EFFECT OF LAND USE ON SOIL CARBON SEQUESTRATION IN SOILS OF THE DESERT MARGIN IN NIGERIA.

BY

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ABSTRACT

Exploring the impact of changes in land use in soils of the desert margin soils in Nigeria .This research is a key component to global climate change. Soil samples were taken in two vegetation zone Sahel and Sudan Savannah under four different land uses(Forest Area, Arable land, Fallow land and Grazing land) at a depth of 0-15cm. The locations under Sahel Savannah are Goronyo ,Gamawa and Minjibir while the site under Sudan Savannah are Hadeija and Illela. A 5x4x3 factorial experiment was conducted in randomized complete block design (RCBD) for the five locations, four land uses and three replicate for physical and chemical analysis. The results showed variation of soil organic carbon in different land use types. The soils have very high sand content. Grazing land had the highest organic carbon content(0.58%). Dry stable aggregate was higher in grazing land and lowest in cropland. This results suggest that AS has an interpretable relationship with grazing land and soil organic matter appears to be the main determining factor controlling aggregate stability. However since soil nutrients depletion was very high in arable land, there must be a careful choice of appropriate use of land to reduce soil nutrients depletion and enhance soil productivity. Land use approaches, multiple cropping, organic mulching are recommended in other to minimize soil nutrients depletion which mostly accounted for major degradation in arable land.

KEY WORDS: Desert margin soils ,Aggregate stability, Land use ,Carbon sequestration

CERTIFICATION

This project entitled **"EFFECT OF LAND USE ON SOIL CARBON SEQUESTRATION AS AFFECTED BY DESERT MARGIN SOILS, NIGERIA"** by FAMOYE AYOMIDE FIDELIS, meets the regulation governing the award of a Bachelor degree in Agriculture(SOIL SCIENCE AND LAND RESOURCES MANAGEMENT) of the Federal University Oye-Ekiti and it is approved for its contribution to the scientific knowledge and literally presentation.

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DEDICATION

I dedicate this project to God Almighty for giving me the grace and and strength throughout the course of my study. I dedicate this project to my parents,Eng. Famoye Femi and Mrs Famoye Tinuade as well as Mr Isaac Omotayo ,Mr and Mrs Banji Ojo and Eng. Adekanle Adesoji. God bless you all abundantly in Jesus name(AMEN).

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To my family, Mr & Mrs Famoye I appreciate the love and support during this period, especially the endless support from my sisters and brother (Mr and Mrs Banji-Ojo, Engineer Adekanle),I need to seize the opportunity to thank Miss Bello Precious for her unlimited help. A gratitude goes to my friends, Alasoluyi Oluwaseun Desmond and Aluko Iyanu John for their immense support

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CHAPTER ONE

1.0 INTRODUCTION

Soil organic carbon (SOC) representing 2-3 fold the carbon pool of vegetation or atmosphere, soil is the terrestrial biospheres largest carbon sink (Muñoz-Rojas *et al* 2011).The organic carbon pool in agricultural land uses is capable of enhancing agricultural sustainability and serving as a potential sink of atmospheric carbon dioxide . The SOC is an important factor controlling other soil attributes, which in turn are responsible for the sustainable, maintenance of soil quality, concentration and stock of carbon. (Singh *et al* 2011). The effect of soil management and land use change are of interest to the sustainable land management for improving the environment and advancing food security in developing countries. Both anthropogenic changes and natural processes affect agriculture primarily by altering soil quality. Intrinsically related to the productivity of vegetation, the SOC is accordingly very sensitive to natural and anthropogenic disturbances (FAO 2017). Given its enhancement of global climate change, losses of soil carbon to the atmosphere will likely adversely affect food security. Accordingly, reducing SOC losses has become an important strategy in climate change mitigation and food security enhancement. Land use and ecosystem services need to be assessed simultaneously to better understand the relevant factors in sustainable land management (Golchin *et al* 2014). During the past two centuries global industrialization has increased concentration of greenhouse gases. Concerns about the amount of Carbon emissions in the atmosphere and their effects on the environment were increasing every day. As a result of these concerns almost all the countries in the word including Iran signed the United Nations Framework Convention on Climate Change (UNFCCC).The long-term objective of the carbon sequestration is based on agendum to stabilize greenhouse gas concentrations in the atmosphere to an acceptable level. Therefore, to reduce atmospheric carbon dioxide (CO_2) and create balance between the elements of the greenhouse gases the existing atmospheric Carbon must be captured and stored in one or multiple forms. The most simple and economic way for reducing the level of atmospheric CO2 is carbon sequestration in plant biomass and soil (Abdi, 2005).

The term Carbon sequestration is used to describe both natural and deliberate process by which CO_2 is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments (vegetation, soils and sediments) and geological formations (Eric sundquist *et al* 2008).

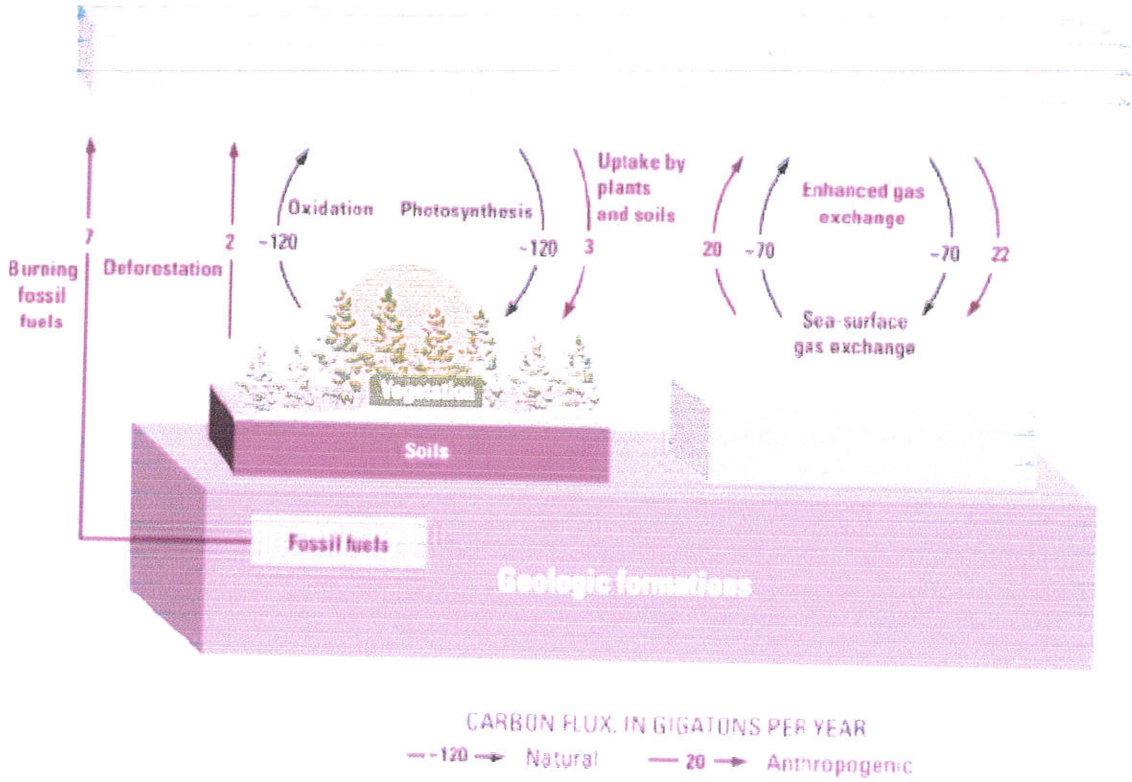

Figure 1. The global carbon cycle. Carbon naturally moves, or cycles, between the atmosphere and vegetation, soils, and the oceans over time scales ranging from years to millennia and longer. Human activities, primarily the burning of fossil fuels and clearing of forests, have increased the transfer of carbon as CO_2 to the atmosphere. Although some of this anthropogenic CO_2 is removed from the atmosphere by the natural uptake processes ("sinks") of the carbon cycle, much of it remains in the atmosphere and causes rising CO_2 concentrations. The goal of deliberate carbon sequestration is to decrease the net flux of CO_2 to the atmosphere by sequestering carbon in the oceans, vegetation, soils, and porous rock formations. Fluxes shown are approximate for the period 2000–05, as documented by the Intergovernmental Panel on Climate Change.

Nigeria is losing about a half kilometer of its land mass annually to desert encroachment in little time before the entire country becomes a desert. NAN reports that Director-General of the Nigerian Conservation Foundation, Dr Muktari Aminu-Kano, raised the alarm in Lagos. He made the disclosure at the 2018 edition of the Green Ball series with theme: "Green Recovery Nigeria" Restoring Mangroves and Reclaiming the Desert. Aminu-Kano said that mangroves were also being lost in the Niger Delta and that the nation had already lost up to 95 per cent of its forest cover. He warned that urgent measures must be taken to curb deforestation and forest degradation to stop what he described as ugly consequences of climate change .Stressed on the need to strengthen the Green Recovery Nigeria scheme, aimed at retaining a significant proportion of Nigeria's landmass under forest.

