) also reported that macro-aggregates were more susceptible to the disruptive forces of cultivation and to the dispersion that result from rapid wetting or rain drop impact. Golchin et al; (1995) observed that soil particle bound OM occluded within aggregate particulate organic matter (POM) correlated better with aggregate stability than total soil OM. Mbagwu and Piccolo, (1998) in their studies, found out that there was no general trend in the distribution of Om fractions within aggregates of different sizes. Rather they found that distribution varied between soil types and cultivation histories. Cultivation have been shown to have a mark able effect on the soil organic matter content which can bring about reduction in crop production soil fertility and stability and reduction in micro-organism activities that will help to liberate mineral elements into soil for crop uses. Therefore, studying the organic matter concentration in the aggregate fractions of fallow and cultivated soils can proffer solution to management strategies that can be adopted in a tropical environment to avoid risk of soil degradation and ensure increased crop productivity and soil sustainability.

MATERIALS and METHODS

Field methods

Soil samples from the 0-25cm depth were collected from cultivated and adjacent fallow lands in four different locations in Nsukka area of south eastern Nigeria. Care was taken to minimize disturbance during sampling and transportation. The area has a rainforest savannah type of vegetation with a mean annual temperature of 24^{oc}. The area lies within latitude 06^0 61^1N and longitude 07^0 25^1E of Nigeria. The soils sampled for the study are classified according to soil taxonomy as an Ultisol, belonging to the sub-group, Typic Kandiustult (Nkpologu series), Entisol belonging to Lithic Ustorthent (Uvuru series), while the other two soils belong to Vertic Inceptisol (SSS, 1992). These soils have been under cultivation for over and about 8years while fallow soils varied from 3 to 4years old. The cultural practices adopted in these soils were slashing and burning and tillage is merely by the use of Hoe. Fertilizer application is basal and it is mainly NPK. While the paramount crop culture in the study area is mixed cropping.

Table 1 Location, Classification and Land use type



Location	Classification	Treatment symbol	Land use type
Nsukka Hill Site	Lithic Ustorthent	ENsk (F)	Fallow
	(Uvuru series)	ENsk (C)	Cultivated
Nsukka Poultry Site	Typic Kandiustult	UNsk (F)	Fallow
	(Nkpologu series)	UNsk (C)	Cultivated
Eha-Amufu Site	Inceptisol	IEh (F)	Fallow
	(With vertic properties)	IEh (C)	Cultivated
Ikem site	Inceptisol	Ik (F)	Fallow
	(With vertic properties)	Ik (C)	Cultivated

Laboratory method

The soil samples were air-dried at room temperature and then sieved through a 5mm sieve. Clods were carefully crushed by hand along lines of natural cleavages to pass the sieve. Two hundred and fifty grams (250g) of the sieved sample, at a time, were transferred to the upper most of a nest sieve of sizes 2, 1, 0.5 and 0.25mm. They were shaken mechanically for 10 minutes. Further sieving by hand was done were necessary. This procedure, similar to that described by Kemper and Chepil (1965), resulted in the separation of the following aggregate fractions 5-2, 2-1, 1-0.5, 0.5-0.25 and < 0.25mm. The separation continued until enough quantity of each fraction was collected

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for further analysis.

Organic Matter

This was determined from walkley and Black's method (1934), by multiplying the determined percentage organic carbon by the conventional 'Van Bemmeler Factor' of 1.724.

