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Soil Carbon: Pool, Loss, Emission and Climate Change Sources and Knowledge Level of Some Land Use Systems in Sudan Savanna, Kwara State

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ABSTRACT: This research work was carried out in Sudan savanna of Kwara State to determine the effects of land use types on soil carbon pool, loss, emission and to determine the farmer's knowledge level and sources of information on climate change. Six villages were selected randomly and in each Local Government Area, three villages were visited and three farms planted each with maize/cassava intercrop, cashew plantation and natural forest were sampled. Soil samples were collected from the farmland randomly at the depth of 0–20cm and analysed for physical and chemical properties in the laboratory. Carbon pool index was higher under cashew plantation. The mass of carbon lost recorded was higher under maize/cassava intercrop and cashew plantation recorded the lowest mass of carbon lost. Equivalent Carbon dioxide emitted recorded was lower under cashew plantation and maize/cassava intercrop recorded higher equivalent of carbon dioxide emitted. Natural forest had the highest organic carbon. Simple random sampling of 126 respondents were interviewed. Results revealed majority (71.4%) are willing to invest in residue retention and 92.9% are willing to engage in climate change mitigation practices free of charge. Maize/cassava intercrop recorded the lowest carbon pool due to burning of plant residues and the use of tillage practices. The highest carbon pool index recorded under cashew plantation was due to leaves litter decomposition. Carbon emitted was generally higher under maize/cassava intercrop as a result of continuous and vigorous cultivation leading to loss of carbon. Some farmers are not fully aware of climate change mitigation practices, therefore, more observation should be given to afforestation scheme to mitigate climate change and government and nongovernmental organization (NGOs) should educate and encourage farmers to practice crop residue retention and also minimize bush burning.

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KEYWORDS: Soil carbon, Land use systems, Climate change mitigation, carbon emission

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1. INTRODUCTION

Research on soil carbon for the last couple of decades has focused on the change in carbon storage due to change in land use and management practices. Based on diverse climate and soil types, results of soil organic carbon storage under different land uses and soil management practices in Nigeria are often conflicting and in some cases, inconsistent with other findings. Anikwe (2010) reported that the highest carbon stocks of 7906 – 9510 g cm^{-2} under natural forest, artificial forest and artificial grassland ecosystems while continuously cropped and conventionally tilled soils had about 70% lower carbon stock (1978 – 2822 g cm^{-2}). In addition, carbon stock of continuously cropped and conventionally tilled soils was 25% lower than the soil cultivated by the use of conservation tillage. More so, (Akpa *et al*., 2016) reported a mean soil organic carbon concentration range of 4.2 and 23.7 g kg^{-1} in the top 30 cm and a range of 2.6 and 9.2 g kg^{-1} at the lower soil depth. However, almost half of the soil organic carbon stock was found in the top soil (0 – 30 cm) layer which represents the rooting depth of many agronomic crops and is more easily affected by management practices.

Several researchers (Anikwe, 2010; Nwite and Alu, 2017; Mbah *et al*., 2017), have provided evidence that the incorporation of crop residues may increase carbon input while decreasing the rate of carbon loss from the agricultural soil and other land use practices have a significant influence on the amount and duration of carbon sequestration in the soil before it is returned to the atmosphere (Anikwe, 2010). Potentially, carbon stock of soil could be increased by improving soil management practices and land use change towards a system that ensures high organic matter input to soil and slow decomposition (Rabbi *et al*., 2014). Since land use management practices play an important role in the global carbon pool and fluxes, their impact demand quantification. Soil carbon quantification is a useful index in the determination and management of soil organic matter (SOM) which is very important in soil physical, chemical and biological fertility as well as the overall soil quality (Stockman *et al*., 2013; Hobley *et al*., 2015). Such quantification can provide useful information that will necessitate farmers to adopt appropriate measures in order to minimise soil organic carbon loss from crop lands.

Carbon dioxide is mainly emitted from combustion of fuels and industrial processes, but also deforestation and biomass burning are large contributors (IPCC, 2014). Carbon dioxide can be removed from the atmosphere by photosynthesis and soil storage, phenomenon called carbon storage, which is an important measure of climate change mitigation (Katterer *et al*., 2013). However, some soil, e.g. organic soils, can act as a carbon source by rapidly oxidising carbon into carbon dioxide and emitting it to the atmosphere (Roos, 2013). Methane (CH_4), as the second most prevalent greenhouse gas is produced by natural biological processes in areas such as wetlands, but also through anthropogenic activities including rice agriculture, waste management, raising of ruminant animals and fossil fuels industries (Roos, 2013; USEPA, 2014).

