SOIL CARBON VARIABILITY ACROSS DIFFERENT AGRICULTURAL LAND USE TYPES IN IKOLE-EKITI, EKITI STATE.

BY

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CERTIFICATION

This is to certify that this is an original and independent research project carried out by **ADETUNLE, E. I** (SSC/11/0038) in the department of Soil science and land Resources Management in partial fulfillment for the award of Bachelor of Agriculture (B.Agric.) in Soil Science, Federal University of Oye, Oye-Ekiti Nigeria.

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DEDICATION

This project is dedicated to my father in Heaven the institutor of Agriculture, to my Lord Jesus Christ, my protector and supplier.

TABLE OF CONTENTS

ABSTRACT

This research was conducted in Ikole-Ekiti to evaluate the effects of four land use types (forest plantation, arable land, fallow land and ranchland) and soil depth on soil organic carbon fractions namely; particulate organic carbon (POC), soil microbial biomass carbon (SMBC), total organic carbon (TOC) and water soluble organic carbon (WSOC). Soil samples were taken at 0-5, 5-10, 10-20 and 20-30 cm and 0-30 cm depths at each site using soil auger. The soil samples were analyzed for physical and chemical properties. At 0 – 5 cm depth, fallow land had the highest TOC, (30.27 g/kg), followed by forest plantation, ranchland and arable land at 29.70, 28.57 and 19.60 g/kg respectively. At 5-10 cm, TOC significant differed across the land use, with fallow land and forest plantation given the highest values while ranchland and arable land had the least values. The SMBC at 20-30 cm depth in the fallow land was significantly different from other land use types. The arable land had the highest concentration of SMBC, POC and WSOC among the agricultural land use types but least TOC content at all depths. The carbon fractions decrease with depth across the land use type. The depth-wise distribution of soil organic carbon forms did not follow a particular trend across the land use types. Generally, soils in Ikole-Ekiti were characterized with medium to high variations in the forms of soil organic carbon except for WSOC with low variations at all depths.

Keywords: Land use, carbon fractions and depths.

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LIST OF TABLES

CHAPTER ONE

1.0 INTRODUCTION

Soils store two or three times more carbon than that which exists in the atmosphere as CO_2 and 2.5-3 times as much as that stored in plants in the terrestrial ecosystem (Post *et al;* 2000; Houghton and Skole, 1990). Schimel *et al.* (2000) pointed out that the knowledge of the spatial distribution of soil organic carbon is an important requirement for understanding the relief of soils in the global carbon system.

Soil quality is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health and thus has a profound effect on the health and productivity of a given ecosystem and the environment related to it. The type of land use system is an important factor controlling soil organic carbon levels since it influences the amount and quality of litter input, the litter decomposition rates and the processes of organic matter stabilization in soils (Römkens *et al.*, 1999; Eaton *et al.,* 2007). The total organic carbon (TOC), soil water soluble carbon (WSOC), soil microbial biomass carbon (SMBC) and particulate or labile organic carbon (POC) are some of the soil properties that are used as basic indicators in assessing soil quality. The soil microbial biomass (SMB) is a small but key component of the active soil organic matter (SOM) pool and serves as a source and sink of soil nutrients. It has been used to understand soil nutrient dynamics and as an ecological marker. The reduction of SOC will lead to a decrease in soil fertility, soil nutrient supply, porosity and an increase in soil erosion (Gray and Morant, 2003).The POC consists of partly decomposed plant and animal residues with a rapid turnover, it is more responsive to management factors and it is believed to make a greater contribution to nutrient cycling (Janzen *et al.*, 1992). WSOC is considered as a most mobile and reactive soil carbon source which modulates a number of physical, chemical and biological processes in both aquatic and terrestrial environments (Schnabel *et al.*, 2002; Marschner and Kalbitz, 2003; Havorson and Gonzalez, 2008). In most soils, the majority of organic carbon is in insoluble form except for a small fraction that is water soluble and not yet leached out. This fraction of organic carbon is called the water soluble organic carbon (WSOC).

The public concern about the issue of global climate change has emphasized the need for developing and implementing strategies of agro-ecosystem management that will reduce carbon dioxide concentration in the atmosphere as well as improving soil fertility, SOC storage and the dynamics of C stock are important in evaluating the impact of agro ecosystem management on global climate change. Soils represent an important terrestrial stock of C.(Smith *et al.,*2008). Thus, the dynamics of SOC as affected by agro ecosystem to a large extent affects the carbon dioxide concentration in the atmosphere as well as even the global climate change (Tan and Lal, 2005). Recent interest in evaluating soil quality has been stimulated by the increasing awareness that the soil is a critically important component of the earth biosphere that functions not only in the production of food and fiber but also in the maintenance of environmental quality as related to agro ecosystem management and in formulating and evaluating sustainable agricultural and land use policies (Huang, *et al.,*2007). In Nigeria, studies have been conducted on the use of SOC, and SMBC to evaluate the effects of management practices such as legume rotation on soil fertility (Granatstein and Bezdicek, 1992; Adebayo *et al.,* 2006), but there is dearth of information on the assessment of soil quality under different agro ecosystems using the TOC, POC, WSOC and SMBC (Yusuf *et al.,*2009). This study was carried out to assess the quality and quantity of various forms of soil organic carbon under forest plantation(oil palm, cashew and teak), arable land cultivation(cassava, yam, vegetable and maize), ranchland and fallow land. This will provide Information on the characterization of SOC and qualitative data on dynamics and nutrient cycling across major land uses.

The general objective was to determine the variability of soil carbon across different agricultural land use in Ikole-Ekiti. The specific objectives were of the study were to;

Evaluate the dynamics of SOC under different agricultural landuse.

Investigate the relationship between forms of organic carbon and some selected soil properties.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soil Carbon

Soil organic carbon (SOC) is the organic matter constituent of soil, composed of plant and animal residues synthesized by soil. It is of significant importance in soils because it has high cation exchange capacity (CEC) which influences plant nutrients availability, aggregate stability and microbial activity (Woomer *et al.,* 1994; Bationo *et al.*, 2006; Milne *et al.,* 2006). Therefore the degradation of SOC would have negative effects mainly on cation exchange capacity, nutrient availability, aggregate stability and microbial activity (Cooperband, 2002;Bot and Benites, 2005; Gosain *et al.,* 2015; FAO, 2015). The soil microbial biomass (SMB) is a small but key component of the active soil organic matter (SOM) pool and serves as a source and sink of soil nutrients. It has been used to understand soil nutrient dynamics and as an ecological marker (Adeboye *et al.* (2011).

The soil organic matter (SOM) and its key component, soil organic carbon (SOC), are one of the most important elements in the soil system. SOC is the substantive and energetic basis of all biological soil processes. Thus, it is the basis of the most productive and nonproductive soil functions. SOC is also one of the major criteria used in soil classification system (Micheli *et al.*2014),because of the controls it exerts on many physical and chemical properties of the soil. Thus the conversion of forests to arable land is usually accompanied by a decline in soil carbon which is linked to soil disturbance and change in plant litter composition (Yitbarek,2013). Research has shown that plant residue addition in forest can increase soil carbon content (Spaccunni *et al.*, 2001;Bossuyt *et al.,*2002) in evaluating soil structure degradation in Ethiopia and Nigeria concluded that in all agro ecological zones, soil organic carbon content was 2-4 times higher in forest than in cultivated soil.

2.2 Soil Organic Carbon Fractions

The ease and speed with which soil organic carbon (SOC) becomes available is related to the soil organic matter (SOM) fraction in which it resides. In this respect, SOC can be partitioned into fractions based on the size and breakdown rates of the SOM in which it is contained. The first three fractions are part of the active pool of SOM. Carbon sources in this pool are relatively easy to break down.