Recent studies indicate that climate change is a major driver of shifts in land use and land cover accordingly; it has a major impact on the global biogeochemical cycle. This is particularly reflected in changing soil carbon storage (SC), net primary productivity, and soil respiration. In turn, the impact of shifts in land use on SC further contributes to global warming. Reflecting the human-land relationship over the long period of human development, alterations in the earth's surface through anthropogenic shifts in land use have become a concern and a topic of research. The soils of dry lands are characterized by frequent water stress, low organic matter content and low nutrient content, particularly nitrogen (N) (Skujins,2011). Although dry land vary considerably, they are mostly Aridisols (2,120,000,000 ha) and Entisols (2,330,000,000 ha). Soils are the basic resource of drylands as they provide the medium in which plants grow, and their properties, such as texture and water holding capacity (FAO 2017).

All of these effects accentuate the emission of CO_2 to the atmosphere. Lal (2001) estimated the carbon(C) loss as a result of desertification. Assuming that two-thirds of the C lost can be sequestered through soil and vegetation restoration. These estimates provide an idea about the loss of C as a result of desertification and the potential for carbon sequestration (CS) through the restoration of soils in dry lands. Opportunities for improved land management as well as increasing CS should be developed in these areas. Agricultural systems contribute to carbon emissions through the use of fossil fuels in farm operations and through practices that result in loss of organic matter in soils.

Changes in land use and land cover are among the main human activities affecting the surface of the earth [Lambin *et al* (2001).The causes of land use and land-cover change moving beyond the myths with the expansion of agriculture posited as one of the main causes of land cover change globally. The role of terrestrial ecosystems as sources and sinks of C has been highlighted, underscoring the impact of land use and land cover changes on the global climate. It is as much as three times greater than the atmospheric carbon pool and doubles that in the biota. Soils are the largest organic carbon sink on Earth. The abundance of organic C in the soil affects and is affected by land use and land cover changes, and organic carbon role as a key determinant of soil fertility and vegetation production has been documented in recent years. Therefore understanding the changes in the organic carbon storage space distribution in soil is crucial for assessing current regional, continental, and global soil C stores and predicting and ameliorating the consequences of global change. The magnitude of the change in C storage depends on how physical, chemical, or biological processes are altered over time under different land uses. The extent to which soils and vegetation act as carbon sinks or sources depends largely on land-use management. Appropriate land use management practices can improve SOC, whereas unreasonable practices reduce SOC. Some of the land use activities that affect carbon fluxes in soils are deforestation, afforestation, biomass burning, cultivation, crop residue management, and the application of inorganic fertilizers and organic manure. Generally, soil organic carbon (SOC) stocks under cropland are lower than those under pasture or forest, and forest SOC stocks tend to be higher than pasture SOC stocks. The conversion of forest to pasture or to cropland or the conversion of pasture to cropland decreases SOC stocks, whereas the opposite conversions usually lead to increased SOC stocks. Historically, when croplands have been established on land previously used for native vegetation, the soil C pool has been a major source of atmospheric carbon dioxide. At a global scale, land use and land cover changes (LULCC) are estimated to contribute 25% of the anthropogenic flux of carbon dioxide to the atmosphere, the second highest contribution after that of fossil fuel. However, reducing CO_2 emissions and increasing C sequestration by vegetation and soils can contribute to decreasing this rate. Davidson and Ackerman suggested that nearly all C lost from soil occurs within 20 years and that most occurs within 5 years, after initial cultivation. Therefore, decreasing the atmospheric CO contraction is necessary, which requires understanding the variations in regional SOC stocks by land use history and the resulting patterns.

Arid and semi-arid lands cover approximately 45% of the global terrestrial area and contain 16% of the global soil carbon pool. Overgrazing, human activities, and climate variation have contributed to the desertification and degradation of more than two-thirds of these fragile ecosystems. Changes in the vegetation and the release of carbon from these drier regions must be considered when discussing carbon balance on a global scale. Desertification is estimated to affect approximately 1.137 Billion ha of soils and an additional 2.576 Bha of rangeland vegetation in dry lands around the world. Furthermore, the total historic loss of C due to desertification may be tillage, nitrogen, and cropping system effects on soil carbon sequestration. Soil Sci Soc Am J 66: 906–912. 2011, indicating that land desertification characterized by soil degradation and the diminution or destruction of the biological potential of ecosystems have played an important role in the atmospheric CO_2 enrichment.

Soils are made up of aggregated sand,silt and clay particles bound together to form the soil matrix.Soils which have stable aggregates are invariably more productive. The soil matrix regulates the movement of air and water to plants root.It also hold the organic carbon in their micro aggregate capsulate.

1.1 PROBLEM STATEMENT

Historical CO_2 emissions from different land use has influenced carbon sequestration at desert margin soils and has increased global warming which has been a threat to the environmental. If current trends continue, cumulative emissions are projected to double by 2050 and increase by a factor of three to four by 2100. According to the Intergovernmental Panel on Climate Change Fourt Assessment Report of 2007.

Agriculture has been found to contribute to global warming; in which improper land use such has deforestation has depleted the carbon drastically.

1.2 JUSTIFICATION

More than anywhere else in the world the desert margin soils is on the frontline of climate change and millions of people are already facing its devastating effect.

Little or no work has been done to quantify the knowledge of the influence of land use on soil carbon sequestration considering global warming and desertification which are critical for soil sustainability at the desert margin soils.

This study will help to monitor changes in level of organic carbon in aggregrate. Thus, for sustainable livelihood timely information is necessary to implement adequate measures foe carbon sequestration.

1.3 MAIN OBJECTIVE

The main objective is to determine the influence of land use on soil carbon sequestration at the desert margin soils of Nigeria.

The specific objectives are to;

- assess soil carbon content in various land use
- determine effect caused by land use on soil aggregate stability under different land use.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 DESERT MARGIN SOILS

About 47 percent of the surface of the earth can be classified as dryland (FAO, 2017). Drylands are considered to be areas where average rainfall is less than the potential moisture losses through evaporation and transpiration. According to the World Atlas of Desertification (UNEP, 2002), drylands have a ratio of average annual precipitation (P) to potential evapotranspiration (PET) of less than 0.65. Where the water deficit prevails throughout the year, for carbon sequestration drylands are classified as extremely arid or hyper arid, whereas when it occurs for most of the year they are arid and semi-arid regions. Aridity is assessed on the basis of climate variables or according to FAO on the basis of how many days the water balance allows plant growth (growing season). The aridity index uses the P/PET to classify drylands into hyper arid, arid, semi-arid and dry sub humid .The negative balance between precipitation and evapotranspiration results in a short growing season for crops (usually less than 120days). Hyper arid regions are not considered as there is no crop growth unless under irrigation. Droughts are characteristic of drylands and can be defined as periods (1–2 years) where the rainfall is below the average. Droughts that persist for a decade or more are called desiccation, which can have disastrous consequences for land productivity and vegetation loss. Drought preparedness and risk mitigation are essential for the proper management of dryland areas. Populations living in these regions have been developing strategies to cope with them. These measures include: strengthening indigenous strategies to cope with drought, supporting the development and adoption of resource management practices that will protect and improve productivity, thereby increasing the resilience of agricultural systems; reducing fluctuations in prices of livestock and grains during drought periods through expanding market size and reducing transaction costs; developing a set of warning indicators; and setting aside drought grazing reserves or strategic water reserves (Oygard, Vedeld and Aune, 2009)

2.2 LAND DEGRADATION IN DESERT MARGIN SOILS

Desertification results from the degradation of the natural ecosystems in drylands and constitutes a major global problem (FAO, 2017). It is defined as "Land use degradation in arid, semi-arid and dry humid areas resulting from various factors, including climatic variation and human activities". The main consequences of land degradation are: the chemical degradation of the soil, loss of vegetation cover, loss of topsoil infiltration capacity, reduction in soil water storage, loss of SOM, fertility and structure; loss of soil resilience, loss of natural regeneration, and lowering of the water table. Soil degradation affects about one fifth of arid zones, mostly on semi-arid margins where cultivation take place. Land degradation may have a significant impact on climate. The loss of plant cover can alter the surface energy balance. Atmospheric dusts from deserts modify the scattering and absorption of solar radiation. Although uncertainty exists with regard to the causes of climate change and global warming and the possible consequences, there is agreement that some impacts are probable. For example, temperature increases will affect evapotranspiration, which will be most significant in places where the climate is hot. Predictions about the quantity and distribution patterns of rainfall in these regions are uncertain, but the Intergovernmental Panel on Climate Change indicated that semi-arid regions are among those most likely to experience increased climate stress (IPCC; 2010). Furthermore, climate change may have unpredictable and perhaps extreme consequences with respect to the frequency and intensity of precipitation and temperature variability for semi-arid regions. One of the problems of assessing the extent of desertification and the measures to prevent it is the lack of reliable and easily measured land quality indicators. The Land Degradation Assessment in drylands project, initiated by FAO, focuses on the development of a detailed methodology for the assessment of land degradation in an area that covers as much as half of the global land surface (FAO, 2003).

Several estimates exist for the extent of desertification. According to the Global Assessment of Human and Induced Soil Degradation methodology, the land area affected by desertification is 1 140,000,000 ha, which are similar to the UNEP estimates. According to UNEP (2011), when rangelands with vegetation degraded are included (2,576,000,000 ha), the percentage of degraded lands of the dry lands is 69.5 percent physical mainly driven by climate factors such as floods and droughts that cause soil erosion (by wind and water), chemical generally in the form of salinization (in irrigated lands), biological mainly as a result of the oxides. Desertification can be prevented through a proper management of the land to ensure sustainable development of its resources. Strategies for desertification control include: establishment and protection of vegetation cover to protect soils from erosion, controlled grazing, improved water conservation by residue management and mulching to help decrease water losses by runoff and evaporation; supplemental irrigation, soil fertility management which enhances biomass productivity; increased water use efficiency, and improved soil quality, improved farming systems that include crop rotations; fallowing, agroforestry and grazing management (Lal, 2001b). All these strategies increase Carbon Sequestration in soils. Desertification affects more than 100 developed and developing countries in all continents (UNEP, 2007). Some 200 million people are believed to be affected directly by desertification and more than 1,000,000,000 people at risk. The future sustainability of dryland ecosystems and the livelihoods of people living in them depend directly on the actions taken for land-use management. These activities should include soil and water conservation for improved land-use management practices and farming systems, taking into account health, social and economic issues when developing strategies and policies to improve land management.