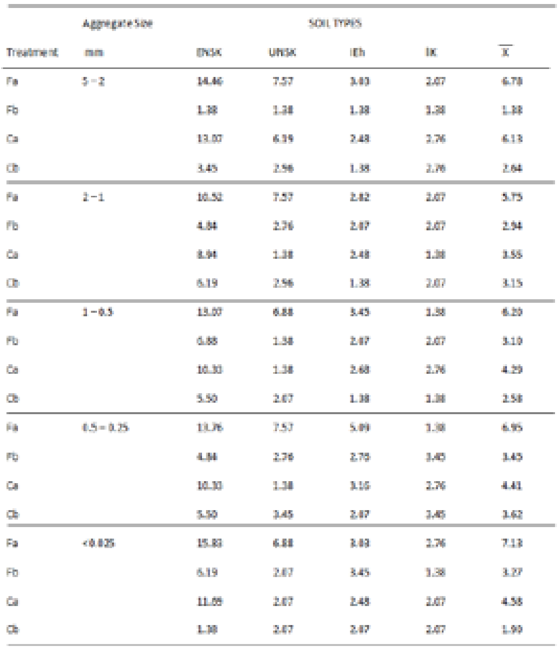
Data analysis

Little and Hills (1972), Statistical methods in Agricultural research was used to analyze the data obtained from the study. The mean of the individual aggregate size was later cartographed to give a vivid picture of the concentration of OM in the aggregate sizes of each soil type.

Result and Discussion

The organic matter (OM) content within the aggregate fractions of both dry and wet-sieved samples of the four soils, ENsk, UNsk, IEh and lik are given in Table 3

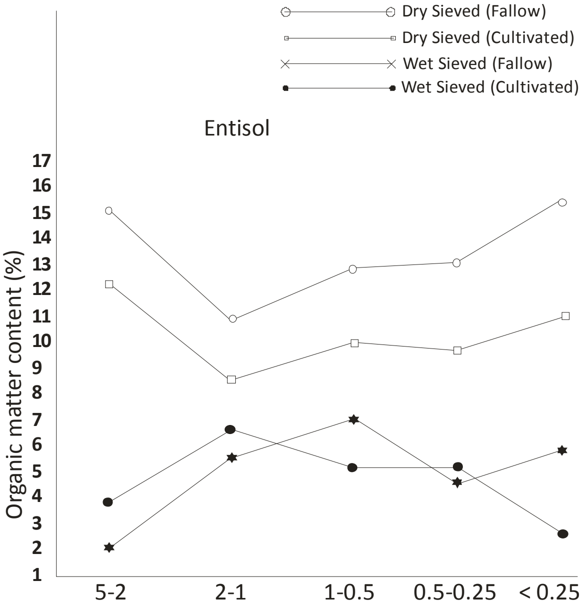
Table 3Effect of land use on organic matter concentration % of four soils



Treatment	Aggregate Size mm	SOIL TYPES ENSK	UNSK	IEh	IK	$\overline{X}$
Fa	5 – 2	14.46	7.57	3.03	2.07	6.78
Fb		1.38	1.38	1.38	1.38	1.38
Ca		13.07	6.19	2.48	2.76	6.13
Cb		3.45	2.96	1.38	2.76	2.64
Fa	2 – 1	10.52	7.57	2.82	2.07	5.75
Fb		4.84	2.76	2.07	2.07	2.94
Ca		8.94	1.38	2.48	1.38	3.55
Cb		6.19	2.96	1.38	2.07	3.15
Fa	1 – 0.5	13.07	6.88	3.45	1.38	6.20
Fb		6.88	1.38	2.07	2.07	3.10
Ca		10.33	1.38	2.68	2.76	4.29
Cb		5.50	2.07	1.38	1.38	2.58
Fa	0.5 – 0.25	13.76	7.57	5.09	1.38	6.95
Fb		4.84	2.76	2.75	3.45	3.45
Ca		10.33	1.38	3.16	2.76	4.41
Cb		5.50	3.45	2.07	3.45	3.62
Fa	<0.025	15.83	6.88	3.03	2.76	7.13
Fb		6.19	2.07	3.45	1.38	3.27
Ca		11.05	2.07	2.48	2.07	4.38
Cb		1.38	2.07	2.07	2.07	1.90

a = Dry sieved, b = Wet sieved, F = Fallow, C = Cultivated, X = Mean, ENSK = Entisol at Nsukka, UNSK = Ultisol at Nsukka, IEh = Inceptisol at Eha-Amufu, IiK = Inceptisol at Ikem.