The Greenhouse Gases (GHG) mitigation potential of Sustainable Land Management (SLM) in agricultural lands is very large (Liniger *et al*., 2011). Sustainable Land Management (SLM) strategies and practices can prevent land degradation, restore degraded lands, and reduce the need for further conversion of natural forests and grasslands. Farmers can reduce greenhouse gas emissions, increase carbon sequestration and maintain above and below ground carbon stocks at relatively low cost, while also improving food production and livelihoods (Owoade et al., 2020). Improved agricultural practices can reduce carbon emissions from soil erosion and disturbance, and capture carbon from the atmosphere to store long-term in soils (Owoade, 2020). Practices like cover cropping, applying crop residues, mulch, manuring, reduced tillage and rotational cropping with legumes increase organic matter in soil, while also increasing crop yields. With better agronomic practices, nutrient and water management, reduced tillage and crop residue management, African croplands could potentially reduce greenhouse gas emissions by 2.0 – 3.5 million tons of carbon dioxide eq per hectare per year or a total of 52.3 – 91.5 million tons of carbon dioxide eq equal to 5 – 9% of annual African fossil fuel emissions in 2005 (Liniger *et al*., 2011). As part of sustainable soil management, farmers grow trees in and around their farm fields, to harvest useful products such as fruit, livestock fodder and medicines. This benefits climate as well as ecosystems. In humid zones of Africa, retaining shade and understory trees in cacao can provide vast carbon stores. For example, mature cacao agro – forestry systems in Cameroon store 565 tons of carbon dioxide eq per hectare. Even in semi – arid lands, agro – forestry system like intercropping and silviculture, with 50 trees per hectare, can store 110 to 147 tons of carbon dioxide eq per hectare in the soil alone (Liniger *et al*., 2011).

Arable lands all over Nigeria have seen an alarming decline in soil productivity as a result of continuous agricultural practices without application of adequate restorative measures (Ndor *et al*., 2010). Changes in land use may alter land cover, which results in carbon stock changes in biomass as well as in the soil. Carbon capture and storage (or sequestration) is receiving increasing attention as one tool for reducing carbon dioxide concentrations in the atmosphere. Land use change, inappropriate agricultural practice, and climate change can all lead to a net release of carbon from soils to the atmosphere, enhancing the problems of greenhouse gas release (Nguyen, 2011, Owoade, 2021).

Soil management practices have been proven to help in sequestering soil carbon including restoration of degraded soils and ecosystems, no – till farming, nutrient management, water conservation and harvesting, agroforestry practices, the adoption of recommended agricultural practices on prime land and retiring marginal agricultural land to restorative land use (Owoade et al., 2021). Through these healthy practices, forest vegetation can be maintained; thereby increasing the carbon stock of forest soil by reducing direct loss to the atmosphere (Offiong and Iwara, 2012).

2. RESEARCH METHODOLOGY

The study was carried out in Asa and Moro Local Government Areas of Kwara State, Nigeria. Six (6) villages (Ajuwon, Ogele, Kajola, Oniso, Budo – apata, Eleshinnla) were randomly selected. The choice of these locations was based on the predominance of farming occupation over other occupations in the local government areas. Kwara state has two climatic seasons, the dry and wet seasons with an intervening cold and dry harmattan from December to January. The annual rainfall ranges between 1000 mm and 1500 mm while average temperature ranges between 30°C and 36°C. Relative humidity in Ilorin in the wet season is between 75 to 80% while in the dry season it is about 65%. It is located on latitude 8° 30' and 8° 50'N and longitude 4° 20' and 4° 35' E. It is situated in the transitional zone within the forest and the Guinea savanna zone of Nigeria. It has extensive fertile soil suitable for agriculture. The total land area is 32,500 square kilometres out of which 75.3% is cultivable (National Population Commission, 2010). The vegetation covers are characterized by coexistence of trees (locust – bean tree, shea and baobab) and grasses (beard grass, bluestem grass and broom sedge). The study areas involve a natural forest, farmlands used for cultivation of arable crops such as maize/cassava intercrop farm land and plantation crop such as cashew.