2.3. SOILS AND CARBON SEQUESTRATION

Soils are the largest carbon reservoir of the terrestrial carbon cycle. The quantity of carbon stored in soils is highly significant. Soils contain about three times more C than vegetation and twice as much as that which is present in the atmosphere (Batjes and Sombroek, 2007).

Carbon storage in soils is the balance between the input of dead plant material (leaf and root litter) and losses from decomposition and mineralization processes (heterotrophic respiration). Under aerobic conditions, most of the C entering the soil is labile and therefore respired back to the atmosphere through the process known as soil respiration or soil CO_2 efflux (the result of root respiration, autotrophic respiration, and decomposition of organic matter, heterotrophic respiration). The process of soil CS or flux of C into the soil forms part of the global carbon balance. Many of the factors affecting the flow of C into and out of soils are affected by land-management practices. Therefore, management practices should focus on increasing the inputs and reducing the outputs of C in soils. The long-term Carbon Sequestration potential is determined not only by the increase of C inputs into the soil but also by the turnover time of the carbon pool where the C is stored. For long-term Carbon Sequestration, C has to be delivered to large pools with slow turnover. The partitioning between different soil carbon pools with varying turnover times is a critical controller of the potential for terrestrial ecosystems to increase long-term carbon storage. Allocation of C to rapid-turnover pools limits the quantity of long-term carbon storage, as it is released rapidly back to the atmosphere. A proper analysis of the Carbon

Sequestration potential of a specific management practice should consider a full carbon balance of the management practice if it is to be used for carbon mitigation purposes. Another problem is the cost of agricultural practices in terms of Carbon. Application of fertilizers, irrigation and manure are all common practices that reduce carbon. Therefore, full carbon accounting should take into account all activities associated with a particular practice. Furthermore, other greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) are influenced by land use. Although emitted in smaller amounts, they have a much larger greenhouse potential. Therefore, they should be quantified explicitly and included in the total balance. One kilogram of methane(CH_4) has a warming potential 23 times greater than 1 kg of CO_2, over a 100-year period, while the warming potential of 1 kg of N is nearly 300 times greater (Ramaswamy, Boucher and Haigh, (2001).

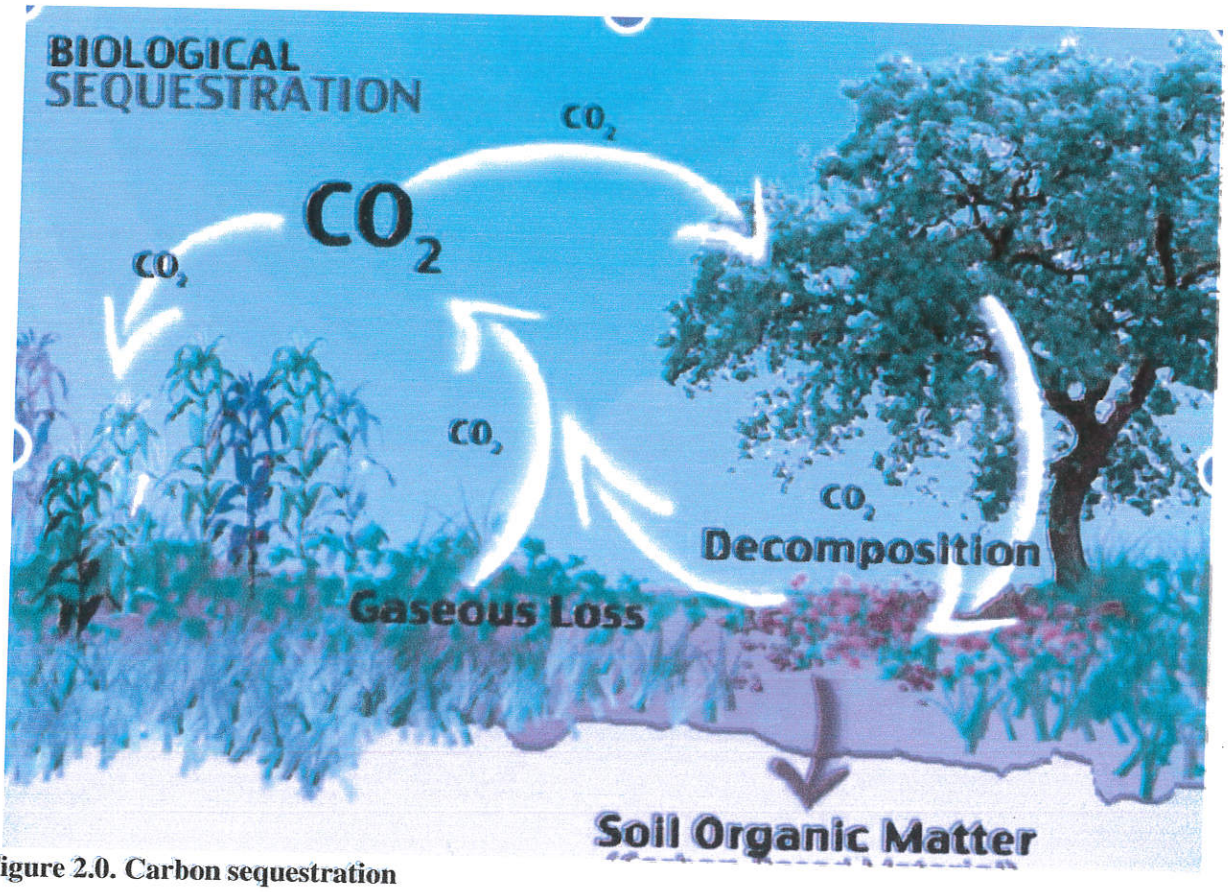

Figure 2.0. Carbon sequestration

2.4 THE NEED OF MODELS TO SIMULATE CHANGES IN SOIL CARBON

Soil Organic matter (SOM) is a key indicator for soil quality, both economically, as it enhances plant productivity, and from an environmental point of view on account of Carbon Sequestration and biodiversity. SOM is the main determinant of soil biological activity, which in turn, has a major impact on the chemical and physical properties of soils (Charles 2011). The increase in SOM can improve: aggregation and the stability of soil structure, infiltration rate and water retention, and resistance to erosion.

Soil carbon storage is controlled primarily by two processes: primary production (input) and decomposition (output). Measurements of Carbon storage in an ecosystem alone reveal little about how Carbon has changed in the past or will change in the future. The effect of climate and/or land-use change can be predicted only through the use of accurate dynamic models. Modeling has been used as an effective methodology for analyzing and predicting the effect of land-management practices on the levels of soil carbon. A number of process-based models have been developed over the last two decades to fulfill specific research tasks. Each model varies in its suitability for application to new contexts. Various models have been developed to simulate C dynamics in soils. SOM is very complex, formed of very heterogeneous substances and generally associated with minerals present in soils. The mean residence time is determined not only by the chemical composition of SOM but also by the kind of protection or bond within the soil. The stable carbon fraction is protected either physically or chemically. Physical protection consists of the encapsulation of SOM fragments by clay particles and micro aggregates (Balescent, Chenu and Baladene, 2000). Chemical protection refers to specific chemical bonds between SOM with other soil constituents, such as colloids or clays. Different factors influence different pools.

Given the complexity of the nature of SOM, most models describe soil organic carbon (SOC) as divided in multiple parallel compartments with different turnover times.

FAO has developed a model as a methodological framework for the assessment of carbon stocks and the prediction of Carbon Sequestration scenarios that links SOC turnover simulation models (particularly CENTURY and Rothamsted) to geographical information systems and field measurement procedures (FAO, 2009). However, the real potential for terrestrial soil CS is not known because of a lack of reliable database and fundamental understanding of the SOC dynamics at the molecular, landscape, regional and global scales (Metting; Smith and Amthor,2009. It has been speculated that improved terrestrial management over the next 50–100 years could sequester up to 150 Pg of C, the amount released to the atmosphere since the mid-nineteenth century as a result of past agricultural conversion of grasslands, wetlands and forests (Houghton 2005; Lal *et al.*, 2008). Evidence for long-term experiments reveals that soil C losses as a result of oxidation and erosion can be reversed through improved soil management such as reduced tillage and fertilization (Rasmussen, Albrecht and Smiley, 1998; Sa et al., 2

001). Therefore, improved land-management practices to enhance CS in soils have been suggested as a viable way to reduce atmospheric C content significantly (Cole et al., 1996; Rosenberg, Izaurralde and Malone, 1999).