The result of the ENSK in Fig 1 indicated that the lowest concentration of OM for the dry-sieved samples, were recorded in the 2-1mm fractions of both the fallow and cultivated soil and concentration of OM varied with the aggregate sizes of the soil. The OM content decreased in 2-1mm, but increased as the aggregate sizes decreased to < 0.25 where the highest concentration of OM was recorded for both fallow and cultivated soils. The percentage decrease relative to <0.25mm aggregate size was 23.52% for cultivated soil and 33.52% for the fallow soil. The result of the wet-sieved samples of fallow soil showed that the OM increased as the aggregate sizes decreased, though it decreased in 0.5-0.25mm aggregate size, but increased in <0.25mm. The cultivated soil follow the same trend though the 1-0.5mm and 0.5-0.25mm aggregate sizes recorded the same value, while OM content decreased drastically in <0.25mm aggregate size. The lowest OM concentration was recorded in 5-2mm and <0.25mm fractions for the fallow and cultivated soils, respectively. The concentration of OM was higher in the fallow soil than in the cultivated soil for all the size classes which reveled that cultivation decreased the OM concentrations of the soil. Lemenin (2004) and Hajabbasi et al (2007) observed decreased OM content following land use changes. The wet-sieved samples which showed contrary observation could be due to loss of some of the OM in water solution through the disintegration of organic material binding agents by wet-sieving process.



Aggregate sizes (mm) Fig 1

The OM concentration within the aggregate sizes of both dry and wet-sieved samples of UNSK is given in Fig 2. The result of the dried sieved samples of the cultivated soil showed that OM concentration decreased as the aggregate fractions decreased except at <0.25mm aggregate size where it increased but less in value compared to the value obtained In 5-2mm aggregate size. For the fallow soil, the OM concentration observed at 5-2mm, 2-1mm and 0.5 - 0.25mm sizes were at par with each other, the same goes with OM concentration recorded in 1-0.5 and <0.25mm aggregate fractions which invariable show the lowest concentration of OM in fallow soil. The highest OM concentration in the cultivated soil was observed in the 5-2mm aggregate size. The result of the wet-sieved samples showed that the OM concentration for the fallow soil increased in 2-1mm size, but then decreased as the aggregate sizes decreased, except in <0.25mm size where it increased, while for the cultivated soil the OM concentration decreased as the aggregate sizes decreased. The result of OM concentration obtained in 1-0.5mm size showed a decrease for the two land use types. Also higher concentrations of OM were observed in fallow that cultivated soils.