2.1. Soil sampling and analysis

Soil samples were collected in triplicate from two Local Government Areas of Kwara State, namely; Asa and Moro with the aid of a soil auger. In each Local Government Area, three villages were visited. In each village, three farms planted each with maize/cassava intercrop, cashew plantations and natural forest were sampled. Soil samples were collected from the farmland randomly at the depth of 0 – 20 cm with the use of soil auger for physical and chemical analysis in the laboratory. The samples were bulked to form a composite and air-dried, crushed and sieved through 2 and 0.5 mm meshes for the determination of pH, particle size and carbon. The bulk density of each land use was taken at 0 – 5 cm, 5-10 and 10 – 15 cm with core samplers.

Laboratory analysis was carried out at the International Institute of Tropical Agriculture (IITA), Ibadan. Particle size analysis was carried out with the aid of hydrometer using sodium hexametaphosphate as the dispersant (International Soil Research, 1993; AOAC, 1990). Soil pH was determined in 1:1 soil water ratio (Black, 1965). Organic carbon was determined by chromic acid digestion method (Heanes, 1984).

2.2. Determination of carbon stock

Soil carbon stocks (C stock, kg/ha) at the 20 cm depth were calculated from the total carbon content and bulk density as in Owoade et al., 2020 as follows:

C – Stock (kg/ha) = SOC X BD X A X D

Where SOC – Soil Organic Carbon

BD – Bulk density (Mgm^{-3})

A – Area (1 ha = $10{,}000m^2$)

D – Soil depth (0.2m)

2.3. Determination of carbon pool index

Based on the concentrations of these different carbon forms determined, the carbon pool index (CPI) was calculated according to the steps described by (Xu *et al*. 2011) and (Lou *et al*. 2011).

$$\text{Carbon pool index (CPI)} = \frac{\text{Total carbon content in the sample (mg g}^{-1}\text{)}}{\text{Total carbon content in the reference soil (samples from control) (mg g}^{-1}\text{)}}$$

2.4. Calculation of carbon dioxide (Co_2) emitted

The SOC of the pristine forest sites at each sampling location were assumed to represent the maximum or saturation SOC. Therefore, the difference between the forest SOC (SOC_f) and the actual SOC under a given land use system (SOC_a) constituted the carbon lost, which was attributed largely to emissions. According to IPCC (2006), equivalent CO_2 lost by emission was therefore calculated as:

CO_2 emitted = (SOC_f – SOC_a) X 44/12

The total carbon emission from the 2 local governments and land use systems especially from the arable lands were determined considering the total cropped acreages.

2.5. Questionnaire approach and sampling strategy

Structured questionnaires were administered to the farmers to obtain information on socio-economic variables (education, demography, income); current cropping practices, knowledge of soil types and properties, crop and soil management history and their understanding of the relationship between climate change and soil/crop residue management. After interviews, soils were sampled from each land use system and farms for SOC storage determination.

2.6. Data analysis

The data obtained from the farmers and sampled soils were processed and analysed using descriptive statistical tools such as frequency, distribution and percentages.

Soil data was subjected to analysis of variance (ANOVA) to test differences in soil properties, soil carbon and sequestration across soils of different land use types. For statistically different parameters ($p < 0.001, 0.01, 0.05, p > 0.05$), means was separated using Least Significant Difference (LSD).

3. RESULTS

3.1. Soil carbon pool index in Sudan savanna

From the result in Table 1, the carbon pool index stored in the cultivated maize and cassava intercrop farm land ranged between 0.22 – 0.68 and that of cashew plantation ranged from 0.34 – 0.94. Cashew plantation recorded the highest carbon pool index of 0.94 compared to maize and cassava intercrop farm land which recorded (0.68) as the highest carbon pool index. The lower carbon pool was recorded under maize and cassava intercrop land (0.22) compared to cashew plantation which recorded (0.34) as the higher carbon pool index.