2.5. SOIL DEGRADATION

Soil degradation is a global problem, particularly the desertification of drylands. Most of the drylands are on degraded soils, soils that have lost significant amounts of Carbon. Therefore, the potential for sequestering C through the rehabilitation of drylands is substantial (FAO, 2001b). Annual increase in atmospheric CO_2 concentration could be balanced out by the restoration of

2,000,000,000 ha of degraded lands, to increase their average carbon content by 1.5 tonnes/ha in soils and vegetation. The benefits would be enormous. Enhancing Carbon sequestration in degraded agricultural lands could have direct environmental, economic, and social benefits for local people. Therefore, initiatives that sequester C are welcomed for the improvement in degraded soils, plant productivity and the consequent food safety and alleviation of poverty in dryland regions. The effects of soil degradation and desertification affect the global C cycle. Landuse change leads to a loss in vegetation cover and subsequent loss in organic C in soils and soil quality. The processes of plant productivity, soil degradation and Carbon Sequestration are closely linked. A decline in soil quality leads to a reduction in the soil organic Carbon pool, and an increase in the emission of CO_2 to the atmosphere. The decline in soil quality and structure leads to a loss in the capacity to retain water, and therefore in plant productivity.

2.6 SOIL AND VEGETATION OF DRYLANDS

The soils of drylands are characterized by frequent water stress, low organic matter content and low nutrient content, particularly nitrogen (N) (Skujins,2011). Although dryland vary considerably, they are mostly Aridisols (2,120,000,000 ha) and Entisols (2,330,000,000 ha). Whatever their type, soils are the basic resource of drylands as they provide the medium in which plants grow, and their properties, such as texture and water holding capacity, determine the proportion of rainfall available for plant growth. Low organic matter content, low germination and high seedling mortality are the main causes of very low plant productivity. The vegetation supported by these soils ranges from barren or sparsely vegetated desert to grasslands, shrub lands and savannahs, croplands and dry woodlands. Forest vegetation is usually poor, and is at low density with species adapted to arid soils and with high water-use efficiency. Perennial vegetation varies considerably and tends to be sparse and patchy. Plants that have adapted to drylands survive irregular rainfall, high solar radiation and drought periods. Plants protect the soil surface from wind and water erosion. Removal or loss of vegetation cover results in an increased risk of soil erosion and degradation. The predominant land uses of the drylands are pastoralism and subsistence food production. Cereals produced in drylands include wheat, barley, sorghum and millet and pulses such as chickpea, lentils, peas and groundnuts. Less important are oil crops and a wide range of fruits, vegetables, herbs and spices. Pastoralism is widespread and highly mobile. Food production is mainly from smallholding rainfed systems for subsistence or local consumption and markets. Natural woodlands are used for fuel wood, and efforts are ongoing to extend the forested areas for fuel and for Carbon Sequestration describe the farming systems of drylands in detail. The major constraint on agricultural development is low and highly variable rainfall and the consequent high risk for agriculture and animal husbandry. Traditional systems of rain fed cropping have evolved for thousands of years. Several general strategies have been developed to cope with low and erratic rainfall. Rainfed agriculture is generally practiced in areas with a reasonable amount of rain and where soils are relatively deep.

Drier regions are generally used for livestock grazing, with regular seasonal movements. Normally, several crops are sown to reduce the risk of total crop failure. Varieties that are resistant or adapted to drought are used. Long fallows are used to prevent stress on the land. During the fallow periods, soils are protected by a vegetation cover that provides nutrient and organic matter to the soils. Many pastoralists and sedentary farmers work together by exchanging crops and meat.

2.7 CHARACTERISTICS OF DRYLANDS THAT AFFECT CARBON SEQUESTRATION

Dryland environments are characterized by a set of features that affect their capacity to sequester C. The main characteristic of drylands is lack of water. This constrains plant productivity severely and therefore affects the accumulation of C in soils. The problem is aggravated because rainfall is not only low but also generally erratic. Therefore, good management of the little available water is essential. In addition, the SOC pool tends to decrease exponentially with temperature (Lal,2002a). Consequently, soils of drylands contain small amounts of C (between 1 percent and less than 0.5 percent) (Lal,2002b).

The SOC pool of soils generally increases with the addition of biomass to soils when the pool has been depleted as a consequence of land uses. Soils in drylands are prone to degradation and desertification, which lead to dramatic reductions in the SOC pool. A good overview of the extent of land degradation in different dryland regions of the world is given in Dregne (2002). However, there are also some aspects of dryland soils that work in favor of CS in arid regions. Dry soils are less likely to lose C than wet soils (Glenn *et al.*, 2012) as lack of water limits soil mineralization and therefore the flux of C to the atmosphere. Consequently, the residence time of C in drylands soils is long, sometimes even longer than in forest soils.

The issue of permanence of C sequestered is an important one in the formulation of CS projects. Although the rate at which C can be sequestered in these regions is low, it may be cost-effective, particularly taking into account all the side-benefits resulting for soil improvement and restoration. Soil-quality improvement as a consequence of increased soil C will have an important social and economic impact on the livelihood of people living in these areas. Moreover, given the large extent of drylands, there is a great potential for CS. The potential offered by drylands to sequester C is large, not only because of the large extent, but because historically, soils in drylands have lost significant amounts of C and are far from saturation. Because of all of these .characteristics, any strategy to re-establish SOM in these regions is particularly interesting.

2.8 DESERTIFICATION AND CARBON SEQUESTRATION

The effects of desertification on soil quality include: All of these effects accentuate the emission of CO_2 to the atmosphere. Lal (2001c) estimated the C loss as a result of desertification. Assuming a C loss of 8–12 Mg C/ha (Swift et al., 1994) on a land area of 1,020,000,000 ha (UNEP, 2007), the total historic C loss would amount to 8–12 Pg C.The total C loss as a consequence of desertification may be 18–28 Pg C. Assuming that two-thirds of the C lost (18–28 Pg) can be sequestered (IPCC, 2006) through soil and vegetation restoration. These estimates provide an idea about the loss of C as a result of desertification and the potential for CS through the restoration of soils in drylands. Opportunities for improved land management as well as increasing CS should be developed in these areas. Agricultural systems contribute to carbon emissions through the use of fossil fuels in farm operations and through practices that result in loss of organic matter in soils. On the other hand, farming systems can offset carbon losses when accumulating organic matter in the soil, or when aboveground woody biomass is increased, which then acts either as a permanent sinks or used as an energy source that substitutes fossil fuel. The potential for global benefits, as well as local benefits, to be obtained from increased CS in drylands should be an additional incentive for stronger support for reforestation and agriculture in drylands. Although drylands have been studied,the impact of desertification on the global carbon cycle and the potential impact of desertification control on CS in dryland ecosystems have not been well established. Extensive land use in areas where both population densities and rainfall are low, patterns of extensive land use predominate either as a longer-term system state or a more recent major pathway of change (Mortimore and Adams, 2009). As land scarcity does not represent a constraint in this case, fallow lands constitute an important element of the farming system, allowing for short- and medium-term soil regeneration. In general, field sizes are significantly larger than in areas under intensification. Given the amount of land available to individual households, manure is generally only used for fields that are under continuous cultivation, primarily those adjacent to the settlements and others in close proximity. Remote fields and those left fallow are accessible to grazing animals all year round. Unlike animals in intensified systems, herds are not forced to leave for transhumance and thus contribute to a continuous flux of organic matter input. Weeding and harvest activities might occur with less intensity, while more agricultural residues are left on the fields.

Agroforestry may play an important part in these extensive systems based on multiple pathways of change offers useful guidelines for potential CS schemes. Project design and implementation should start with a local understanding of environmental change and its underlying processes. The next step is to identify positive pathways of change at the local level and then finally to assess opportunities to encourage such pathways on a larger scale.

2.9THE BIOPHYSICAL POTENTIAL FOR CARBON SEQUESTRATION IN FARMING SYSTEMS

In dryland environments, SOC in the first 100 cm soil amounts to about 4 tonnes/ha (Batjes, 2009). This is considerably lower than in other environments. Batjes estimates for current SOC are: 7–10 tonnes/ha in the tropics; 7–13 tonnes/ha in the subtropics; 11–13 tonnes /ha in temperate regions; and 21–24 tonnes/ha in boreal, polar and alpine areas. Few reliable numbers exist for the entire Sahel, with the exception of estimates for semi-arid savannahs and dry forests in Senegal (the West-Central agricultural region) as reported Ringius, 2002 and Tschakert, Khouma and Senè, 2004, ranging from 4.5 tonnes C/ha for continuously cultivated areas without manure input to 18 tonnes C/ha for non-degraded savannahs (top 20 cm soil). There is a suite of recommended practices and land-use types that are recommended to increase both the uptake of C from the atmosphere and the duration of storage in soils. As for croplands, FAO (2001b) differentiates practices that decrease carbon losses from the soil from those that increase organic matter inputs into the soil, and considers a combination of both. The first category includes reduced/conservation/zero tillage, crop residue management, green manure, cover crops, and integrated weed control.

The second category is based on increases in biomass resulting from manure, compost, mulch farming, mineral fertilization and irrigation as well as improved crop-residue management and green manure with leguminous species. All these practices simultaneously increase CS, improve soil fertility, and decrease erosion through soil restoration in drylands, thus offering real potential for a win–win situation for local smallholders. However, reliable dryland estimates on how much C could be sequestered under the various management practices and farming patterns are still sparse. The most comprehensive estimates range from 0.05 to 0.3 tonnes C/ha/year for croplands and from 0.05 to 0.1 tonnes C/ha/year for grasslands and pastures (Lal *et al.*, 2008). The estimates by Lal et al for tropical areas are about twice as high as those for drylands.