2.2.1 Total Organic Carbon

Total organic carbon (TOC) influences many soil characteristics including colour, nutrient holding capacity (cation and anion exchange capacity), nutrient turnover and stability, which in turn influence water relations, aeration and workability (Soil Quality, 2017). It is the carbon stored in soil organic matter (SOM). Organic carbon enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. SOM is the organic fraction of soil exclusive of non-decomposed plant and animal residues. Nevertheless, most analytical methods do not distinguish between decomposed and non-decomposed residues. SOM is a heterogeneous, dynamic substance that varies in particle size, carbon content, decomposition rate and turnover time (Sikora and Stott, 1996; Edward *et al.*, 1999).

In soils with high clay content the contribution to cation exchange from the organic fraction is generally small compared to that from clay. In sandier soils, the relative contribution of the organic fraction is higher because there is less clay, even though the amount of total organic carbon present may be similar or less to that in clays. By providing a food source for micro-organisms, organic carbon can help improve soil stability by micro-organisms binding soil particles together into aggregates or 'peds'. Bacteria excretions, root exudates, fungal hyphae and plant roots can all contribute to better soil structure (soilquality.org.au).

2.2.2 Soil Microbial Biomass Carbon

Microbial biomass in soil is the living component of soil organic matter. Many models of organic matter formation include microbial biomass as a precursor to the more stable fractions of organic matter (Parton et al., 1987). Because as much as 95% of the total soil organic matter is non-living and, therefore, relatively stable or resistant to change, decades may be required to observe a measurable change in soil organic matter. Microbial biomass has a turnover time of < 1 year (Paul, 1984) and therefore, responds rapidly to conditions that eventually alter soil organic matter levels. Thus, the size of the microbial may indicate degradation or aggradations of soil organic matter (Powlson*et al.*, 1987; Sparling, 1992).

The microbial biomass consists mostly of bacteria and fungi, which decompose crop residues and organic matter in soil. This process releases nutrients, such as nitrogen (N), into the soil that are available for plant uptake. About half the microbial biomass is located in the surface depth (0

- 10 cm) of soil and most of the nutrient release also occurs here (Murphy *et al.*, 1998). When microorganisms die, these nutrients are released in forms that can be taken up by plants. The microbial biomass can be a significant source of N, in some cases holding more than 60 kg N/ha. As an active component of soil organic matter, soil microbial biomass is involved in nutrient transformations and storage. Nutrients released during turnover of the microbial biomass are often plant available.

In soil the microbial biomass is usually starved because soil is too dry or does not have enough organic C. The amount of labile organic C is of particular importance as this provides a readily available carbon energy source for microbial decomposition. Soils with more labile C tend to have a higher microbial biomass. Fresh plant residues and soluble compounds released into the soil by roots (root exudates) are important sources of energy (C) for the microbial biomass.

2.2.2.1 Factors affecting microbial biomass

The microbial biomass is affected by factors that change soil water, temperature or carbon content, and include soil type, climate and management practices whereas soil properties that affect microbial biomass are clay content, soil pH, and organic C content. Soils with more clay generally have a higher microbial biomass as they retain more water and often contain more organic C. A soil pH near 7.0 is most suitable for the microbial biomass. Management of plant residues influences microbial biomass as residues are one of the primary forms of organic C and nutrients used by the microbial biomass. Retaining crop residues rather than burning them provides a practical means of increasing the microbial biomass in soil by increasing the amount of organic matter available to them.

Type of crop can also affect the microbial biomass. The residues of legume crops can increase microbial biomass due to their greater nitrogen contents. Rotations that have longer pasture phases generally increase microbial biomass because soil disturbance is reduced and organic matter supply is increased. However this may not be the case in very sandy soils, where the lack of clay means organic matter is broken down rapidly if there is sufficient moisture which tends to leaves the microbial biomass starved.

Minimizing tillage increases microbial biomass by protecting soil aggregates formed by fungal networks. The pore spaces in the aggregates are an important habitat for the microbial biomass in soil. Conversely a change to more disruptive practices can quickly deplete soil carbon in the topsoil, particularly microbial biomass carbon. Direct drilling can provide more efficient use of residues by microbial activity in 0–5cm layer compared with other tillage treatments. Stubble incorporation relocates residues deeper into soil, but the lack of aeration may limit decomposition and therefore microbial activity and microbial biomass carbon (Pankhurst *et al.*, 2002).

2.2.3 Water Soluble Organic Carbon

Water soluble organic carbon (WSOC) was defined as the entire pool of water soluble organic carbon either sorbed on soil or sediment particles or dissolved in interstitial pore water (Tao and Lin, 2000). WSOC accounts for a small portion of the total soil organic carbon content (Ohno *et al.*, 2007; Barbara and Fabrizio, 2009). Nevertheless, WSOC are considered as a most mobile and reactive soil carbon source which modulates a number of physical, chemical and biological processes in both aquatic and terrestrial environments (Schnabel *et al.*, 2002; Marschner and Kalbitz, 2003; Halvorson and Gonzalez, 2008). In most soils, the majority of organic carbon is in insoluble form except for a small fraction that is water soluble and not yet leached out. This fraction of organic carbon is called the water soluble organic carbon (WSOC). It is the most important carbon source for soil microorganisms (Sparling *et al.*, 1998; Schnabel *et al.*, 2002; Marschner and Kalbitz, 2003), so both the quantitative and qualitative aspects of WSOC are very important for soil ecosystem studies (Gao *et al.*, 1999; Gregorich *et al.*, 2003; Kalbitz *et al.*, 2003; Shamrikova *et al.*, 2006; Embacher *et al.*, 2007; Barbara and Fabrizio, 2009).

2.2.4 Particulate Organic Carbon

Particulate organic carbon (POC) is a labile intermediate in the soil organic matter continuum from fresh organic materials to humified SOC, and is more sensitive to changes in management than total SOC (Cambardella and Elliott, 1992). Aggregate formation was directly related to root-residue decomposition and POC dynamics under no-tillage practices and in undisturbed soils (Gale *et al.*, 2000).New micro aggregates probably form around decomposing pieces of root-derived POC inside macro aggregates. An aggregate life cycle was proposed by Six *et al.* (2000) in which aggregates form and stabilize around fine POC encrusted with microbial products, and eventually destabilize due to a cessation of microbial activity.

2.3 Management Practices Beneficial To Soil Organic Carbon Pool

According to Corsi *et al.*, (2012) and Banwart *et al.*, (2015), loss of SOC results in soil degradation and once organic matter is lost, a major repercussion is declined production functions of the soil that can only be restored by addition of soil organic matter through amendments or by changes of management practices such as adoption of conservation tillage. Generally, land use changes and poor agronomic practices have been reported to deplete soil organic carbon thereby lowering soil productivity but, conservation tillage practices have been known to increase soil organic carbon and improves soil productivity (Al-Kaisi *et al.*, 2005; Bot and Benites, 2005).

For the sustainable growth of both productivity and soil fertility, good management practices are essential (Aziz *et al.*, 2009). A variation in management practices results in alterations in quality and quantity of soil carbon (Cambardella and Elliott, 1992). Conventional management practices include plowing, chisel plowing and multiple tillage trips. Conventional tillage incorporates residues into soil, thereby increases soil-residue contact, favoring rapid decomposition of soil organic matter (Campbell *et al.*, 1996). Incorporation of soil residues results in an optimum level of moisture and temperature with proficient microbial population, healthier soil structure and significant enhancement in soil qualities and thus decreases the degradation of carbon (Krishan *et al.,* 2006). Soil biological, chemical and physical quality, enhanced in No-tillage and degraded under conventional tillage under a certain period of time (Madejon *et al.*, 2009; Naudin *et al.,* 2010; Derpsch *et al.,* 2010; Moussa-Machraoui *et al.,* 2010; Benitio, 2010; Alvaro-Fuentes *et al.*, 2012). According to Lee *et al.*, (2009) tillage can physically disrupt the soil aggregates and decreases its stability. Conservation management practices include putting off the remains of plant biomass on an uninterrupted surface which greatly enhances C accumulation within soil aggregates. Increased tillage intensity in many conventional tillage systems decreases total carbon, particularly active carbon and increases catabolism of carbon by disrupting soil aggregates and exposure of aggregate protected C to microbial attack (Mikha and Rice, 2004). The adoption of conservation tillage practices offers soil carbon sequestration opportunity, more favorable plant growth environment and soil health improvement relative to conventional tillage (Awale *et al.*, 2013). Conservation tillage practices prevent the loss of SOC (Cihacek *et al.,* 1998; Halvorson *et al.*, 2002). Among the conservation and conventional management practices, the conservation management practices implemented better to develop soil quality properties over time. No-till greatly enhances long term carbon conservation within different sizes of soil aggregates (Shan *et al.*, 2010; Erkossa, 2011).

