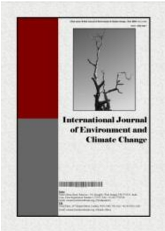

International Journal of Environment and Climate Change

12(11): 629-641, 2022; Article no.IJECC.88439
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Comparative Assessment of Soil Carbon Sequestration and Carbon Dioxide Emissions from Agroforestry Systems in Kogi East Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2022/v12i1131015

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/88439

Original Research Article

Received 04 May 2022
Accepted 08 July 2022
Published 22 July 2022

ABSTRACT

This study was conducted to assess the below ground carbon sequestration (soil carbon stock per unit land area) and carbon dioxide (CO_2) emissions from agroforestry systems (AFSs) in Kogi East (Ankpa, Dekina, Ofu, Olamaboro, and Omala local government areas) Nigeria. Stratified random sampling was used to select study locations of the agroforestry systems in Kogi East, Nigeria. Four AFSs were selected in each local government area (LGA) - this consisted majorly of smallholder farmer's farm with silvoarable systems in the region (4 communities per LGA, total of 20 communities). The selection criteria for AFS was based on farm size not less than 1 hectare. The results from the analysis revealed that highest soil carbon stock [C stock (Mg Cha-1)] was recorded from AFSs in Dekina (334.43 Mg Cha-1) while no significant difference in carbon stock was observed from the soils of AFSs in Ankpa, Ofu, Olamaboro, and Omala LGAs (69.01, 159.21, 142.58, 117.33 Mg Cha-1 respectively). Nonetheless, the soils from AFSs in Dekina LGA had highest CO_2 emissions followed by Ofu LGA (186.23 and 159.40 gCO_2 emitted/50g wet soil slice respectively) while the lowest CO_2 emissions (104.15 and 88.88 gCO_2 emitted/50g wet soil slice) were recorded from Ankpa and Omala LGAs respectively. The highest carbon sequestration recorded from soils of AFSs in Dekina LGA may depend on the soil C input and soil stabilization processes including tree species and density and again highest CO_2 emissions from the same Dekina LGA can be attributed to the coarse texture of the soils as coarse soils are considerably

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more susceptible to releasing their carbon. On the other hand, the absence of variation in CO_2 emission levels in some of the locations studied can be attributed to similar land management practices like tillage, bush burning and soil fertility management.

Keywords: Agroforestry; climate change; soil carbon sequestration; soil management.

1. INTRODUCTION

Carbon (C) sequestration can be described as the process of capturing atmospheric C and safely storing it in long-lived pools [1,2]. Globally, carbon sequestration in terrestrial vegetation systems is recognised to have potential to mitigate the increasing levels of CO_2 in the atmosphere [3,4,5]. On the other hand, agroforestry can be referred to as combination of agriculture (crops and/or livestock) and forestry (trees and shrubs) on the same land management unit [6,7]. Carbon sequestration in agroforestry involves the process of taking up atmospheric CO_2 during photosynthesis and the transfer of fixed C into vegetation, detritus, and soil pools for long-term storage [8]. Agroforestry can prevent the deliberate harmful circle of deforestation, soil erosion and other environmental problems in Nigeria [9,10].

Carbon sequestration in agroforestry systems can be categorised into: 1) aboveground segment of trees and herbaceous parts like leaves, stems, etc. and 2) belowground segment comprising of the roots, c stored in different soil horizons, and soil organisms [11]. Under the same ecological conditions, the above and below ground C sequestration of agroforestry systems (woody perennial-based land use systems) are higher than monocultures of crops or pasture due to the ability of trees to absorb atmospheric carbon to store in their tissues and soils for a longer period of time [12,13,14,15]. Soil organic matter and nutrient stocks in agroforestry systems are improved by the abundant and frequent addition of leaf litter and/or prunings including root biomass over a period of time which is vital for soil carbon dynamics [16,17].

Agroforestry as a practice can create an integrated and sustainable land use systems [18,19]. It can increase the productivity of land while applying management practices that are environmentally and socially acceptable [14,20]. The environmental benefits of AFS include:

1) Soil quality improvement*:* Agroforestry systems have improved nutrient cycling through leaf litter production and decomposition as well as deep nutrient capture by their root systems (the roots of the trees in agroforestry system are deep and strong accessing nutrients deeper in soil profile that are most times not available for monocultures) [17], they enhance soil organic carbon and greater soil microbial dynamics compared to monocultures [21,22].