3.2. Soil carbon loss and estimated Co_2 equivalent emission in Sudan savanna

It was shown that the mass of carbon lost varied between 0.17 – 1.43 kg Co_2 e (Table 2). Maize and cassava intercrop farm land had the highest (1.43 kg Co_2 e) carbon lost in all the villages compared to cashew plantation. Lowest mass of carbon was lost in cashew farms in all the villages compared to maize and cassava intercrop farmland.

It was revealed in Table 2 that carbon dioxide emission from maize and cassava intercrop farm land varied between (1.25 – 5.24 kg Co_2e) and that of cashew plantation varied between (0.15 – 4.40 kg Co_2e). Comparing maize and cassava intercrop farm land with cashew plantation in each village, maize and cassava inter- crop recorded the highest carbon emission (0.95, 3.85, 1.25, 0.84, 1.03 and 5.24 kg Co_2) in all the villages compared to cashew which recorded the lower carbon emission (0.48, 3.23, 0.62, 0.15, 0.66 and 4.40 kg Co_2 e).

3.3. Socio – economic characteristics of the respondents

The distribution of the respondents according to types of crop planted, their sex, age, marital status and level of education respectively are presented in Table 3. It showed that 48.4% of the respondents planted maize/cassava while 46.8% planted cashew and 4.8% of the respondents were into forest reserve. The result further showed that 90.5% of the respondents were males while 9.5% of the respondents were females. Again 51.7% of the respondents were between 41 – 50 years of age, 23.8% of the respondents were between 51 – 60 years of age, 19.9% were between 31 – 40 years of age and 4.8% were between 70 – 85 years of age. Majority (98.4%) of the respondents are married while 1.6% of the respondents are single. Also the Table showed that more than half (59.5%) of the respondents attended primary schools while 40.5% attended junior secondary schools.

3.4. Relationship between the selected demographic characteristics of the farmers and their climate change knowledge level

For the test of significant relationship between the demographic characteristics of the farmers and their climate change knowledge level, the study employed Pearson Product Moment Correlation (PPMC) to test for the relationship between the dependent and the independent variables (Table 4). The result revealed that some of the selected demographic variables such as age (0.269^{xx}; $P \leq 0.01$), source of climate change information (0.236^{xx}; $P \leq 0.01$), association membership (0.301^{xx}; $P \leq 0.01$, crop grown (0.273^{xx}; $P \leq 0.01$), years of experience (0.215^{xx}; $P \leq 0.01$) and cropping system (0.356^{xx}; $P \leq 0.01$) respectively exhibited significant relationship with the climate change knowledge level of the farmers in the study area.

3.5. Sources of climate change and knowledge level

It was revealed in table 5 that 94.4% of the respondents had moderate knowledge of climate change while 4.8% of the respondents had low knowledge level of climate change and only 1% of the respondents had high knowledge level of climate change. The result showed that 62.7% of the respondents obtained information from extension officer while 27.8% of the respondents obtained information on climate change from other farmers and 9.5% of the respondents obtain information on climate change from their own personal observation.

3.6. Membership of association

It was shown in table 6 that 66.7% of the farmers belong to farmer's association while 33.3% of the farmers did not belong to any farmer's association. In this table, it was shown that 57.1% of the farmers did not play any special role while 42.9% of the farmers played special role (leader, secretary). It was shown in this table that 68.3% of the respondents did not discuss climate change issues at their meeting while 31.7% of the respondents discussed climate change issues at their meetings

Table 1. Soil carbon pool index in sudan savanna

LGA	Village	Land use	Carbon pool Index
Asa	Ogele	Cashew	0.83
		Maize & Cassava	0.67
	Ajuwon	cashew	0.40
		Maize & cassava	0.29
	Kajola	Cashew	0.80
		Maize & Cassava	0.59
Moro	Oniso	Cashew	0.94
		Maize & Cassava	0.68
	Budo-Apata	Cashew	0.80
		Maize & Cassava	0.68
	Eleshinnla	Cashew	0.34
		Maize & Cassava	0.22

Field Survey, 2018

Table 2. Soil carbon loss and estimated CO_2 equivalent emission in Sudan savanna