Other management practices beneficial to SOC include: increase in the rate of organic matter production, changes in the decomposability of organic matter that increase organic carbon, placing of organic matter deeper in the soil, and enhancing physical protection and aggregation (Post and Kwon, 2000). Tree-base land-use systems have greater potential of soil carbon sequestration potential than agronomic crops (Post and Mann, 1990). Trees have the potential of producing larger quantities of above ground and below ground biomass compared to shrubs or herbs. More biomass results in increased production of above ground litter and below ground root activity and these make trees an important factor for SOC sequestration (Lemma *et al.*, 2007). Forest ecosystems store more than 80% of all terrestrial above ground carbon and more than 70% of all SOC (Batyes, 1996; Six *et al.*, 2002). When forests are converted to treeless system, they lose SOC. The conversion of forest to arable agricultural land use results in depletion of SOC by 20-50% (Post and Mann, 1990; Davidson and Ackerman, 1993) which also influence the forms of organic carbon.

2.4 Changes in Forms of Organic Carbon with depth under the various land use Management

The content of total, particulate, microbial biomass and soil water soluble organic carbon was significantly influenced by soil depth (Jamala and Oke, 2013). All the different land use types showed highest accumulation of the various carbon fractions in the surface layer (0 - 15 cm). This high level of organic carbon stock in the surface layer could be due to the slow of mixing of the soil and the litter layer formed as a result of leaf-fall from the trees (Jamala and Oke, 2013). In a 12-year experiment, Bayer *et al.*, (2000) found that by the third year, the increase in carbon and nitrogen stocks were minimal and occurred only in the 2.5 cm top layer, however, by the 5th year, this effect had spread to the 7.5 cm depth. In the 9th and 11th year, carbon and nitrogen stocks increased through to 12.5 and 17.5 cm depths respectively. Soil organic carbon storage in deeper soil layer has been related to the development of roots systems (Pillon, 2000) and to the amount of above ground biomass addition on the soil surface (Burle *et al.*, 2005) implying that the trees will normally improve in their respective organic carbon addition potentials, depending on the length of time and fallow period since the biomass increase with age. The organic carbon fractions were observed to decrease with depth. The top layer recorded the highest concentration of these fractions (Jamala and Oke, 2013).While the existence and activity of microorganisms in the subsurface, particularly in deep soils and aquifers, have been reported by various researchers and recently reviewed by Krumholz (2000), less information is available concerning the microbial populations in the shallow subsurface. Studies that have examined the seasonal effects on microbial activity and biomass size of the subsurface have been contradictory. Buchanan and King (1992) and Kaiser and Heinemeyer (1993) observed a greater microbial biomass size in the summer as compared to winter and suggested this is a direct consequence of higher temperatures. Bååth and Söderström (1982) and, Sarathchandra *et al.,* (1989) showed that soil microbial biomass was greatest in the spring and fall and lowest in the summer and winter. However, Holmes and Zac (1994) reported no differences in the size of the biomass as related to season.

2.5 Landuse Type Concepts

Land use refers to man's activities on land which are directly related to the land (Clawson and Stewart, 1965).Land use affects basic processes such as erosion, soil structure and bulk density, organic carbon, leaching, nutrient cycling and other similar physical and chemical processes (Jamala and Oke, 2014). Maddonni *et al.*, 2001.The concept of landuse is related to the use of land which is used for certain activity for a given period of time. Land use in a particular location is based on the extent to which the land characteristics match the use the land will be utilized (Verheye, 1986). Generally, land use changes and poor agronomic practices have been reported to deplete soil organic carbon thereby lowering soil productivity but, conservation tillage practices have been known to increase soil organic carbon and improves soil productivity (Al-Kaisi*et al.*, 2005; Bot and Benites, 2005).Tangtrakamang and Vitykcan (2004) have shown that in all pools, soil carbon in forest soil were higher than in adjacent cultivated soils. The conversion of natural forest to other form of land use can causes loss of soil quality, lead to soil erosion and reduction in soil organic content (Chen *et al.,* 2001). In the forest land, much of the soil nutrient is stored in the trees, whose canopy protects the soil against the impact of the heavy rainfall and other weather elements in a delicate ecological relationship. Therefore, exposure of the soils by deforestation and bush burning leads to impaired nutrient status of the soil (Owusu-Bennoah, 1997). Fuller, (1995) and Anderson, (2003) noted that forest soils maintain high levels of organic matter comparable to soil from the continuously cultivated fields. Litter-fall is a major contributor to soil organic matter in the forest ecosystem (Chen *et al.,* 2000).

When forest land are converted to cultivated land there is an appreciable change in organic matter content resulting in nutrient imbalances, and reduction in nitrogen, calcium, magnesium, potassium and phosphorus, (Brown and Lugo, 1990).By conversion of forest land to crop fields, Soil cation exchange capacity (CEC) increased (McGrath *et al.,* 2001). Blake *et al.,* (1999) found that the CEC of the soil under cultivated land increased with the depth, because the clay content increased. Also, they found that the CEC of the surface soil decreased by 47% during the last 100years after forest conversion. However CEC appears to rise and remain elevated in pasture soils following conversion from forest (McGrath *et al.,* 2001). Nair and Chamuah (1988) reported that in some pine forest, the CEC value decreases with the depth. The percentage of the base saturation is also higher in the surface soils as compared to subsurface layers, possibly, because of plant recycling (Seubert *et al.,* 1997). There are several factors which contribute to the loss of N in shifting cultivation fields. When forest is cleared and burned, there is large losses of nitrogen that occur upon burning by volatilization and reduction of organic matter (Gimeno-Garcia *et al.,* 2000; Gol and Dengiz, 2008). After clearing and crop harvest, the topsoil remains open for climatic conditions which allow for an increase in soil temperature and rates of microbial decomposition, and the lack of vegetation reduces plant uptake of mineralized N, which is then more vulnerable to losses by leaching (Alegre *et al.,* 1999).

In the forest area, phosphorus is considered a limiting nutrient for biological activity. The traditional slash and burning method produced more favorable change in supply of available soil phosphorus (Awoteye *et al.,* 2013). There is a transformation of un-available phosphorus in soil into mineral forms readily available to plants which are caused by burning (Giardina *et al.,* 2000).Shukla and Agrawal, (1994) reported that available phosphorus in the top soil increased after few years of continuous cultivation. The total amount of available phosphorus in the soil was reduced during cropping and this was attributed to crop uptake and phosphorus remains become insoluble. Burning dried vegetation will result in higher concentration of Ca, Mg and potassium in top soil layer as compared to mechanical treatment (Marafa and Chau, 1999). The basic cations in the ash will give marked increases in exchangeable Ca, Mg and potassium level after burning (Stromgaard, 1991).

Some of the agricultural land uses peculiar to the tropical region are:

Arable land: This originated from the Latin word "arabilis" meaning able to be plough). It is then defined as land capable of being ploughed and used to grow crops. In Britain, it was traditionally contrasted with pasturable lands such as heaths which could be used for sheep-rearing but not farmland.

Fallow land: This simply refers to a cropland that is not seeded for a season and it may or may not be plough. The land may be cultivated or chemically treated for control of weeds and other pests or may be left unaltered. Allowing land to lie fallow serves to accumulate moisture in dry regions or to check weeds and plant diseases.

Forest plantation: This is a large scale farm that specializes in cash crops, usually tree crops. These crops grown include cashew, cotton, coffee, cocoa, oil palms, rubber trees, teak, melaina and so on.