2) Climate change adaptation and mitigation: for example soil carbon sequestration. Intergovernmental Panel on Climate Change (IPCC) [23] posited that assuming a global implementation of agroforestry systems, about 1.1 to 2.2 Pg of carbon can be captured from the atmosphere globally over 50 years. This is reported to have a compensating effect on greenhouse gas (GHG) emissions (10 – 15 % reduction in CO_2 emissions annually) in terms of climate change adaptation and mitigation strategies [16]. Furthermore, it is projected that a C sequestration of 0.586 Tg C per year can be achieved by 2040 by converting 630 million ha of unproductive croplands and grasslands to agroforestry [23].

3) Water quality management: agroforestry can reduce water contamination and eutrophication by reduction in the use of inputs such as fertilizers (nitrate and phosphate fertilizers), herbicides and fertilizers [14]. Trees in agroforestry systems act as dispersion barriers to pest reducing the use of pesticides and herbicides. Also, the deep and strong rooting zones of trees in agroforestry systems uptake surplus nutrients that would otherwise contaminate rivers. Furthermore, water quality can be protected by riparian buffer strips (strips of perennial vegetation-tree/shrub/grass) either natural or planted between croplands/pastures and water sources like streams, lakes, wetlands, and ponds to reduce non-point source pollution from agricultural lands [18,24,25]. The riparian buffer strips will help decrease sediment and nutrient load from soil erosion, and also filter surface water and groundwater runoff [26,27]; and

4) Conservation of biodiversity: AFS provides habitat for biodiversity to live and breed [13,28-30]. The combination of mulching and shading effects created by trees in an agroforestry system helps to improve the microclimatic conditions (temperature, water vapour content of air and wind speed) which lowers soil surface temperature as well as reduced rates of evaporation of soil moisture. This modified microclimatic conditions have beneficial roles on the system such as enhancing biodiversity and animal well-being, improved soil quality, pest and disease control [31,32].

In terms of socioeconomic benefits, agroforestry systems are source of nutrition as well as additional income for farmers engaged in it. The farmers are gainfully employed with reduced level of poverty and improved standard of living [33]. The diversification of farm outputs in an agroforestry system is helpful in the reduction of risks from total crop failure compared to monoculture system in periods of extreme weather events including floods and droughts [29]. In addition to production of food crops, agroforestry systems provide different products such as fuel wood, timber, fruits, nuts, fibre, fodder and forage, gums and resins, hatching and hedging materials, gardening materials, craft products, medicinal products, and shade for animals and farm workers including recreation. Socioeconomic development (diversification of rural economies, skills, and products) can be sustained by the sales these timber and non-timber products by the farmers [7,28]. The aim of this study was to assess soil carbon sink of agroforestry systems in Kogi East Nigeria. This can provide insights on the possible contribution of AFS as an adaptation measure to climate change impacts in Kogi East, Nigeria.

2. METHODOLOGY

2.1 Study Location

Four agroforestry systems were selected from five local government areas (Ankpa, Dekina, Ofu, Olamaboro, and Omala) within Kogi East, Nigeria. This consisted majorly of smallholder farmer's farm with silvoarable systems in the region (4 communities per LGA, total of 20 communities) (Table 1). The communities within Ankpa LGA were Odagbo, Oje Elanyi, Ojogobi Olaji, and Okaba. Dekina LGA communities were Anyigba, Dekina, Egume, and Odu Ogbaloto. Ofu LGA communities were Ogbulu, Ugwolawo, Ejule, and Ochadamu. Olamaboro LGA communities were Ejoka, Igoti Ade, Unobe, and Ubalu while Omala LGA were Ajedibo, Ajomakoji, Odumukpo, and Okugba.

2.2 Sample Size and Sampling Techniques

Stratified sampling was used to select study locations that gave a good representation of the AFSs in Kogi East Nigeria. The selection of agroforests was based on farm size not less than 1 hectare. In each Local Government Area (LGA), four (4) AFSs were selected from four communities (1 AFS per community, total of 20 agroforestry systems from 5 LGAs) were selected for the study.