2.10 EFFECT OF LAND USE ON AGGREGATE STABILITY

Soil aggregate stability is an attribute that contributes to sustainable soil quality and soil erodibility (Barthe et al 2002).Soil structural stability is a measure of soils ability to retain its structure after the application of a mechanical stress or destructive forces(Cosentino et al 2006). During soil aggregate formation ,primary particles are bound into micro aggregates .Organic matter play a role on control of aggregates formation, which in turn affect the organic matter stabilization and long term soil aggregate stability. Land use system involves changes, maintenance, arrangements, activities and inputs people take in different land cover type to produce their major needs. The distribution and supply of nutrients in the soil are affected by modifications in land use system altering soil properties and influencing biological activities over a period of time (Lambin *et al* 2006).

CHAPTER THREE

3.0 METHODOLOGY

3.1SAMPLE LOCATION

The samples were taken in two vegetation zones Sahel savannah(SHS) and Sudan Savannah(SDS). The samples were taken under four different land uses; Forest Area, Arable land, Fallow land and Grazing land. The location site under Sahel Savannah are Goronyo ,Gamawa and Minjibir while the site under Sudan Savannah are Hadeija and Illela.

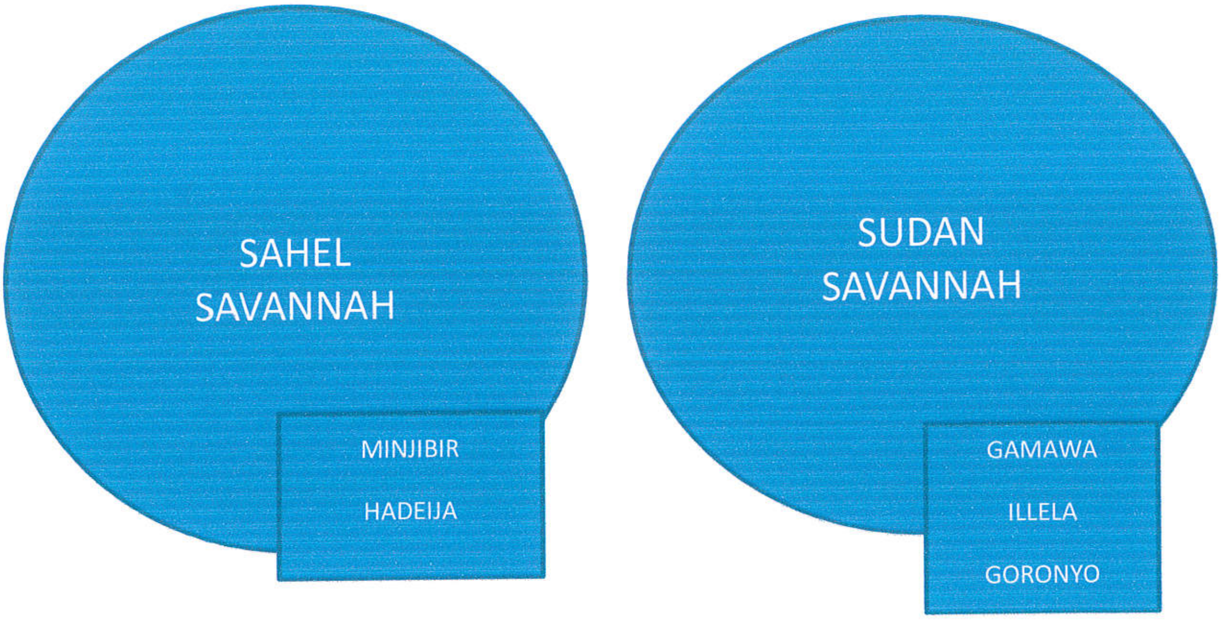

FIGURE 3.0: Samples Location

3.1.2 Study area

The study area is located in latitude 12°03' 34.4"N to longitude10°33'38"E in the Sahel savannah (Gamawa) and latitude 13°42'44.6'N to longitude 005°17'28.7"E in Sokoto (Illela) . The sample was first taken in Northern part of Nigeria, Gamawa (Bauchi State) on 13th-21st of January 2018 of elevation 360m-366m in Gamawa and Illela in an Arable land which has been cultivated in the range 10-15years, Grazing land of about 15years, Excavated land which has been left for many years and fallow area which has not been cultivated for more than 5years.

The studied area in the Sudan Savannah was located latitude 12°09'29.7' to longitude 008°40'04.5'E in Minjibir and latitude 12°32'37' to 10°08'30.1"E in Sudan savannah(Hadeija).The elevation range from 440-442m in Minjibir and 259-351m in Hadeija. Samples was taken in an Arable land where millet and guinea corn was cultivated ,Fallow area which has been uncultivated for 5-7years , Excavated land ,Forest area and Grazing land for about 15years.The sampling started on 16th -17th of Jan 2018.

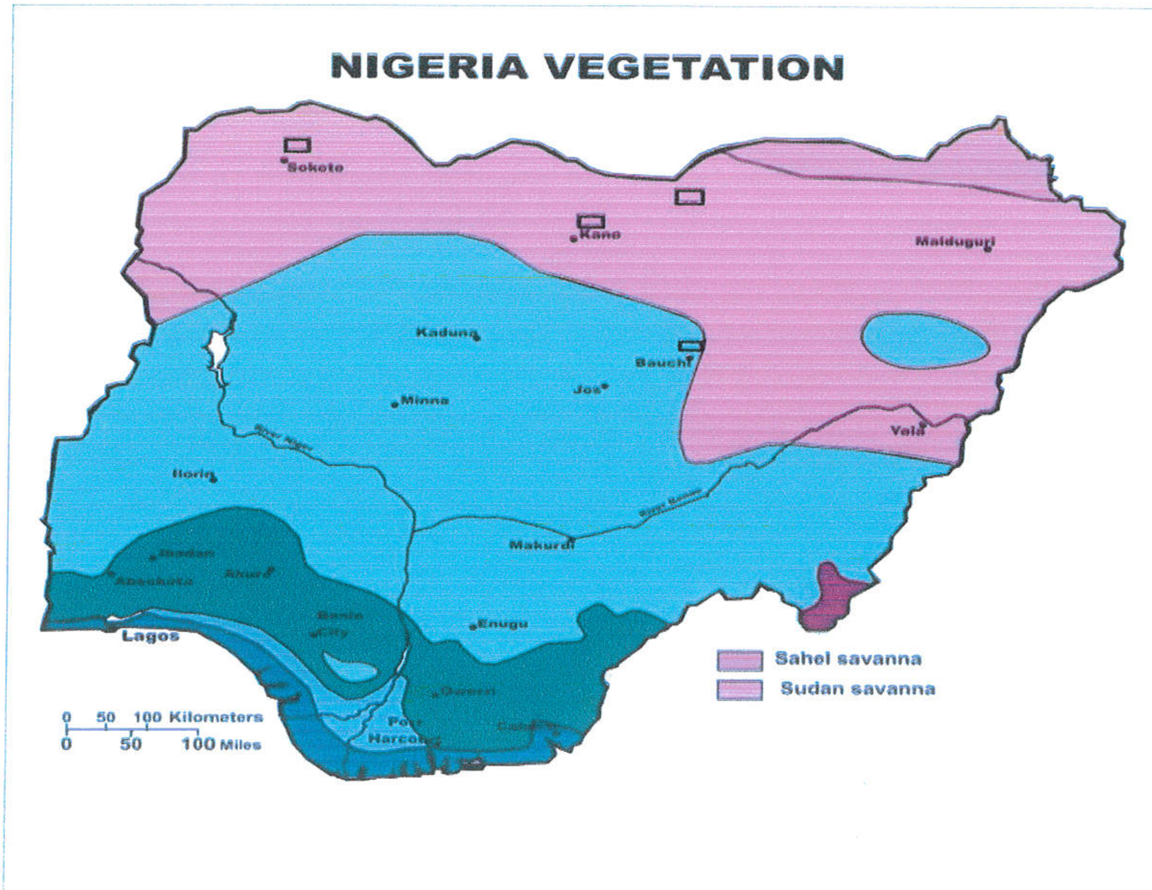

Figure 4.0: STUDY MAP

3.1.3 SAMPLING METHOD

Five land mapping unit under two agro ecological zones(Sahel and Sudan Savannah) and 5land use types(forest area, grazing land, fallow area, arable land and excavated land) where considered taking samples using random sampling method from (0-15cm) on each land use and replicated 3 times.

3.1.4 SAMPLE PREPARATION

The samples was well air dried, packaged and well labeled .It was allowed to pass through a 2mm sieve for the physical parameters analysis(Particle size analysis,dry aggregrate,) and the chemical analysis (Organic carbon, determination of carbon in aggregrate) in a standard laboratory.

3.2 LABORATORY ANALYSIS

The physical parameters that was analyzed are the particle size distribution and aggregate fractionation using 2mm, 0.25 , 0.053 and <0.053 seive and the chemical analysis (Organic Carbon, organic matter and determination of Carbon in aggregate)

3.2.1PHYSICAL ANALYSIS

PARTICLE SIZE ANALYSIS

The particle size analysis was conducted using Boyoucous hydrometer reading and sodium hexametaphosphate as the dispersal agent. 100 ml of dispersing solution(calgon) and 880 ml of deionized water was mixed in a 1000 ml cylinder. This mixture is the blank. (Note: 100 ml + 880 ml = 980 ml. This blank is not diluted to 1000 ml; the other 20 ml is the volume occupied by 50 g of soil.). 50 g of soil was weighed and transfered to a dispersing cup 20ml of calgon was then added .Attach dispersing cup to mixer and mix the sample for 30 – 60 sec. Transfer the suspension quantitatively from the dispersing cup to a 1000 ml cylinder. Fill to the 1000-ml mark with deionized water.At the beginning of each set, record the temperature, and the hydrometer reading of the blank.Insert plunger into suspension, and carefully mix for 30sec until a uniform suspension is obtained.