Ranchland: This is an area of land, including various structures, given primarily to the practice of ranching, the practice of raising grazing livestock such as cattle or sheep for meat or wool. The word most often applies to livestock raising operations in Mexico, the Western United States and Canada. People who own or operate a ranch are called ranchers, cattlemen, or stock growers. Ranching is also a method used to raise less common livestock such as elk, American bison or even ostrich, emu, and alpaca.

2.6 Agricultural Land Use Types and Carbon Fractions

2.6.1. Effect of Land Use on Total Organic Carbon (TOC)

The changes in land use means changes in total stock of soil organic carbon. Guo and Gifford (2002), on the basis of meta-analysis, show that the conversion of pasture into arable land SOC decreased up to 59%; however, change from crop to pasture can increase the SOC stock (19%). The direction of changes and conversion of SOC is in the most current ecosystems influenced by human activity – land use. This is especially true for agricultural land, where soil organic matter represents more as 95% (pastures, meadows) or almost 100% (arable land) of total organic carbon accumulated in human-amended ecosystems (Stolbovoy and Montanarella, 2008). Continuous pasture builds organic carbon quicker than other rotations. In soils with high clay content the contribution to cation exchange from the organic fraction is generally small compared to that from clay. Bationo *et al.* (2003) noted that one single most important biophysical constraint to food security in the West African savanna has been identified to be soil fertility degradation. In sandier soils the relative contribution of the organic fraction is higher because there is less clay, even though the amount of total organic carbon present may be similar or less to that in clays.

According to Lal (2003), change in land use from natural to agricultural ecosystems depletes the SOC pool over time, generally in the order cropland> grazing land> forest. A loss of

SOC due to soil erosion and incompatible land use change degrades the soil ecosystem and environmental quality (Lal, 2002).

2.6.2 Effect of Land Use on Particulate Organic Carbon (POC)

POC are more responsible for stability of aggregates (Debasish-Saha *et al.*, 2011). Being a labile intermediate fraction, the POC can be used as an early indicator of changes in C dynamics and total SOC under different land uses and management systems (Pikul *et al.*, 2007).Bescansa *et al.* (2006) stated that, particulate organic carbon is an accurate soil quality indicator despite soil differences, and therefore advocated that it should be considered when assessing the quality of different soil management practices. Under forest soils, the presence of litter recycles continuously organic carbon storage in topsoil horizons (Garcia-Pausas *et al.*, 2004). However, in the pasture lands and specially cultivated soils, perennial herbaceous or crop residues were the only carbon resources. Moreover, Cultivation decreases the amount of carbon by the following processes: (i) accelerated mineralization, (ii) leaching and translocation as dissolved or particulate organic C and (iii) accelerated erosion (Bongiovanni *et al.*, 2006; Li *et al.*, 2007). Change in soil occupation from forest to pasture or agriculture lands harmfully affected SOC and POC content (Bongiovanni *et al.*, 2006) essentially in sandy soils. This is because a higher amount of clay in these soils does not reduce organic carbon sequestration (Feller and Bear, 1997). As perhaps the most easily decomposable fraction of non-living SOM after microbial biomass, POM fulfills many soil functions mediated by OM. It is a source of food/energy for microorganisms and soil fauna as well as nutrients for plant growth. Particulate organic matter enhances aggregate stability, water infiltration and soil aeration; it increases cation exchange capacity and buffers pH. It also binds environmental pollutants such as heavy metals and pesticides. Particulate organic matter may play an important role in the suppression of soil borne diseases (e.g. damping off of cucumber) by compost. This may be explained by the fact that POM is an important source of food/energy in the compost for microorganisms responsible of disease suppression. Being a labile intermediate fraction, the POC can be used as an early indicator of changes in C dynamics and total SOC under different land uses and management systems (Pikul *et al.*, 2007).

2.6.3 Effect of land Use on Water Soluble Organic Carbon (WSOC)

Water soluble organic carbon (WSOC), defined as the entire pool of water soluble organic carbon either sorbed on soil or sediment particles or dissolved in interstitial pore water (Tao and

Lin, 2000). WSOC accounts for a small portion of the total soil organic carbon content (Tao and Lin, 2000; Ohno *et al.*, 2007; Barbara and Fabrizio, 2009). Nevertheless, WSOC are considered as a most mobile and reactive soil carbon source which modulates a number of physical, chemical and biological processes in both aquatic and terrestrial environments (Schnabel *et al.*, 2002; Marschner and Kalbitz, 2003; Halvorson and Gonzalez, 2008). Results of forty years of continuous conventional cropping indicated significant reduction in the content of alkali extractable and water-soluble carbon as compared to grassland soils (Saviozzi *et al.*, 1994).This fraction of organic carbon is called the water soluble organic carbon (WSOC).Many environmental factors affect WSOC in soils, such as ecosystem acidification (Shamrikova *et al.*, 2006; Karavanova *et al.*, 2007), litter quality as influenced by forest composition (Shamrikova *et al.*, 2006; Ohno *et al.*, 2007), pig slurry addition (Hernández *et al.*, 2007), steam soil disinfestations (Roux-Micholl et *et al.*, 2010) and soil temperature (Tao *et al.*, 2000). Soil temperature and moisture are key factors that control plant growth, distribution, and soil ecology in this cold and semi-arid ecosystem (Baumann *et al.*, 2009; Gao *et al.*, 2009). It is well established that soil temperature and moisture are key factors influencing soil microbial activity and soil organic matter decomposition (Chen *et al.*, 2007; Dijkstra and Cheng, 2007; Gao *et al.*, 2009). Vegetation types such as mature forest, lichens and shrubs apparently serve to elevate the WSOC. The quantity of WSOC was not necessarily related to the amount of TOC in a soil profile (Michaelson *et al.*, 2001).

2.6.4 Effect of Land Use on Soil Microbial Biomass Carbon (SMBC)

Microbial biomass is the characteristics of microorganism, which participate in the biochemical cycles and are the live part of soil organic matter (Cengel, 1990; Srivastava,1992). Microbial biomass which represents an important labile pool of nutrients in soil (Henrot and Robertson 1994) plays a significant role in nutrient transformation and conservation processes in grassland, forest and cropland ecosystems. (Sarathchandra *et al.*, 1984; Singh *et al.*, 1989;Bolton *et al.*,1993) in both tropical and temperate climates. The activity of microbial biomass is commonly used to characterize the microbiological status of soil (Nannipieri *et al.*,1990,Gil-Sotres*et al.*, 2005). Measurements of soil microbial biomass have been used in studies of the flow of carbon, cycling of nutrients and plant productivity in a variety of terrestrial ecosystems (Voroney *et al.*,1993).The microbial biomass carbon has been used as an approach to evaluate soil quality (Gil-Sotres *et al.*, 2005).Measuring microbial biomass is a valuable tool for understanding and predicting long-term effects on changes in land use and associated soil conditions (Sharma *et al.*, 2004). It is well known that soil organic C strongly affects the amount and activity of soil microbial biomass (Diaz-Ravina *et al.*, 1988; Jenkinson, 1988).

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Study Area

The study site was in Federal University Oye-Ekiti, Ikole Campus, (9^o 14'N, 6^o 30'E) in the derived savanna of Nigeria with a gently undulating topography. The climate is sub-humid tropical with mean annual rainfall of about 1200 mm (90% of the rainfall is between June and August). The mean daily temperature rarely falls below 22 ^oC with peaks of 40 ^oC and 36 ^oC between February to March and November to December respectively. The soils of Ikole-Ekiti are Alfisols (USDA) developed from basement complex rocks ranging from shallow to very deep soils overlying deeply weathered gneisses and migmatites with some underlain by iron pan to varying depths.

3.2 Site Description

SITE 1: Arable Farm Land

The arable farm land had been under continuous cultivation for over 10 years. Some arable crops present as the time of the soil sampling were cassava (*Manihot spp*), Amaranthus (*Amaranth spp*), maize (*Zea mays*), yam (*Dioscorea spp*) etc.