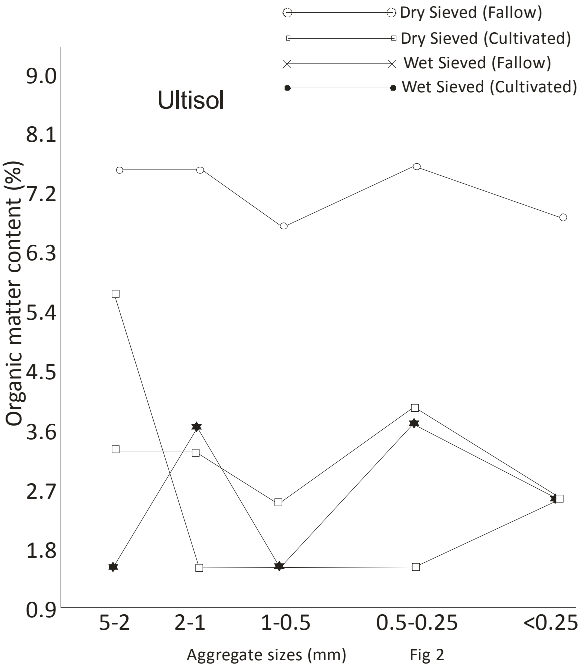


Fig 2

The result of OM concentration of IEh soil in Fig 3 was observed to be higher in fallow than cultivated soils for both dry and wet-sieved samples. The highest OM concentration for the fallow and cultivated soils was observed in 0.5-0.25mm aggregate size. The wet sieved result showed that the effect of cultivation on the OM concentration was non-effective in 5-2mm aggregate size, apart from this, the OM concentration increased with decreasing aggregate sizes, more especially for fallow soil. This result though not on the same parameter, tend to be similar to the one obtained by Tabatabai and Hanway (1968), who reported that OC concentration tended to increase as the aggregate size decreased.

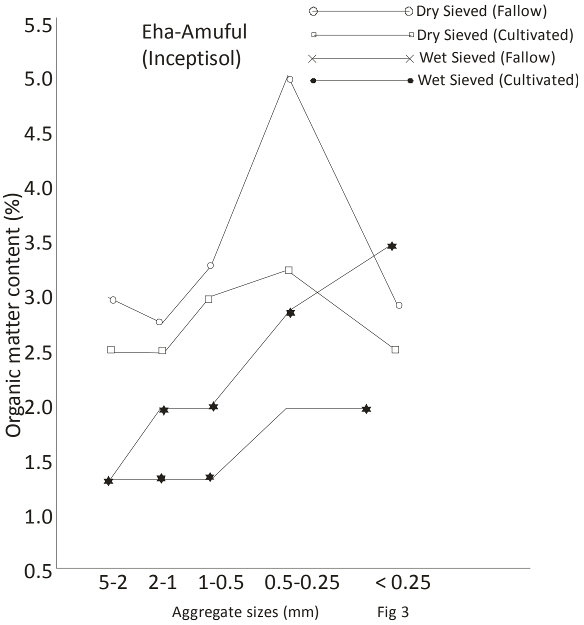


Fig 3

The highest OM concentration in the dry-sieved lik was observed in <0.25mm size for fallow soil, while there was no change in the OM concentration of 5-2mm sizes as well as 1-0.5mm and 0.5-0.25mm sizes. The cultivated soil showed lowest OM concentration in 2-1mm size, but showed no particular change on the OM concentrations recorded in 5-2mm, 1-0.5mm and 0.5-0.25mm fractions. The result of the dry-sieved samples also revealed higher OM concentration on most of the fractions of the cultivated soil than the fallow soil, which indicated that cultivation was not all that effective on this particular soil. This probably maybe attributed to the physical-chemical properties of the clay content of the soil or that OM has differed attack by micro-organism by adsorption to clay minerals. Warkentin (1982) observed that clay mineral encourage aggregation and that stability of high clay soils depends on the physical-chemical properties of clay, while Oades (1984) and Ladd et al; (1985) found out that OM may be protected from microbial attack by adsorption to clay minerals.

The percentage decrease in OM concentration recorded in 1-0.5mm and 0.5-0.25mm aggregate sizes relative to <0.25mm fractions was 50% for the fallow soil, the decrease was also 50% in 2-1mm size for the cultivated soil when compared with the concentration obtained in 1-0.5mm or 0.5-0.25m aggregate sizes. The result of the wet-sieved samples showed that cultivation had no effect on the OM concentration of the 2-1mm and 0.5-0.25mm fractions. While the lowest OM concentration was obtained in 5-2mm and <0.25mm aggregate sizes, respectively for the fallow soil. The OM concentration in the 0.5mm-0.25mm aggregate fractions was high, but decreased in the <0.25mm fraction for the two land use types. The percentage decrease relative to the 0.5-0.25mm aggregate size was 60% in the fallow and 40% in the cultivated soils.