Remove plunger (begin 40 second timer) and gently insert the hydrometer into the suspension.

Record the hydrometer reading at 40 sec. This is the amount of silt + clay suspended. The sand has settled to the bottom of the cylinder by this time. Record the hydrometer reading again after 2hours.This is the amount of clay in suspension. The silt has settled to the bottom of the cylinder by this time28

%SILT+CLAY=(R40sec-Ra) +Rc/wt of soil *100

%CLAY= (R2hrs-Rb) +Rd/wt of soil *100

Where R40sec=Hydrometer reading for 40sec

Ra=40sec Blank Reading

Rc= Temp correction factor for 40sec

R2hrs=Hydrometer reading for 2hrs

Rb= 2hrs blank Reading

Rd= Temp Correction factor for 2hrs

Clay dispersion index (CDI) was obtained by dividing the percentage clay obtained without chemical dispersion (calgon).It is expressed thus

CDI = [% clay (water) / % clay (calgon)] x 100

The dispersion ratio(DR) :As described by Mbagwu and Piccolo was used as an index of micro aggregate stability

DR = [% silt + % clay (water)] / [% silt + % clay (calgon)]

Aggregate Silt +Clay (ASC)

Aggregate silt +caly was calculated thus:

ASC = [% clay + % silt (calgon)] – [% clay + % silt (water)]

Clay Flocculation Index (CFI) was calculated by substrating the total percentage of clay treated with water and dividing it with total percentage of clay treated with calgon multiplying by 100.This is expressed as;

CFI = [% clay (calgon) – % clay (water)] / [% clay (calgon)] x 100

Water dispersible clay (WDC)= %Clay in water.

3.2.2. Aggregation Fractionation

Dry aggregate was determined using 2mm, 0.25mm, 0.053mm and <0.053mm sieves .The samples was allowed to pass through each sieve for 5 min .The weight was then measured

DSA= Mr/Mt * 100

Mr is the mass of dry aggregate in each fraction

Mt is the total mass of the initial material.

The mean weight diameter (MWD) of each WSA fraction was calculated from the equation:

MWD = $^{n}_{i=1}$ wi xi

Where xi = mean diameter of each size fraction (mm)

wi = proportion of the total sample weight occurring in the corresponding size fraction

3.3CHEMICAL ANALYSIS

3.3.1 ORGANIC CARBON

Soil organic carbon (SOC) was determined following the Walkley and Black wet oxidation method (Walkley and Black 1934) where 5 g each, of the soil samples is placed in a conical flask, followed by the addition of 10 ml of 1 N Potassium dichromate ($K_2Cr_2O_7$) into each flask, in a fume cupboard. Twenty milliliters of concentrated sulphuric acid (H_2SO_4) was then added to each flask and the solution mixture was allowed to stand for at least 30 min. One hundred milliliters of distilled water were then added to each flask followed by one drop of the indicator Barium diphenylamine sulfate. The solution was then titrated with ferrous sulfate solution while stirring the mixture to the end-point (when the brown colour changes sharply to green). The amount of ferrous sulfate required for each sample for complete combustion was read and recorded. The difference between the amounts of $FeSO_4$ added for the samples compared to that added to the blank titration determines the amount of combusted carbon. A correction factor of 0.39 was used to account for the incomplete combustion of organic carbon. The percent carbon content of the soil samples was then calculated using the following formula proposed by Van Reewijk (2002):

$$\%OC = M \text{ X } V_1 \quad V_2/S \times 0.39 \times mcf$$

Organic Matter (g/kg of soil) = SOM (g/kg of soil) = Organic Carbon X 1.724

where M the molarity of ferrous sulfate solution (from blank titration),

V1 the ml of ferrous sulfate solution required for blank,

V2 the ml of ferrous sulfate solution required for sample

S the weight of the air-dry sample in gram,

mcf the moisture correction factor

while 0.39 a constant.

3.3.2. AGGREGATE IN CARBON

1g of soil was measured from the separate seive of 2mm, 0.25mm and 0.053mm and the soil carbon was determined using walkley black oxidation process using 0.39 to account for the incomplete combustion of organic carbon.

3.4 EXPERIMENTAL DESIGN

The experimental designs that will be performed for this experiment is factorial in RCBD plot design. The 5 locations by 4 Land use and 3 replicate. Minitab Computer package will be used in analyzing the result.Mean effects that showed significant F-test will be separated using Tukey's HSD at 5% level of probability.

HYPOTHESIS

- N_A= Different land use affect soil carbon sequestration.
- N_0= Different land use doesn't affect soil carbon sequestration.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The effect of land use on carbon sequestration on selected soils in Sudan and Sahel savannah, Nigeria was studied, 11 physical parameters where evaluated with 2 chemical parameters. The mean values of properties in land uses and location which is replicated three times are as presented below;

TABLE 4.1 EFFECT OF LOCATION ON PARTICLE SIZE DISTRIBUTION

LOCATIONS	CLAY (%)	SILT (%)	SAND (%)
ILL	17.03^{a}	9.33^{a}	73.63^{c}
HDJ	9.33^{b}	8.58^{a}	81.60^{b}
GMW	9.57^{b}	4.98^{b}	85.45^{a}
MJB	8.99^{b}	8.70^{a}	82.31^{b}
GRY	5.96^{C}	4.66^{b}	64.38^{d}

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise.

ILL-ILLELLA HDJ-HADEIJA GMW-GAMAWA MJB- MINJIBIR GRY-GORONYO

The Illella has the highest significant ($P < 0.05$) mean for clay (17.03%). However, Goronyo had the least (5.96%) value for the the same soil physical property from (Table 4.1).Further from Table 4.1, the mean performances of Minjibir,Illela and Hadeija were significantly ($P<0.05$) the same for silt content, however Gamawa had the least quantity of silt. For sand Gamawa had the highest, while Goronyo had the least sand content of 64.38% (Table 4.1).

TABLE 4.2 .EFFECT OF LOCATION ON AGGREGRATE STABILITY INDICES

LOCATIONS	C.F.I%	A.S.C%	C.D.I%	DR%	W.D.C%	A.S%	TMWD%
ILL	0.90[c]	16.93[a]	0.14[b]	0.57[a]	1.12[a]	40.66[a]	1.27[b]
HDJ	0.96[b]	7.97[c]	0.06[d]	0.55[b]	0.34[d]	29.49[a]	1.04[c]
GMW	0.88[d]	8.34[c]	0.19[a]	0.43[b]	1.12[b]	26.11[a]	0.77[d]
MJB	0.99[a]	10.25[b]	0.01[e]	0.41[b]	0.08[e]	35.07[a]	1.39[a]
GRY	0.64[e]	4.75[d]	0.11[c]	0.41[b]	0.84[c]	16.82[a]	0.38[e]

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise.

C.F.I- Clay Flocculation A.S.C-Aggregated Silt +Clay C.D.I- Clay Dispersion Index D.R –Dispersion ratio W.D.C- Water Dispersible Clay A.S- Aggregate Stability TMWD- Total Mean Weight Diameter ILL- ILLELLA HDJ-HADEIJA GMW-GAMAWA MJB- MINJIBIR GRY- GORONYO

The means of the Clay Flocculation Index at (P<0.05) are significantly different. Minjibir having the highest mean (0.99%) with Goronyo having the lowest mean (0.64%) from Table 4.2 .The means of the ASC are significantly different at (P<0.05) with Illella having the highest mean (16.93%) while Goronyo has the lowest mean value(4.75%) .The means of the Clay dispersion index are significantly different at (P<0.05) .The means range from (0.19%) to (0.01%) .Gamawa having the highest Clay dispersion Index with Minjibir having the lowest mean. The Dispersion ratio of Illella and Hadeija are statistically the same with Goronyo, Gamawa and Minjibir which are statistically the same. Water Dispersible Clay have means which are statistically different at (P< 95% confidence).Illella has the highest mean (1.12%) with Minjibir the lowest with (0.08%).The total mean weight diameter are statistically different at (P<0.05) with Minjibir having the highest mean weight diameter and Goronyo having the lowest (0.38%).

TABLE 4. 3. EFFECT OF LOCATION ON CARBON

LOCATIONS	O.C%	O.M%
ILL	0.29^{b}	0.51^{b}
HDJ	0.27^{b}	0.46^{b}
GMW	0.15^{c}	0.26^{c}
MJB	0.61^{a}	1.054^{a}
GRY	0.16^{c}	0.28^{c}

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise. ILL-ILLELLA HDJ-HADEIJA GMW-GAMAWA MJB- MINJIBIR GRY- GORONYO O.C – Organic Carbon O.M – Organic Matter

In Table 4.3 the carbon content of the means ranges from (0.61%) to (0.15%). Minjibir having the highest organic carbon, the land can be recommend for agricultural practices due to the abundance of biological activities on the soil, while Illella and Hadeija are statistically the same at ($P<0.05$) level of significance. Gamawa have the lowest mean value (0.15%) but it is statistical the same with Goronyo. This applies with the organic matter where Minjibir has the highest organic matter content with Gamawa which is the lowest. Illella and Hadeija are statistically the same at ($P<0.05$) level of significance while Goronyo and Gamawa are statistically the same at ($P<0.05$) level of significance.