SITE 2: Forest Plantation

The forest plantation had a plantation history of over 10 years and the following tree crops were present: cashew (*Anacardium occidentale*), cocoa (*Theobroma cacao*), teak (*Tectona grandis*), oil palm (*Elasis guineensis*) and various under-growths.

SITE 3: Fallow Land

The fallow land which served as the control had been left to fallow for a period of over 7 years. The land was occupied by grasses and shrubs and few tree species.

SITE 4: Ranch Land

The ranchland had been in use for about 4 years. There were scanty trees and shrubs species that served as a source of shade for the animals (cattle, goat and sheep).

3.3 Soil Sampling and Preparation

Undisturbed soil samples were collected from 0-5, 5-10, 10-20 and 20-30 cm depths from the four land use types and the land use were replicated three times. Soil samples were also collected at each site using soil auger at the depth of 0-30cm for the purpose of routine soil analysis. The samples obtained from the field were air-dried, crushed, (when found necessary) and passed through a 2 mm sieve. The processed samples were then placed in fresh, well labeled plastic bags prior to laboratory analysis.

3.4 Laboratory Analysis

3.4.1 Routine Soil Analysis

Samples for the determination of total N were passed through 0.5mm sieve. Soil pH (1:1 soil/water ratio) was determine in both water and KCL and measured with a glass electrode pH meter, particle size analysis was carried out using the Bouyoucos Hydrometer method (Bouyoucos 1951); organic carbon was determined via the Walkley- Black dichromate oxidation method; total N by the Kjeldahl digestion method and available P by Brays P-1 method (Bray and Kurtz, 1945). Exchangeable bases (K, Na, Ca and Mg) were extracted using neutral normal NH_4OA_c; while K, Na and Ca were read with flame photometer while Mg was read through atomic absorption spectrophotometer. Exchangeable acidity was determined by 1N KCl extraction method (Mclean, 1965) Effective cation exchange capacity (ECEC) was by summation of exchangeable bases and exchangeable acidity and percent base saturation calculated is as follows:

$$\%\ \textit{Base saturation} = \frac{\textit{Exchangeable bases}}{\textit{ECEC}} \times 100$$

3.4.2 Soil Organic Matter Determination

3.4.2.1 Determination of Total Organic Carbon Fraction (TOC)

The amount of milliequivalent of readily oxidizable material, O_x per gram of soil was determined in 0.5g soil samples using procedure described by Walkley and Black (1934). The percent organic C content was later determined by multiplying the amount by a factor 0.39.

3.4.2.2 Determination of Soil Microbial Biomass Carbon (SMBC)

The chloroform fumigation – incubation technique described by Anderson and Ingram (1993) was employed. The procedure is described as follows:

Two 10 g sub samples of thoroughly sieved soil were weighed from each soil sample into small plastics containers; while a third sub sample of 10 g was weighed into a 125 ml water tight plastic bottle. The sample in one of the containers (t_1) was used for the determination of percent water content so as to be able to express the results on a dry-soil basis; while the second sample (t_2) was fumigated prior to incubation, and subsequent extraction of dissolved organic carbon. The third sample (t_3) was used for the extraction of dissolved organic carbon in un fumigated were arranged at a time on a wire gauze in a vacuum desiccator containing 300 ml alcohol free $CHCl_3$ in a shallow dish beneath the gauze. The lid of the desiccator was closed and vacuum applied through a pressure pump until the $CHCl_3$ evaporates. The tap on the desiccator was closed and then placed in the dark for 5 days at room temperature. After 5 days, the desiccator was removed from the dark, and samples transferred into water tight 125 ml extraction bottles. 50 ml 0.5 M K_2SO_4 was added into each sample in the bottle, tightly stopped and shaken on a rotary shaker for 30 minutes. The samples were thereafter each filtered and extracted through a N0.42 Whatman filter paper, and filtrate retained for analysis. The extracts were analyzed for dissolved organic carbon by titration method described by Nelson and Sommer (1982).Estimate of the microbial biomass C of each soil sample was obtained by multiplying the difference in extracted C of fumigated and un-fumigated samples by a factor 2.64 (Vance *et al.,* 1987).

$$\textbf{\textit{Microbial biomass C}} = (\textit{Extracted } Ct_2 - \textit{Extracted } Ct_3) \times 2.64$$

3.4.2.3 Determination of Particulate Organic Carbon Fraction (POC)

Particulate organic carbon (POC) according to Anderson and Ingram (1996) is defined as that with diameter between 53μm and2mm; captured using wet sieving technique. This size definition is similar to that of Cambardella and Elliot (1992) who considered POM to range between 53μm and 2mm. Its determination was carried out by adapting with modification the procedure described by Cambardella and Elliot (1992), Anderson and Ingram (1996). 10g air dried sieved (2mm sieve) soil samples were weighed into plastic sample bottles. 30ml of $(NaPO_3)_{13}$ were added and shaken for 15 hours on a rotary shaker. The suspension in the sample bottles was passed through a 53μm sieve. The materials retained on the sieve were then washed with plenty of distilled water into a pre-weighed and dry beaker until the water flow was clear, (now this suspension is called particulate organic carbon, POC, with a particle size > 53μm).The beakers and the samples were then oven-dried to a constant and recorded weight at $60^{O}C$, homogenized by grinding using a mortar and pestle; and used for the determination of percent organic carbon. The determination of organic carbon was by wet oxidation procedure described by Walkley and Black (1934). The total POM content of the soil was estimated using the relationship:

$$POMt = DW\ (53\mu m) \times (\%\ Organic\ C/100)$$

Where:

DW = Oven dried weight of dispersed soil on 53μm sieve

%Organic C = Organic C of dispersed soil on 53μm sieve

3.4.2.4 Determination of Water Soluble Organic Carbon Fraction (WSOC)

Water soluble organic carbon in soils was determined as per the procedure outlined by McGill *et al.* (1986). 5g freshly drawn field moist soil sample was shaken with 10 ml (1:2: soil: water) distilled water for 60 minutes followed by 30 minutes centrifugation at 10,000rpm. Water soluble organic carbon was determined using a liqui TOC analyzer.

3.5 Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) procedure for Randomized Complete Block Design (RCBD). The land use types constituted the treatments while soil depths constituted the blocks. The Statistical analysis was performed with SAS System, mean separation was performed using Duncan's Multiple Range Test (DMRT) at $P<0.05$.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Physical and Chemical Properties of the Soil in the Study Sites

Physico-chemical properties of the soils taken from different land use types in Ikole-Ekiti are presented in Table 1. The pH (H2O) across the land use types ranged between slightly acidic to neutral pH reactions based on the classification in Foth and Ellis (1997). The pH values were: Fallow land of 6.09; arable land 5.96; forest plantation 6.07; and ranchland 7.22. Many chemical reactions that influence nutrient availability are influenced by the soil chemical environment, especially the soil. (Schoenholtz *et al.* 2000). Soil pH is important in determining the availability of many elements. Optimum availability of nutrients for most plants appears to be between pH 6 and 7 (slightly acid to neutral).

Organic carbon content of the soils varied from 36.5 - 39.9 g/kg. The differences in organic carbon content of the soils of the four land use types and may be linked to the heterogeneity of land use pattern, rainfall and temperature regimes.

According to Landon (1991) available soil P level < 5mg/kg is rated as low, 5-15 mg/kg as medium and > 15mg/kg is rated as high. Thus, the available P ranges from 1.73-2.03mg/kg was deficient considering 8-25mg/kg critical level by Adepetu and Barber (1979). The low native of available P in these soils could be as a result of low SOM which is a characteristic of acid mineral soils of the basement complex (Agboola and Oko, 1976; and Mengel, 1997). The total N is at1.14-1.71g/kg.