LGA	Village	Land use	Mass of carbon lost (kg ha^{-1})	EquivalentCO_2 Emission(kg CO_2 ha^{-1})
Asa	Ogele	Cashew	0.13	0.48
		Maize & Cassava	0.26	0.95
	Ajuwon	cashew	0.88	3.23
		Maize & cassava	1.05	3.85
	Kajola	Cashew	0.17	0.62
		Maize & Cassava	0.34	1.25
Moro	Oniso	Cashew	0.04	0.15
		Maize & Cassava	0.23	0.84
	Budo-Apata	Cashew	0.18	0.66
		Maize & Cassava	0.28	1.03
	Eleshinnla	Cashew	1.2	4.40
		Maize & Cassava	1.43	5.24

Field Survey, 2018

Table 3. Distribution of respondents by socio – economic characteristics

Characteristics	Frequency	Percentage (%)
Sex		
Male	114	90.5
Female	12	9.5
Age (years)		
31 – 40	25	19.9
41 – 50	65	51.7
51 – 60	30	23.8
70 – 85	6	4.8
Marital status		
Married	124	98.4
Unmarried	2	1.6
Highest Education		
Basic	75	59.5
Junior Secondary School	51	40.5
Types of crop planted		
Maize/Cassava	61	48.4
Cashew	59	46.8
Forest	6	4.8

Field Survey, 2018

Table 4. Test of significant relationship between the selected demographic characteristics of the farmers and their climate change knowledge level using Pearson Product Moment Correlation (PPMC).

Variables	Correlation coefficient	P-value	Decision	Remark
Sex	0.084	0.345	NS	Accept H_o
Age	0.269^{xx}	0.000	S	Reject H_o
Marital status	0.033	0.712	NS	Accept H_o
Education	0.088	0.323	NS	Accept H_o
Source of climate change information	0.236^{xx}	0.006	S	Reject H_o
Association membership	0.301^{xx}	0.001	S	Reject H_o

Crop grown	0.273^{xx}	0.002	S	Reject H_o
Years of experience	0.215^{xx}	0.005	S	Reject H_o
Cropping system	0.356^{xx}	0.000	S	Reject H_o

Correlation is significant at 0.01 level.

Table 5. Sources of climate change and knowledge level

Climate change sources and knowledge level	Frequency	Percentage
Climate change knowledge level		
Medium	119	94.4
Low	6	4.8
High	1	0.8
Source of climate change		
Extension officer	79	62.7
Farmer to farmer	35	27.8
Personal observation	12	9.5

Field Survey, 2018

Table 6. Membership of association

Association	Frequency	Percentage
Belong to any farmer's association		
Yes	84	66.7
No	42	33.3
If so, do you pay any special role (leader, secretary)		
No	72	57.1
Yes	54	42.9
If so, do you discuss climate change issue at your meeting		
Yes	40	31.7
No	86	68.3

Field Survey, 2018

4. DISCUSSIONS

According to the ratings of Fagbami & Shogunle (1995) the organic carbon is medium. The result showed that forest in most of the villages contained the highest proportion of organic carbon when compared to other land use. This in line with the report of Anderson–Teixeira *et al*., 2009 and Owoade et al., 2020 that conversion of uncultivated land for agricultural purpose results to significant soil organic carbon loss. Natural forest land in Kajola and Budo – Apata villages recorded the highest soil organic carbon amongst the land use. This corroborate with the work of Zhou *et al*. (2017) that the higher amount of carbon accumulation under forest land may be due to leaf litter fall on the surface and through root deposition in deeper layers (Owoade et al., 2020). Furthermore, the higher soil organic carbon in forest soils might be as a result of higher organic matter inputs from above and below ground litter (Materechera, 2010). During the whole cycle, forest species deposit a large quantity of residues into the soil due to the natural process of senescence. The high carbon input in these areas is associated with increase in soil carbon stocks in afforestation areas worldwide (Shi *et al*. 2015).

Soil organic carbon and total soil organic carbon percentage under natural forest of the present study area are higher in all the villages than other land use types. These nutrient elements were rated as high (Fagbami & Shogunle, 1995). Natural forest has higher soil organic carbon percentage than cashew plantation, but cashew plantations still contain a good percentage of soil organic carbon compared to maize and cassava cultivated land. The higher soil organic carbon percentage recorded under natural forest could be as a result of organic carbon input from forest canopy as litter fall and partially or completely decomposed vegetations on the soil surface that leads to improved soil organic carbon. According to Zhou *et al*. (2007) reported higher amount of carbon accumulation under natural forest land may be as a result of leaf litter fall on the surface and through root deposition in deeper layers.