Generally, the OM concentration in the soils studied show a trend of ENsk > UNsk > IEh > Iik higher concentration of OM was observed in the aggregate sizes of the fallow than those of the cultivated soils of the dry sieved samples. This agrees with the result of Emmond, (1971), Li et al; (2005), Fallalzade and Hajabbasi, (2011) and carter (2002) that cultivation is the most important factor that is effective in accelerating reduction of organic matter. The reduced concentration observed in the cultivated soils probable may be due to low residue inputs due to small fallow period observed which may have contributed to a reduction in the amount of OM returned to the soil or may be due to rapid OM decomposition in the cultivated soils. Dalal and Mayer, (1986), reported that the OM concentration in the cultivated soil was influenced by the amount of OM returned to the soil and more rapid OM decomposition in the cultivated soils. While Lal and Kimble (1997) observed that tillage practices, low residue inputs have caused rapid losses of soil OM and unstable aggregation worldwide from conventionally cultivated soils. Where this reduction continues unchecked can lead to land degradation, which FAO (1990) argued that it may be the most serious problems of the African countries in the near future, Brabant et al; (1996) observed that when land is cropped continuously, productivity declines faster. The result also revealed that there was a decrease in OM concentration in macro-aggregates with cultivation, though the proportion of micro-aggregates increased (Tisdall and Oades, 1980a, b). Elliot (1986) and Gupta and Germida (1988), observed that the content of OM in micro aggregates was small and less labile compared to macro-aggregates which invariable stipulates that the OM mineralization in macro-aggregates will be more readily compared with OM associated with micro-aggregates. Holeplass et al (2004) reported trend of increasing soil OM concentration with decreasing aggregate size for >0.25mm fraction. While Saroa and Lal

(2003) observed that the soil OM concentration decreased with decreasing aggregate size and was statistically higher in aggregate >0.5mm than <0.5mm.

However most of the OM concentration observed in the aggregate sizes of the soils studied agreed with the findings of Skoien (1993), who did not observe any differences in the soil OM concentration in different size fractions, although he observed a slight trend of a decrease in soil OM concentration with decreasing aggregate size. Mbagwu and Piccolo (1998), in their studies found that there was no general trend in the distribution of OM fractions within aggregates of different sizes. The protective effect of clay on OM is well known (Sorensen, 1981); this could be the reason why some aggregate sizes of cultivated soils showed higher OM concentration compared to the fallow soils. According to Mortland (1970), montmorillonite clays can protect OM substances better than illitic clays. Furthermore, it might be that through the processes of wet-sieving the soils, some of the OM binding agents dissolved and moved out with water solution. These reasons probable might have been associated with or behind the higher OM concentrations observed in the dry-sieved samples compared to the wet-sieved ones among the four soils. The OM concentration in the four soils studied was also observed to be varied with site and cultivation history and the general reduction in the OM concentration of cultivated soils relative to the fallow ones was a clear indication that cultivation reduced the OM of the studied soils. Hence the result of the study tend to substantiate the effective reduction of OM on four Nigerian soils due to cultivation thereby re-affirming the observations of Mbagwu and Piccolo (1998) Tisdall and Oades (1982) and Curtin et al (1994) that management practices affect the organic content of soils. Also the result of the study revealed that when considered on the average, there was an increase in OM concentration as the aggregate sizes decreased, the OM concentration in dry-sieved aggregation of various sizes were not similar. The macro-aggregates, >0.25mm had more OM concentration than the micro-aggregates, <0.25mm

Conclusion

From the result of the study, it was evident that continuous cultivation reduced the soil organic matter content of the soils. The concentration of the OM in the dry-sieved samples was greater than that of the wet-sieved samples. The OM lost during the cultivation was the organic material that bound micro-aggregates into macro-aggregates. The "Seat" of plant nutrients and structural stability of soil aggregates is the soil OM therefore its reduction will adversely influence crop productivity, soil fertility and micro-organism activities, infiltration and increase run off and erosion. Therefore management practices that will ensure much return of residues to the soil to improve OM content should be encouraged in order to improve the fertility and the stability of the aggregates of the soil for the sustainability of the crop yield and less stress on the soil.

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