Table 1. Physical and chemical properties of the soils in Ikole-Ekiti

	Agricultural Land Use Type			
Properties	Fallow	Forest plantation	Arable	Ranchland
pH (H_2O)	6.19	5.96	6.07	7.22
Org. Carbon (g/kg)	36.5	36.7	38.3	39.9
Total N (g/kg)	1.43	1.71	1.14	1.28
Avail. P (mg/kg)	1.51	1.72	1.72	2.03
Ca (cmol/kg)	0.13	0.15	0.11	0.13
Mg (cmol/kg)	0.12	0.15	0.09	0.10
K (cmol/kg)	0.51	0.56	0.09	0.10
Na (cmol/kg)	0.26	0.23	0.23	0.24
CEC (cmol/kg)	1.03	1.48	0.93	0.96
Ex. Acidity (cmol/kg)	0.06	0.06	0.06	0.06
ECEC (cmol/kg)	1.11	1.16	1.0	1.03
% Base Saturation	94.0	94.2	93.5	93.3
% Sand	78.8	77.4	80.1	80.4
% Silt	13.2	11.5	13.2	13.8
% Clay	8.0	11.0	6.6	5.6
Textural Class	LS	LS	LS	LS

LS = Loamy sand

Values for exchangeable bases (Ca, Mg, Na, K) varied across each land use types. Calcium had values of 0.13, 0.15, 0.11 and 0.13cmol/kg for fallow, arable, forest plantation and ranchland respectively. Magnesium had values of 0.12, 0.15, 0.09 and 0.10cmol/kg for fallow, arable, forest plantation and ranchland respectively. Values for K were 0.51, 0.56, 0.09and 0.10cmol/kg for fallow, arable, ranchland and forest plantation, values for Na were 0.26, 0.23, 0.23 and 0.24 cmol/kg for fallow, arable, forest plantation and ranchland respectively. Mg was considered low compared to 1.9 cmol/kg soil established by Agboola and Ayodele (1987), Ca was also low considering the critical level of 2.0-2.6cmol/kg soil by Agboola and Ayodele (1987), Na is high compared to 0.18-0.2cmol/kg by Agboola and Obigbesan (1974). The low exchangeable basic (Na, Ca, Mg and K) cations in the arable land may be due to removal of basic cations (Na^+, Ca^{2+}, Mg^{2+} and K^+) by crop uptake, leaching and erosion which finally intensify the acidification processes. There was a great variation in effective cation exchange capacity (ECEC) of the soils under the different land use systems. This was in line with the reports of (Achalu *et al.*, 2012; Achalu, 2014).

Exchangeable acidity was low (0.06cmol/kg). The CEC was low. Effective cation exchange capacities (ECEC) of the soils were low ranging from 1.0 to 1.1cmol/kg compared with >4 cmol/kg critical level established by FAO (1979),ECEC determines the soils capacity to hold and exchange natural and artificial sources of cationic plant nutrients (Raji, 2011).The base saturation across each land use was high. Fallow land had the highest value of 94 %, forest plantation had the value of 93.5%, ranchland, 93.3% and arable had the least value of 94.2%. According to Urioste *et al.* (2006), addition of organic matter increases the amount of exchangeable bases. Moreover, intensive cultivation and continuous use of inorganic fertilizers in the arable land enhance loss of base cations through leaching, erosion and crop harvest (Negessa, 2001).

The textural class across each land use was pre-dominantly loamy sand. Fallow land (78.8% sand, 13.2% silt and 8% clay), arable land (77.4% sand, 11.5% silt and 11% clay), forest plantation (80.1% sand, 13.2% silt and 6.6% clay) and ranchland (80.4% sand, 13.8% silt and 5.6% clay).

4.2 Effect of Land Use on Total Organic Carbon

At 0 – 5 cm, the fallow land had the highest value of TOC, 30.27 g/kg (Table 2) followed by forest plantation, ranchland and arable land with values of 29.70, 28.57 and 19.60 g/kg respectively. At 5-10 cm, there was significant difference in TOC across the land use types. Ranchland contained the highest 27.67g/kg, which was similar to fallow land (27.30g/kg), and both different from forest plantation (23.47g/kg) and arable land which had the least (16.60g/kg). At 10-20 cm, TOC was 20.90, 20.10, 19.20 and 15.10g/kg for fallow, ranchland, forest plantation and arable respectively. At 20-30 cm, forest plantation, fallow land, ranchland and arable land, had values of 23.63, 19.40, 18.13 and 13.60g/kg respectively.

Generally, across all the land use types, fallow land had the highest values followed by forest plantation, and ranchland while arable land had the least values. The highest values for fallow and forest land could be attributed to no tillage operations at the forest lands, resulting in no disturbance of the soil. According to Lee *et al.*, (2009) tillage can physically disrupt the soil aggregates and decrease its stability. Also, soil biological, chemical and physical quality was enhanced in No-tillage but degraded under conventional tillage under a certain period of time (Madejon *et al.*, 2009; Naudin *et al.*, 2010; Derpsch *et al.*, 2010; Moussa-Machraoui *et al.*, 2010; Benitio, 2010; Alvaro-Fuentes *et al.*, 2012).

Table 2. Effect of different agricultural land use types on various forms of SOC in Ikole-Ekiti

SOC Forms (g/kg)	Depth (cm)	Agricultural Land Use Type				CV (%)
		Fallow	Arable	Forest plantation	Ranchland	
TOC	0 – 5	30.27	19.97	29.70	28.57	27.61
	5 – 10	27.30a	16.60c	23.47b	27.67a	8.47
	10 – 20	20.90	15.10	19.20	20.10	37.14
	20 – 30	19.40	13.60	23.63	18.13	42.67
SMBC	0 – 5	0.74	0.86	0.86	0.72	30.16
	5 – 10	0.86	0.90	0.89	0.64	31.76
	10 – 20	0.68	0.96	0.96	0.80	21.25
	20 – 30	0.73b	1.04a	0.98a	0.87ab	13.69
POC	0 – 5	3.53	4.54	4.15	4.15	14.96
	5 – 10	3.60	4.59	4.17	4.15	17.19
	10 – 20	3.59	4.66	3.95	4.03	15.69
	20 – 30	3.52	4.68	4.02	4.15	15.78
WSOC	0 – 5	1.97	2.10	2.03	2.05	9.39
	5 – 10	2.07	2.08	1.96	2.17	11.92
	10 – 20	1.98	2.09	2.05	2.02	7.01
	20 – 30	1.83	1.98	2.02	2.14	12.39

Means without letters in the same row are significantly different ($p < 0.05$).

TOC = Total organic carbon; SMBC = Soil microbial biomass carbon; POC = Particulate organic carbon and WSOC = Water soluble organic carbon.

The result also showed that values for forest plantation were higher than that of ranchland, arable land had the least values. This finding corroborates the report of Alexandra and Jose (2005), that the conversion of grassland and forest plantations to arable cropping results in the loss of 30% of the soil organic carbon originally present in the soil. This shows that continuous cultivation of these soils can accelerate depletion of the soil organic carbon content. Loss of soil organic matter can therefore, reduce soil fertility, degrade soil structure and lower water holding capacity, ultimately leading to desertification. Also due to the intense litter recycling taking place in forest soils this result is expected (Igwe, 2001). Generally, The consistently low value of TOC in arable land compared to other land uses and may be due to frequent soil erosion phenomena, and intensive human disturbance through inversion and pulverization of soil during tillage that makes for accelerated mineralization of exposed organic matter.