From the result, the lowest carbon pool recorded under maize and cassava may be as a result of land clearing and subsequent cultivation. This corroborate with the findings of Dhakal *et al*. (2010) concluded that conversion of forest to cropland and other land uses has caused reduction in soil organic carbon, whereas vice versa has increased the soil organic carbon stock. Also, the decrease in carbon might be related to the high mineralization rate of soil organic matter (Bationo *et al*. 2012) accentuated by annual ploughing and water erosion effects (Obalum *et al*. 2012). The lowest carbon pool recorded under maize and cassava intercrop farm land may be due to lack of vegetation cover and its associated microclimate. This is in agreement with the findings of other researchers (Djomo *et al*. 2011; Li *et al*. 2010). Also, due to fragile nature of the soils in the savannah, soil organic carbon break down rapidly under continuous and intensive cultivation (Abu and Abubakar, 2012). Eludoyin and Wolkocha (2011) reported that lower organic carbon content of soils under maize cultivation compared to forest due to erosion and leaching. Research findings have shown that conversion of forest land into cultivation requires addition of organic inputs otherwise it could increase global warming by decreasing the amount of soil carbon stock (Chen and Xu, 2010, Owoade et al., 2020). Several farm scale soil carbon sequestration studies have reported reduction in soil organic carbon socks following the change from native vegetation or pasture to annual crops (Luo *et al*. 2010).

The highest carbon pool index recorded by cashew plantation could be as a result of plant litters decomposition, fertilizers and manure applied to the farm land. This corroborate with the work of Moxley *et al*. (2014) that the incorporation of residues (either total straw or stubble) to the soil will tend to increase soil carbon as these residues form the basis for new soil organic carbon. According to Xiang *et al*. (2015) increase in passive carbon with increase in litter fall along successional gradient has also been reported. As these plant litters decompose, part of the carbon is emitted as carbon dioxide and part is incorporated into the soil, promoting increases in carbon stocks (Carvalho *et al*. 2017; Oliveira *et al*. 2017). Furthermore, findings from this study also agrees with that of Ovie *et al*. (2013) & Amama *et al*. (2012) who also observed that litter falls would increase soil organic matter which has a correlation with improved soil structure, soil organic carbon and stability.

It can be deduced from the result that the highest rate of carbon lost in maize and cassava intercrop farm land could be as a result of continuous cultivation, burning of crop residues and crop removal. According to Anikwe (2010) reported that cultivated systems have reduced carbon contents due to reduction in tree cover and increased mineralization as a result of surface disturbance. This is also due to changes in land use from natural forest which resulted in soil organic carbon stock losses within a few decades, which is in harmony with the work of Deng *et al*. (2016) review study. Land clearing and subsequent land cultivation often leads to loss of organic carbon in the soil in tropics (Don *et al*. 2011) because of rapid decomposition of organic matter under tropical climate (Jenkinson and Ayanaba, 1977). Study carried out by Kassa *et al*. (2017) at different sites of Southwest Ethiopia indicated land use conversions of natural forest to cropland led to annual loss of soil organic carbon within the range of 3.3 to 8.0 Mg ha^{-1}. Another studies reported the same losses of soil carbon due to deforestation in Ethiopia in the range from 2.3 Mg ha^{-1} to 8.0 Mg ha^{-1} per year (Assefa *et al*. 2017; Kassa *et al*. 2017). Based on conceptual models and studies, the loss after deforestation considered by improved mineralization rates, reduce litter input and changes in litter quality. According to Don *et al*. (2011) and Harris, (2012) reported that converting natural forests to agricultural land results in the mineralization of soil organic carbon, thus reducing soil organic carbon stocks and increasing atmospheric carbon dioxide concentrations. Generally, soil organic carbon reduces rapidly and then stabilizes after a land use change (Don *et al*. 2011). The lowest mass of carbon lost recorded under cashew plantation could be due to the improved soil organic matter from plant residue decomposition, effect of leaf litter and animal droppings, as well as recycling of nutrients to upper horizons of soil. The litter fall from plantations may have the capacity to increase soil organic carbon (Lu *et al*. 2013). These plantations crops may also have the ability to sequester carbon due to some large sole planting of the crops in southern part of Nigeria. According to Liu *et al*. (2017) and Zhang *et al*. (2011) soil organic carbon is increased as a result of more residuals returning into the soil due to plant litter decomposition. Smallholder agricultural management practices in the Savannah zone of Nigeria are inadequate and have resulted to decline in soil organic carbon stock.