2.3 Soil Sampling and Analysis

Random soil sampling technique was used to collect surface soil samples at 0-15 cm depth from each of the AFS in the selected farms in study locations. A total of 400 samples (20 samples per community, 80 per LGA) were collected and bulked to 200 composite samples (10 samples per community, 40 per LGA) for soil carbon stock and carbon dioxide emissions. The soils were prepared (air-dried, crushed and passed through a 2mm sieve and material larger than 2mm were discarded). Soil samples for carbon dioxide analysis were taken at 0 - 15 cm depth using a tube soil auger and transferred into zip lock bags on the field so as to preserve samples from contamination and drying.

2.4 Determination of Soil Carbon Stock per Unit Land Area

Nair et al. [11] reported that analysis of C content in the soil (mass per unit mass of soil, for example g C per 100 g soil) is the most common method for calculating the amount of C sequestered in soils. Soil Organic Carbon (SOC) Stocks at fixed depth (0-15 cm) was determined using the formula from Carter and Gregorich [36]:

$$\mathrm{SOC_{FD}} = \sum_{1}^{n} D_{cs} C_{cs} L_{cs} \times 0.1$$

where SOCFD is the SOC stock to a fixed depth (Mg Cha^{-1} to the specified depth), D_{cs} is the density of core segment (g cm^{-3}), C_{cs} is the organic C concentration of core segment (mg C g^{-1} dry soil), L_{cs} is the length of core segment (cm), and 0.1 is the conversion factor to Mg Cha^{-1}. Soil organic carbon concentration was determined using the Walkley-Black wet oxidation method. The method involved the oxidation of organic carbon (OC) with dichromate and sulphuric acid (H_2SO_4); the residual dichromate was titrated against ferrous sulphate [37].