TABLE 4. 4. EFFECT OF LAND USE ON PARTICLE SIZE DISTRIBUTION

LAND USE	CLAY %	SILT%	SAND%
GL	15.02^{a}	11.81^{a}	73.17^{b}
AL	9.01^{b}	5.50^{b}	85.49^{a}
FL	8.94^{b}	5.42^{b}	65.63^{C}
FA	8.12^{b}	6.27^{b}	85.61^{a}

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise. GL- Grassland AL-Arable land FL-Fallow Area FA-Forest Area

Grassland has the highest Clay content at ($P<0.05$) Level of significance while Arable land, fallow land and Forest Area are statistically the same at ($P<0.05$) level of significance. Although texture is an inherent property. The means of the forest area and Arable land are significantly the same while the Grassland and Fallow land are statistically different at ($P<0.05$).The soils have low silt ratio. Grassland has the lowest silt content with (11.81%) mean value at $P<0.05$ level of significance .Forest area, arable land and fallow land does not have effect on the silt content because they are significantly the same.

TABLE 4.5.EFFECT OF LAND USE ON AGGREGRATE STABILITY INDICES

LAND USE	C.F.I (%)	A.S.C (%)	C.D.I (%)	D.R (%)	W.D.C (%)	A.S (%)	TMWD(%)
GL	0.93^{a}	15.00^{a}	0.80^{b}	0.49^{b}	0.70^{a}	40.95^{a}	1.48^{a}
AL	0.93^{a}	6.20^{a}	0.81^{b}	0.61^{a}	0.70^{c}	32.26^{a}	1.05^{b}
FL	0.90^{c}	9.46^{b}	0.12^{a}	0.33^{c}	0.69^{d}	18.25^{a}	0.46^{d}
FA	0.73^{b}	7.87^{c}	0.13^{a}	0.48^{b}	0.70^{b}	27.06^{a}	0.89^{c}

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise.

C.F.I- Clay Flocculation A.S.C-Aggregated Silt +Clay C.D.I- Clay Dispersion Index D.R –Dispersion ratio W.D.C- Water Dispersible Clay A.S- Aggregate Stability TMWD- Total Mean Weight Diameter GL- Grassland AL-Arable land FL-Fallow Area FA-Forest Area.

The means of the Clay Flocculation Index are statistically the same for grassland and Arable land at (P<0.05) level of significance. Forest Area and Fallow land are statistically different and the Fallow land has the lowest mean value of (0.73%).The means of the ASC are statistically different from each other, they have different response to the ASC content. Grassland has the highest mean value (15.07%) at P<0.05 level of significance with Arable land having the lowest mean value (6.22%). Forest Area has the highest mean value which is statistically the same with fallow land. Arable land and grassland are statistically the same at P<0.05 level of significance. At the DR, grassland and Forest Area are statistically the same at (P<0.05) level of significance, fallow land has the lowest mean value. The mean values of the WDC are statistically different from each other, the land use have different responses to the effect of the WDC. The aggregate stability is statistically the same. The land uses have the same responses with the aggregate stability. The total mean weight diameter are statistically different from each other at P<0.05 level of significance with Grass Land having the highest TMWD and fallow land has the lowest TMWD.

TABLE4. 6 EFFECT OF LAND USE ON CARBON

LAND USE	O.C %	O.M %
GL	0.58^{a}	0.99^{a}
AL	0.14^{c}	0.25^{c}
FL	0.16^{c}	0.28^{c}
FA	0.30^{b}	0.52^{b}

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise

GL- Grassland AL-Arable land FL-Fallow Area FA-Forest Area O.C – Organic Carbon O.M- Organic Matter

Grassland has the highest organic carbon (0.58%) which might be due to the planting of leguminous grasses on the field and the decomposition of the grasses which lead to increase in organic matter followed by the Forest Area having the second highest carbon content this is due to the decomposition of leaves and litters, low exposure of the bare soil to direct sunlight. Fallow land and Arable land are significantly the same at $p<0.05$ level of significance in Table 4.6. The organic matter content is highest at the Grassland due to the high microbial and fermentation rate at this region and content with the roots of the grasses in fungal hyphae are responsible in increase organic matter content (The result was in agreement with the findings of Negessa(2001)and (Malo *et al* 2005) followed by Forest Area with (0.51%) mean value, Fallow land and Arable land are significantly the same and have the lowest organic matter content. This is due to the cultivation of crops without effective management practices which has depleted the organic matter content and aggravates organic matter decomposition.

TABLE 4.7 EFFECT OF LOCATION ON CARBON AGGREGATE

LOCATIONS	2MM	0.25MM	0.053MM
ILL	0.30[d]	0.29[b]	0.21[a]
HDJ	0.85[a]	0.09[d]	0.18[a]
GMW	0.68[b]	0.11[d]	0.32[a]
MJB	0.49[c]	1.00[a]	0.30[a]
GRY	0.14[e]	0.20[c]	0.13[a]

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise.

ILL-ILLEILA HDJ-HADEIJA GMW-GAMAWA MJB- MINJIBIR GRY-GORONYO

At 2mm sieve they are all statistically different and the locations have different response on the Organic carbon content. Hadeija have the highest organic carbon content (0.85%), followed by Gamawa with Goronyo having the lowest carbon content (0.14). At the 0.25mm sieve Minjibir has the highest carbon content and statistically different from other locations, opposite to the 2mm sieves Hadeija has the lowest carbon content (0.09%) and it's statistically the same with Gamawa. At 0.053mm sieve the organic carbon are statistically the same at $P< 0.05$ level of significance with Gamawa having the highest mean value (0.319200) , followed by Minjibir and Goronyo having the least mean value (0.13%) .

The organic matter content depends on the organic carbon and they are statistically different at $P< 0.05$ level of significance. Hadeija has the highest organic matter content in Hadeija with Goronyo having the lowest carbon content at the 2mm sieves. At 0.25mm sieve Minjibir has the highest organic matter content (1.74%) with Gamawa and Hadeija that is statistically the same at $p< 0.05$ level of confidence. At 0.053mm sieve they are all statically the same and have the same responses to the organic matter content. The high organic matter material in Minjibir is due to the root residues which improved the C storage in the soil.

TABLE 4.8 .INTERACTION TABLE OF LAND USE AND LOCATION ON PARTICLE SIZE DISTRIBUTION

LOCATIONS	LAND USE	CLAY%	SAND%	SILT%
ILL	GL	34.32^{a}	46.77^{j}	18.91^{a}
	FL	19.65^{b}	67.73^{i}	12.61^{bc}
	FA	5.84^{g}	90.35^{a}	3.81^{ghij}
	AL	8.32^{efg}	89.68^{ab}	2.00^{ij}
HDJ	GL	16.32^{c}	67.52^{i}	16.16^{ab}
	FL	8.32^{efg}	88.96^{abc}	2.72^{hij}
	FA	6.32^{fg}	87.63^{abcd}	6.05^{fghi}
	AL	8.32^{efg}	82.29^{fg}	9.39^{cdef}
MJB	GL	8.32^{efg}	80.96^{g}	10.72^{cde}
	FL	8.99^{def}	84.19^{defg}	6.83^{efgh}
	FA	11.65^{d}	76.48^{h}	11.87^{bcd}

	AL	6.99^{efg}	87.63^{abcd}	5.39^{fghi}
GRY	GL	6.37^{fg}	85.63^{cdef}	8.00^{defg}
	FL	0.00^{h}	0.00^{k}	0.00^{j}
	FA	7.76^{efg}	87.29^{abcd}	4.95^{fghi}
	AL	9.71^{de}	84.60^{defg}	5.69^{fghi}
GMW	GL	9.76^{de}	84.96^{def}	5.28^{fghi}
	FL	7.76^{efg}	87.29^{abcd}	4.95^{fghi}
	FA	9.04^{def}	86.29^{bcde}	4.67^{ghi}
	AL	11.71^{d}	83.27^{efg}	5.03^{fghi}

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise.

Grassland has a significant effect on the clay the content in illela having the highest value (34.32%) .The clay content in Minjibir ,Hadeija and Illella are all significantly the same .The effect of Arable land had a negative effect on clay content of the soil. Forest area has the highest sand content in Illela(90.35%). The soils in all the locations contain high sand content this is due to the high rate of desertification in the Northern .Silt to clay content are relatively low compared to sand.

TABLE 4.9 EFFECT OF LAND USE ON CARBON

LAND USE	2MM %	0.25MM %	0.053MM %
GL	0.37[b]	0.37[b]	0.20[a]
AL	0.68[a]	0.356[b]	0.26[a]
FL	0.63[a]	0.55[a]	0.24[a]
FA	0.29[b]	0.08[c]	0.21[a]

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at P<0.05 according to Duncan multiple range test.

At Table 4.10 , On the 2mm sieves ,Arable land has the highest mean value(0.68) which is statistically the same with fallow land(0.63) at P< 0.05,while grassland and forest area are significantly the same .At 0.25mm sieve , Fallow land has effect on the carbon content ,this may be due to increased biological activities on the land which was left uncultivated for more than 7 years, Grassland and Arable land showed the same responses to the amount of carbon content ,Forest area has the lowest carbon content which might be as a result of sparsely vegetation's and trees in the Forest area. At 0.053mm sieve all the land use are significantly the same, they had the same response to the carbon content.