The lowest mass of carbon lost recorded under cashew plantation could be due to the improved soil organic matter from plant residue decomposition, effect of litter droppings, as well as recycling nutrients to upper horizons of soil. The litter fall from plantations may have the capacity to increase soil organic carbon (Lu *et al*. 2013).These plantations crops may also have the ability to sequester carbon due to some large sole planting of the crops in southern part of Nigeria.

From the result of the study, the highest carbon emitted by maize and cassava intercrop farm land could be due to intensive and continuous cultivation which will lead to rapid expelled of carbon from the soil and reduction in the fertility of the soil. Conversion from native vegetation to agriculture typically reduces soil organic carbon by 20 – 70% (Luo *et al*. 2010 & Sanderman *et al*. 2010), and results in reducing soil health and significant emissions of greenhouse gases. Also, in poorly managed cultivated systems, there is loss of carbon due to negative impact on carbon sequestration (Lal, 2011). Furthermore, according to Wei *et al*. (2014) and Don *et al*. (2011) conversion of native soil to agricultural uses typically leads to a decrease in soil organic carbon levels. Soil carbon emitted within cultivated farm land varied considerably. This is explained by a very heterogeneous soil cover (bare soil, grass cover, tree litter), differences in topography and species effect. According to Pineiro *et al*. (2010) reported that negative changes in management causing loss of soil structure and surface litter cover can lead to erosion and loss of productivity resulting in a decline in soil organic carbon.

The result implies that all the sampled respondents have different socio-economic status which is expected to have influence on their land use system in the area. Result of the study revealed that majority of the farmers engage in growing of maize and cassava, while some involve in growing of cashew and very few is into forestry. Maize is the dominant crop together with cassava. This is in line with other work in Cambodia, which reported that decrease in crop diversity with cassava had become predominant crop with fruit trees (Touch *et al*. 2016a). The agriculture in Asa and Moro local government area is male dominated, meaning that men have more access to the resources and information needed to produce crops more efficiently than their female counterparts (Otitoju and Arene, 2010). It can be seen from the result that majority of the farmers are relatively old and they are able men and women who can do manual work without stress. According to similar finding which was reported by Adekunle *et al*. (2011). The finding supports the age distribution of the nation where the aged are minimal. It can also be seen that majority of them are married, which is the main factor influencing the choice of participation among the choice of group. Similar report was documented by Brako (2015) who discovered that sex is one of the factors influencing adoption of new farming practices among farmers. Hence, female group are less likely to partake than the male counterpart. From the result, it can be deduced that majority attended basic school and junior secondary school which implies that they are educated. This is an indication of the impacts of educational exposure (level of literacy) on farmers' practical farm field knowledge. It was revealed that majority of them used the land for more than 50% of the land used activities. It was also revealed that majority of them stated that the level of climate change is medium. From the result, it implies that majority of them obtained information on source of climate change from extension officer, while the minority from farmer to farmer and very few from their own personal observation. According to the report from Lambrecht *et al*. (2014) access to information through extension agents and programs not only boost farmer's awareness about improved technologies but also facilitate access to quality information that is more suitable and adaptable to their local conditions.

Result of the study revealed that majority of the farmer's climate change knowledge level is medium, while some are low and very few are very high. Idoma and Mamman (2016) in their study discovered that 92% of their respondents were aware of the term climate change and variability. Majority of the farmers obtained information on climate change from the extension agents, which will enable the farmers to make adaptive measure to tackle climate change and also have knowledge about the impact of climate change. This is in line with the work of Mugomola *et al*. (2013) in Uganda, information with regard to new agricultural technologies from research organizations is mainly through extension system. The findings by Raut *et al*. (2012) suggested that the success of agricultural extension through radio and television as a way of reaching farmers in which most of the farmers listened or watch agricultural programmes related to pests and diseases, use of organic and chemical fertilizers that were broadcasted through radio and television. Some of the farmers obtained information on climate change from farmer to farmer and few of them from personal observation. Idoma and Mamman (2016) in their study revealed four major channels of climate information communication in their order of acceptance to the respondents. Community channels (extension workers, neighbours/friends) very high significant rate, mass media (radio and television) came second while print media (newspapaers and pamphlets) rank the third and electronic media (internet and sms) ranked fourth.