4.3 Effect of Land Use on Particulate Organic Carbon

Particulate organic carbon, POC was highest in arable land (4.54g/kg) at 0-5 cm followed by ranchland and forest plantation (4.15 g/kg), while fallow land (3.53g/kg). At 5-10cm, POC was 4.59, 4.17, 4.15 and 3.60 g/kg for arable, forest plantations, ranchland and fallow respectively. The corresponding values at 10 – 20 and 20 – 30 cm were 4.66, 4.03, 3.95 and 4.03g/kg; and for arable, ranchland, forest plantations and fallow were 4.68, 4.15, 4.02 and 3.52g/kg respectively. Overall, there were no significant differences among the land use types but arable land contained the highest POC in all the land use types at each depth. However, in the pasture lands and specially cultivated soils, perennial herbaceous or crop residues were the only carbon resources. Moreover, Cultivation decreases the amount of carbon by the following processes: (i) accelerated mineralization, (ii) leaching and translocation as dissolved or particulate organic C and (iii) accelerated erosion (Bongiovanni *et al.*, 2006; Li *et al.*, 2007). Change in soil occupation from forest to pasture or agriculture lands harmfully affected SOC and POC content (Bongiovanni *et al.*, 2006). Janzen (2006) also estimated that soil cultivation, mainly conversion of pasture into arable land, leads to significant organic carbon loses in the overall balance up to 50Pg. Conversely land-use change can offer an opportunity for sequestering atmospheric carbon in soils.

4.4 Effect of Land Use Types on Soil Microbial Biomass Carbon

The SMBC at 0 – 5cm, was highest in forest plantation and fallow land (0.86g/kg) followed by fallow land (0.74g/kg), while ranchland had the least value (0.72g/kg). At 5 – 10 cm, the mean value for arable land (0.90g/kg) slightly differed forest plantation (0.89g/kg) while fallow had value of (0.86g/kg) ranchland had value of 0.64g/kg. At 10-20 cm, arable and forest plantation had the highest mean (0.96g/kg) while ranchland contained 0.80 g/kg followed by fallow with 0.68g/kg. At 20 – 30 cm, the values were 1.04, 0.98, 0.87 and 0.73g/kg for ranchland, arable land, forest plantation and fallow land respectively.

Generally, across all depths no significant difference existed across land use types, except for ranchland at depth 20 – 30cm and arable land had the highest values for SMBC across all the land use types at each depth.

4.5 Effect of Land Use on Water Soluble Organic Carbon

The WSOC was not significantly different across the land use types. At 0 – 5 cm, and across the land use types, the arable land contained the highest WSOC (2.10g/kg), while ranchland, forest plantation and fallow land contained 2.05, 2.03 and 1.97 g/kg respectively. At 5-10 cm the WSOC was 2.17, 2.08, 2.07 and 1.96 g/kg for ranchland, arable land fallow land and forest plantation respectively. Depth 10 – 20 cm recorded values for WSOC as 2.09, 2.05, 2.02 and 1.98 g/kg for arable land, forest plantation, ranchland and fallow land respectively. Contents of WSOC at 20 – 30 cm were 2.14, 2.02, 1.98 and 1.83 g/kg for ranch land, forest plantation, arable land and fallow respectively.

The WSOC showed high variation across the land use types. Boyer and Groffiman, (1996) reported that concentrations of water-soluble, SOC were high in agricultural soils. The data in this study suggest that agricultural soils would support greater rate of microbial activity than forest soils due to increased production of water-soluble carbon. However, there are reports that WSOC was different under different vegetation or land use (Smolander and Kitunen, 2002; Kiikkilä *et al.*, 2005). Many environmental factors affect WSOC in soils, such as ecosystem acidification (Shamrikova *et al.*, 2006; Karavanova *et al.*, 2007), litter quality as influenced by forest composition, manure addition (pig slurry) (Hernández *et al.*, 2007).The soluble fraction of organic matter is the main energy substrate of soil and should therefore be utilized preferentially (Marschner and Bredow, 2002).As the soil temperature increases, soil microbial activity is enhanced leading to accelerated decomposition of organic matter and release of organic carbons (i.e. CO_2) into the atmosphere.

Table 3 shows the mean contents, range, standard deviation and coefficient of variation of the forms of organic carbon in agricultural soils of Ikole-Ekiti. TOC had significantly higher mean content of 27.13 g/kg at 0 – 5 cm compared to non-significant mean contents of23.76, 18.83 and 18.69g/kg at 5 – 10, 10 – 20 and 20 – 30 cm, respectively. The higher TOC in surface layers could be due to litter fall and crop residues that added up to organic matter and expected increase in soil biodiversity (Miller and Gardiner, 2001). The 0-5cm depth gave the lowest mean SMBC (0.79 g/kg) while the highest mean content of 0.90 g/kg was at 20 – 30 cm. POC and WSOC had their highest mean contents at depth 5 – 10 cm which decreased at 10 – 20 and 20 – 30 cm to least means of 4.06 and 1.99 g/kg, respectively. TOC, SMBC and POC had medium to high coefficient of variation, indicating a generally medium to high variation whereas, WSOC had low coefficient of variation values ranging from 6.36 – 12.00 %, which is below the 15 % stipulated as medium variation ranking (Wilding *et al.*,1994).

4.6 Relationships between Organic Carbon Fractions and Selected Soil Properties in Fallow Land

From the Table 4a, it can be observed on the soil properties of fallow lands in Ikole-Ekiti that there is a significantly strong positive correlation between phosphorus and pH water ($r = .99 p < .05$); a perfect relationship between organic carbon and SMBC ($r = 1.00 p < .01$); a perfect relationship between ECEC and pH water ($r = 1.00 p < .05$); near perfect positive relationship between silt and organic carbon ($r = .99 p < .05$); also a significant near perfect relationship between silt and SMBC ($r = .99$ $p < .05$),a perfect relationship between sand and WSOC ($r = 1.00$ $p < .01$).There is no relationship between the forms of organic carbon.

Table 3. Depth-wise mean, range, standard deviation and coefficient of variation of forms of SOC in agricultural soils in Ikole-Ekiti.

SOC Forms (g/kg)		Soil depth (cm)			
		0 – 5	5 – 10	10 – 20	20 – 30
TOC	Mean	27.13a	23.76ab	18.83b	18.69b
	Min/Max	23.10	14.20	21.90	29.60
	Std. Dev.	7.74	4.95	6.40	7.76
	CV (%)	28.52	20.85	34.01	41.51
SMBC	Mean	0.79	0.82	0.85	0.90
	Min/Max	0.70	0.77	0.64	0.53
	Std. Dev.	0.22	0.25	0.20	0.16
	CV (%)	27.09	30.23	23.15	17.94
POC	Mean	4.09	4.13	4.06	4.09
	Min/Max	2.00	2.19	2.06	2.12
	Std. Dev.	0.64	0.17	0.68	0.70
	CV (%)	15.74	17.13	16.67	17.09
WSOC	Mean	2.04	2.07	2.04	1.99
	Min/Max	0.52	0.69	0.45	0.74
	Std. Dev.	0.17	0.23	0.13	0.24
	CV (%)	8.34	10.86	6.36	12.00

Means without letters in the same row are significantly different ($p < 0.05$).

TOC = Total organic carbon; SMBC = Soil microbial biomass carbon;

POC = Particulate organic carbon and WSOC = Water soluble organic carbon.

Table 4a. Correlation of forms of SOC with some soil properties in fallow land in Ikole-Ekiti.

	pH (H_2O)	Org. C	Avail. P	Total N	Ex. Acidity	CEC	ECEC	BS	Sand	Silt	Clay	TOC	SMBC	POC	WSOC
pH (H_2O)	1														
Org. C	.953	1													
Avail. P	.264	.544	1												
Total N	.516	.751	.962	1											
E. Acidity	.703	.455	-.500	-.246	1										
CEC	.992	.984	.385	.621	.607	1									
ECEC	1.00*	.959	.284	.533	.689	.994	1								
BS	-.345	-.045	.814	.626	-.910	-.223	-.326	1							
Sand	.711	.891	.866	.969	0.00	.795	.725	.415	1						
Silt	-.967	-.999*	-.500	-.716	-.500	-.992	-.972	.096	-.866	1					
Clay	.965	.839	0.00	.271	.866	.923	.959	-.581	.500	-.866	1				
TOC	.251	-.055	-.868	-.700	.864	.125	.231	-.995	-.503	.003	.497	1			
SMBC	.954	1.00**	.540	.749	.458	.985	.960	-.048	.889	-.999*	.841	-.051	1		
POC	.460	.169	-.735	-.524	.955	.343	.442	-.992	-.298	-.219	.678	.975	.173	1	
WSOC	-.701	-.885	-.873	-.972	.013	-.787	-.716	-.427	-1.00**	.859	-.489	.514	-.883	.310	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

4.7Relationships between Organic Carbon Fractions and Selected Soil Properties in Arable Land

On the Table 4b, it can be observed on the soil properties of arable lands in Ikole-Ekiti, there are significant perfect negative relationships between silt and pH water (r= -1.00, *p*<.05); a near perfect negative relationship between TN and SMBC (r= -.99, *p*<.05); a significant perfect negative relationship between Sand and TOC (r= -1.00,*p*<.01); a significant perfect negative relationship between CEC and SMBC (r= -1.00, *p*<.05).There is no relationship between the forms of organic carbon.