TABLE 4.10 EFFECT OF LOCATION ON %DSA

LOCATION	2MM	0.25MM	0.053MM	<0.053MM
ILL	28.09^{b}	33.12^{a}	35.41^{c}	3.38^{a}
HDJ	25.53^{b}	18.12^{bc}	50.99^{a}	4.42^{a}
GMW	13.71^{c}	23.09^{b}	43.44^{abc}	19.76^{a}
MJB	38.84^{a}	14.25^{c}	40.50^{bc}	6.41^{a}
GRY	1.92^{d}	22.94^{b}	46.02^{ab}	4.12^{a}

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise.

At the 2mm sieve ,Minjibir has the highest mean value(38.84),with Hadeija and Illela which is significantly the same at $p< 0.05$ level of confidence. Goronyo has the lowest mean value(1.92) .At the 0.25mm sieve Illella has the highest mean value (33.12) while Minjibir has the lowest % dry stable aggregates . Aggregates determine the erodibility, soil physico-chemical properties and the resistance to deformation.

TABLE 4.11 EFFECT OF LAND USE ON %DRY STABLE AGGREGRATE

LAND USE	2MM	0.25MM	0.053MM	<0.053MM
GL	39.05[a]	22.47[a]	34.36[b]	4.13[a]
AL	23.84[b]	24.00[a]	46.52[a]	5.64[a]
FL	4.640[d]	22.22[a.]	49.40[a]	3.00[a]
FA	18.95[c]	20.52[a]	42.81[a]	17.71[a]

Note: Mean having different letters in a column are significantly different and the mean difference with the same alphabet are not significantly different at $P<0.05$ according to Tukey Pairwise.

In Table 4.11, the 2mm sieve are all statistically different from each other with Grassland having the highest mean value (39.05) at $p<0.05$ level of significance and fallow land having the lowest. At all other sieves the response of the land use are significantly the same except for grassland at the 0.053 sieve

TABLE 4.12 INTERACTIONS OF LOCATIONS AND LANDUSE ON ORGANIC CARBON

LOCATIONS	LAND USE	O.C%	O.M%
ILL	GL	0.79[ab]	1.35[ab]
	AL	0.05[ef]	0.08[ef]
	FL	0.16[cdef]	0.28[cdef]
	FA	0.19[cdef]	0.32[cdef]
HDJ	GL	0.61[b]	1.06[b]
	AL	0.07[ef]	0.13[ef]
	FL	0.24[cde]	0.41[cde]
	FA	0.15[def]	0.25[def]
GMW	GL	0.19[cdef]	0.33[cdef]
	AL	0.13[def]	0.22[def]
	FL	0.19[cdef]	0.33[cdef]
	FA	0.09[ef]	0.16[ef]
MJB	GL	0.98[a]	1.69[a]
	AL	0.37[c]	0.63[c]
	FL	0.23[cde]	0.40[cde]
	FA	0.87[a]	1.50[a]
GRY	GL	0.31[cd]	0.54[cd]
	AL	0.11[def]	0.20[def]
	FL	0.00[f]	0.00[f]
	FA	0.21[cde]	0.37[cde]

Minjibir has the highest organic carbon , the effect of grassland and forest are statistically the same in MInjibir The organic matter content is highest at the Grassland due to the high microbial and fermentation rate at this region and content with the roots of the grasses in fungal hyphae are responsible in increase organic matter content(The result was in agreement with the findings of Negessa(2001) and (Malo et al 2005) .High organic content in Forest area can be as a result of deposition and fermentation of leaf litters from the trees. Grassland has effect on the improvement in organic matter content in Illeila(0.79%) and Hadeija (0.61%). In all the locations it has been found that there was a positive response from the effect of grassland on the carbon content. In Minjibir Arable land (0.37%) had a positive effect on the soil , this might be as a result of planting leguminous crops and proper management on the field which is opposite to different locations in which the land use had an effect on the soils. Arable land affected the organic content of the soil ,this might be due to continuous cultivation without effective and proper remedial practices on the field. The responses of fallow land in all the locations are significantly the same at $P<0.05$ level of confidence.

The organic matter content in Minjibir is the highest .Grassland and Forest area are significantly the same at $p<0.05$.They both had a positive increase and improvement in the soil physic chemical properties. Forest has a role in global modern global cycle because they can absorb can absorb photosynthesis and sequester it has biomass.Paustian et al (1996) observed that a greater frequency of cropping patterns affects SOC .

4.1 DISCUSSIONS

The effects of land use on soil Carbon stocks were variable with positive, negative and neutral impacts observed across the various locations. The dominant role of standing Carbon stocks in governing the magnitude of warming induced soil losses fits with expectations from theoretical research (Carey et al,2016). Desertification result in decline of quality of soil and vegetation. The soils of the five locations where characterized by high sand content; this could be as a result of the desertification influence and low soil water in the five locations. The level of sands shows a loose soil prone to erosion and should be considered by NEWMAP(Nigeria Erosion Integrated Watershed Management Project) in designing soil erosion management in the area. The positive response from effect of grassland on Minjibir which increased the organic carbon content this probably explained the significance differences in the level of organic carbon, organic matter and dry stable aggregate in Minjibir. Grassland are the natural biomass in many dry lands, partly because rainfall is insufficient to support trees and because of prevailing livestock management. The productivity of tropical grassland is known to be much higher and they sequester more carbon in accordance with (Scurlock and Hall,1998). Estimates for Carbon stored under grassland are about 0.93%. The average input of organic matter is about double the one contributed by cropped soil (Jenkinson and Rayner, 2007).This fact is gotten from the results of the various locations. It showed that grassland was subjected to controlled grazing and has higher C content than forest area, cropland and forest area. The major factor responsible for enhanced carbon storage in grassland is the high carbon content derived from plants root and maximized grass productivity. This study experiment showed a positive response of carbon to sequester more Carbon in the soil. Aggregates greatly influence the dimension of pore spaces which affects the movement and distribution of air and water. Table 4.8 displayed the results of SOC percentage in the different land use systems. The maximum SOC was observed in GL (0.52%). This studies shows a positive response in Hadeija and Minjibir having the highest percentage dry stable aggregates which lead to the high organic carbon content because they are quite resistance to deformation and not easily erodible there by able to store carbon at the micro aggregates. Minjibir has the highest mean value(38.84) for percentage dry stable aggregates ,with Hadeija and Illela which is significantly the same at P< 0.05 level of confidence. Goronyo has the lowest mean value (1.92) Physical protection consists of the encapsulation of SOM fragments by clay particles and micro aggregates (Balescent, Chenu and Baladene, 2000). There was positive impact on fallow land which allows the soil to restore its nutrient and SOC and strength in the aggregate. Forest area has a little effect on SOC storage due to sparsely vegetation's, uneven distribution of rainfall. Arableland has a drastic decline in the soil due to tillage practices, completely removal of crop residue after harvesting and poor management practices on the crops. The results of intensive cultivation agrees with the result of Sabo and Odus 2008 who reported that soils are exhausted due to intensive cultivation and no adequate application replenishment measures to sustain their productivity. The mean MWD and AS were the lowest in Arable land. This may be due to the presence of the lowest amount of SOM, limited microbial activity, and the lowest root biomass, which may play a major role in the formation of soil aggregates and is important for MWD and AS,the MWD was higher in grassland compared to cropland .The removal of plant residue from the soil surface layer and animal grazing are the main causes of the disturbance of soil aggregates. SOC is the main source of energy that facilitates soil aggregate formation. SOC played a significant role in the improvement of the physicochemical properties of the soil and the formation of soil aggregates (Saroa *et al* 2009). Our results are in line with similar findings of other researchers [49–55] and demonstrate that grassland contains a high amount of SOC and a significantly higher SOC content was observed in AAO. This is perhaps due to slightly higher DSAand MWD in grassland compared to the other types of land use (Brzeziska *et al* 2009).Decay and growth of roots are the main supporters of SOM pools in the soil. Root biomass and SOM were observed as supporting material for the formation of aggregates . In many studies, it has been revealed that GL have the annual mean maximum root biomass, and an estimated annual root biomass was noted in grassland . We assume that it may be affected by the activities of farmers, who remove all types of unwanted vegetation from the soil in cultivated lands. Across the six study sites, there was a decreasing root biomass pattern beginning with GL, followed by Fallow land then Forest area with Arable land being the least.. Generally, the study observations showed that animal grazing, the regular use of farm machinery, and several anthropogenic activities were assumed to be the reasons for low root biomass production in the Arable land , this observed by many researchers in their studies (Wen *et al* 2015).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The concentration of carbondioxide and other greenhouse gases in the atmosphere is increasing as a result of deforestation and improper land use. The study assessed influence of land use under the locations and how it sequesters Carbon. There were variations in the soil physico-chemical properties which is as a result of various usage of land. The result confirmed that grazing land has the highest potential to sequester more carbon rapidly into the soils considering the increase in organic carbon following proper grazing management practices. Arable land has a negative impact on the soil due to intensive cultivation and poor management practices.

To take adequate care of these deficiencies and minimize soil nutrients depletion and degradation in the study sites, the following measures are recommended; Organic mulching, cultivation of cover crops among others, contour ridge and appropriate land use approach.

In addition to the above measures, there is need to understand the soil adequately through detailed soil survey and land evaluation. When this is carefully done , the soil can then be put to appropriate land use that are most suitable for land , having known its capability and constraints as well as use the land for the purposes it is best suited for , this will go a long way to improve the productivity of such lands.

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