It can be seen from the result that majority of them belong to farmer's association which will show a positive relationship between the association and adaptation to climate change. It has been speculated that farmers who observed or have knowledge relating to climate change are more likely to believe in future risks, including risks associated with high end climate changes, and therefore are more likely to adopt adaptation practices (Akerlof *et al*. 2013; Menapace *et al*. 2015). This is also in line with earlier research awareness in Ghana, Nepal and Bangladesh that revealed that farmers belonging to cooperative organizations have greater tendencies of using adaptation practices owing to their capability to share information, discuss problems facing them with one another, share ideas and take common decision (Ndamani and Watanabe, 2016; Tiwari *et al*. 2014; Uddin *et al*. 2014). It can also be seen from the result that most of the farmers did not play any special role, while some of them played special role (leader, secretary). It can be deduced from the result that majority of the farmers did not discuss climate change issues at their meeting, while some of them discuss it. According to Odjugo, (2011) at present the world is passing through global warming situation caused by anthropogenic factor (human activities) and if it continue unabated for decades or centuries with significant ecological impacts then, the earth will attain a changed climate (warm or hot climate).

Also from the result, majority of the farmers are willing to engage in climate change mitigation practices (e.g. planted fallows, residue retention etc) free of charge, which may increase their operation cost but also improve their crop yield. This could be as a result of positive effects that occur from adapting to climate change, known as co – benefits, can motivate farmers to adopt climate change practices (Bain *et al*. 2015). According to Bain, co – benefits such as reduced diseases and poverty levels, economic development, benevolence (a more moral and caring community) motivate people to adapt to or mitigate the risks of climate change impacts. This is also in agreement with the findings of Ndamani and Watanabe (2016) as well as Oyekale and Oladele (2012) that the visible tendency of households to adapt to climate change is probably due to their higher endowment of labour, the result also revealed that the likelihood of adaptation to climate change was as a result of farmers income which was also positively related to adaptation. This corroborate with the work of Ndamani and Watanabe (2016) and Gbetobuou (2009) that revealed that wealthier farmers are more likely to use adaptation practices in response to climate change than poor farmers. While very few are not willing to engage in it. This finding is in line with the work of De Jonge (2010) which showed that most farmers did not see adaptation to climate as being beneficial to them. From the result, it can be seen that majority of the farmers are willing to adopt climate change mitigation practices if externally supported and very few are not willing. Majority are willing to engage in climate change mitigation if they see its benefit and very few are not willing. Similar to this present study, farmers have been found to adopt climate change practices even with the reported low climate science literacy in Nigeria (Ogunyele and Yekini, 2012) and Zambia (Nyanga *et al*. 2011.)

5. CONCLUSIONS

This research work has investigated the effects of land use types on soil carbon, pools, loss and emission in Sudan savanna. Highest carbon pool index and lowest equivalent Co_2 emission were recorded in plantation under cashew. Cashew plantation recorded the lowest mass of carbon loss. All the aforementioned demographic variables have decisive influences on climate change knowledge level of the sampled farmers in the study area. The results revealed use of land clearing and deforestation leads to loss of carbon from the soil, residue burning also leads to loss of carbon into the atmosphere and also loss of nutrients from the soils. The result also showed that carbon emitted were generally higher in maize and cassava farm land and lower in cashew plantation due to continuous and vigorous cultivation of maize and cassava intercrop farm land which result to loss of carbon. Tree and leaves litter from cashew plantation decomposed thereby leading to release of more carbon into the soil which enable more carbon to be trapped in the soil, thereby resulting to a low mass of carbon lost and carbon emitted. Maize/cassava intercrop recorded the lowest carbon pool in all the various land use types compared to cashew plantation which may be due to inadequate application of manure, plant residues or burning of plant residues and the use of tillage practices.

Recommendations

Therefore, reducing intensive cultivation, avoiding deforestation, bush burning, increased fallow period and multipurpose agroforestry trees should be more practiced in the study area.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

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