4.8 Relationships between Organic Carbon Fractions and Selected Soil Properties in Forest Plantation Land

Observing data on Table 4c, it can be established that there is a positive relationship between SMBC and organic carbon (r=1.00, *p*<.05); a significantly strong relationship between exchangeable acidity and ECEC (r=.99*p*<.05); also a significant near perfect relationship between exchangeable acidity and BS (r= .99*p*<.05); a positive relationship between sand and POC (r=1.00, *p*<.01). There is no relationship between the forms of organic carbon.

4.9 Relationships between Organic Carbon Fractions and Selected Soil Properties in Ranch Land

From Table 4d, it was observed that there is a significantly strong relationship between available P and POC (r= .99*p*<.05);a significant negative perfect relationship between pH water and POC(r= -1.00, *p*<.01); a significantly strong relationship between pH and available P (r=.99 *p*<.05);a significantly strong relationship between ECEC and sand (r=.99 *p*<.05); a significantly strong relationship between exchangeable acidity and BS (r= .99*p*<.05)

Table 4b. Correlation of forms of SOC with some soil properties in arable land in Ikole-Ekiti.

	pH (H_2O)	Org. C	Avail. P	Total N	Ex. Acidity	CEC	ECEC	BS	Sand	Silt	Clay	TOC	SMBC	POC	WSOC
pH (H_2O)	1														
Org. C	-.994	1													
Avail. P	.990	-.968	1												
Total N	-.390	.285	-.517	1											
E. Acidity	.841	-.896	.756	.170	1										
CEC	.372	-.267	.500	-1.000*	-.189	1									
ECEC	.644	-.555	.746	-.956	.127	.950	1								
BS	-.754	.822	-.653	-.311	-.989	.329	.017	1							
Sand	.968	-.934	.994	-.608	.679	.593	.815	-.565	1						
Silt	-1.00*	.992	-.992	.405	-.832	-.387	-.656	.743	-.972	1					
Clay	-.787	.713	-.866	.875	-.327	-.866	-.979	.187	-.916	.796	1				
TOC	-.972	.940	-.996	.595	-.691	-.580	-.805	.579	-1.00*	.976	.909	1			
SMBC	-.427	.324	-.551	.999*	.130	-.998*	-.967	-.272	-.640	.441	.894	.627	1		
POC	-.048	-.063	-.189	.938	.500	-.945	-.795	-.620	-.297	.064	.655	.281	.924	1	
WSOC	-.549	.453	-.662	.984	-.009	-.980	-.993	-.135	-.741	.562	.948	.730	.990	.861	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4c. Correlation of forms of SOC with some soil properties in tree forest plantation in Ikole-Ekiti.

	pH (H_2O)	Org. C	Avail. P	Total N	Ex. Acidity	CEC	ECEC	BS	Sand	Silt	Clay	TOC	SMBC	POC	WSOC
pH (H_2O)	1														
Org. C	.851	1													
Avail. P	.751	.986	1												
Total N	.856	.456	.301	1											
E. Acidity	.427	.838	.918	-.102	1										
CEC	.381	.810	.896	-.153	.999*	1									
ECEC	.387	.813	.899	-.146	.999*	1.00**	1								
BS	-.463	-.860	-.933	.062	-.999*	-.996	-.996	1							
Sand	-.969	-.694	-.564	-.958	-.189	-.139	-.145	.228	1						
Silt	.082	-.454	-.596	.586	-.866	-.890	-.887	.845	-.327	1					
Clay	.915	.991	.954	.574	.756	.722	.726	-.782	-.786	-.327	1				
TOC	.588	.925	.976	.084	.983	.972	.973	-.989	-.368	-.758	.864	1			
SMBC	.848	1.00**	.987	.451	.842	.813	.817	-.863	-.689	-.459	.990	.928	1		
POC	.973	.706	.578	.952	.206	.156	.162	-.245	-1.00*	.311	.796	.384	.701	1	
WSOC	.914	.565	.420	.992	.024	-.027	-.020	-.065	-.986	.479	.673	.210	.560	.983	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4d. Correlation of forms of SOC with some soil properties in ranch land in Ikole-Ekiti.

	pH (H_2O)	Org. C	Avail. P	Total N	Ex. Acidity	CEC	ECEC	BS	Sand	Silt	Clay	TOC	SMBC	POC	WSOC
pH (H_2O)	1														
Org. C	.951	1													
Avail. P	.998*	.968	1												
Total N	-1.00**	-.953	-.999*	1											
E.Acidity	-.863	-.977	-.891	.866	1										
CEC	1.00*	.960	1.00*	-1.00*	-.877	1									
ECEC	.994	.912	.986	-.993	-.803	.990	1								
BS	.898	.990	.922	-.900	-.997*	.910	.844	1							
Sand	-.983	-.878	-.971	.982	.756	-.977	-.997*	-.801	1						
Silt	.650	.853	.693	-.655	-.945	.672	.564	.919	-.500	1					
Clay	.333	.025	.277	-.327	.189	.305	.434	-.117	-.500	-.500	1				
TOC	.035	.341	.093	-.040	-.535	.064	-.074	.472	.149	.782	-.931	1			
SMBC	.161	-.151	.104	-.156	.359	.133	.268	-.291	-.339	-.645	.984	-.981	1		
POC	1.00**	.951	.998*	-1.00**	-.863	1.00*	.994	.897	-.983	.650	.333	.035	.161	1	
WSOC	.769	.929	.805	-.772	-.986	.787	.694	.972	-.638	.986	-.347	.666	-.507	.769	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

a significant negative perfect relationship between TN and CEC (r= -1.00, *p*<.01). There is no relationship between the forms of organic carbon.

CHAPTER FIVE

5.0 SUMMARYANDCONCLUSIONS

The concentrations of the forms of organic carbon in Ikole-Ekiti soils were assessed considering the influence of agricultural land use types and soil depths. The soils from the agricultural land use types investigated – arable land, fallow land, forest plantation and ranchland showed a noticeable influence on the forms of organic carbons. The agricultural land use type with the highest concentration of each carbon fractions differs, indicating a diverse influence in the carbon dynamics in Ikole-Ekiti soils as modified by land utilization and management. The distribution of the organic carbon forms down the depths and across the land use types does not follow a similar pattern. TOC and WSOC decreased with depth except for WSOC in ranchland with visible fluctuating pattern whereas, SMBC and POC mostly increased with depths except for POC under forest plantation and ranchland land use types. At 0 – 5 cm depth, fallow land had the highest value of TOC, 30.27 g/kg, followed by forest plantation, ranchland and arable land with values of 29.70, 28.57 and 19.60 g/kg respectively. Also at depth 5-10 cm, there was significant difference in TOC across the land use types with fallow land and forest plantation had the highest values, while ranchland and arable land contained the least. All the land use types showed the highest accumulation of the various carbon fractions in the surface layer (0-5 cm). This high level of organic carbon stock in the surface layer could be due to the slow decomposition, mixing and mineralization of organic materials with the soil.

The TOC, SMBC and POC had medium to high coefficient of variation, indicating a general medium to high variation of these forms of organic carbon in agricultural soils of Ikole-Ekiti irrespective of depth, whereas, WSOC had low coefficient of variation (6.36 – 12.00 %). There is no significant relationship between the forms of organic carbon.

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