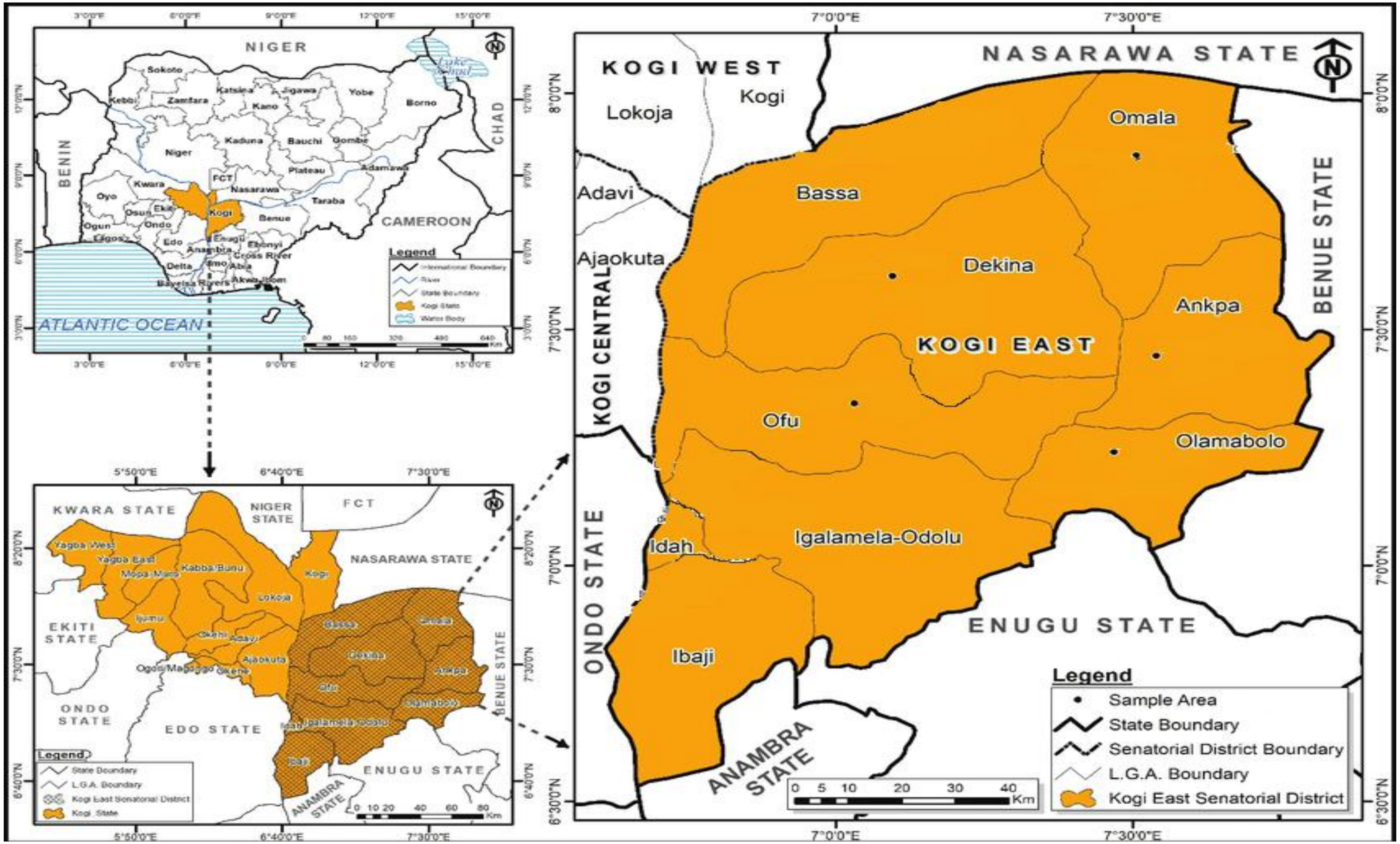

Fig. 1. Map of Study Area - Kogi East, Nigeria (Source: Map Gallery, Geography Department, ABU Zaria [35]

Table 1. Description of Study Locations (Field Survey, 2021)

Local Government Area	Location of Agroforestry System	Vegetation/Cultivated Crops (Agroforestry System)	Coordinate		Topography	Soil Textural Class Amhakhian et al. [34]
			Latitude	Longitude		
Ankpa	Odagbo	***Trees:*** Oil Palm (*Elaeis guineensis*), Cashew (*Anacardium occidentale*), Teak tree (*Tectona grandis),* and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*) and Maize (*Zea mays)*.	7^{0}47’05”N	7^{0}73’55”E	Undulating	Textural class = Sand (88.02, 39.60, and 8.02 % of sand, silt, and clay respectively)
	Oje Elanyi	***Trees:*** Oil Palm (*Elaeis guineensis*), Cashew (*Anacardium occidentale*), Mango (*Mangifera indica*), Mahogany (*Swietenia*), Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.), and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Egusi/Melon (*Cucumeropsis mannii*), and Groundnut (*Arachis hypogaea*).	7^{0}36’25”N	7^{0}62’37”E	Nearly flat	
	Ojogobi Olaji	***Trees:*** Oil Palm (*Elaeis guineensis*), and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Egusi/Melon (*Cucumeropsis mannii*), and Groundnut (*Arachis hypogaea*).	7^{0}18’63”N	7^{0}57’54”E	Nearly flat	
	Okaba	***Trees:*** Oil Palm (*Elaeis guineensis*), Kolanut tree (*cola nitida),* Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.), Teak tree (*Tectona grandis),* and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*), and Maize (*Zea mays)*.	7^{0}46’94”N	7^{0}73’92”E	Gentle undulating	
Dekina	Ayingba	***Trees:*** African Locust Bean (*Parkia biglobosa*), Oil Palm (*Elaeis guineensis*), Teak tree (*Tectona grandis)* ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Egusi/Melon (*Cucumeropsis mannii*), Yam (*Dioscorea spp*).	7^{0}29’10”N	7^{0}11’32”E	Nearly flat	Textural class = Loamy Sand (76..02, 3.18, and 20.8 % of sand, silt, and clay respectively)
	Dekina	***Trees:*** Cashew (*Anacardium occidentale*), Mango (*Mangifera indica*), African Locust Bean (*Parkia biglobosa*), and Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.) ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Soybean (*Glycine max*)	7^{0}41’13”N	7^{0}12’10”E	Lower slope	

Local	Location of	Vegetation/Cultivated Crops (Agroforestry System)	Coordinate		Topography	Soil Textural
	Egume	***Trees:*** Cashew (*Anacardium occidentale*), Plantain (*Musa x paradisiaca*), African Locust Bean (*Parkia biglobosa*), and Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.) ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Egusi/Melon (*Cucumeropsis mannii*)	7^{0}28’45”N	7^{0}12’10”E	Undulating	
	Odu Ogbaloto	***Trees:*** Oil Palm (*Elaeis guineensis*), ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Yam (*Dioscorea spp*).	7^{0}29’28”N	7^{0}10’15”E	Undulating	
Ofu	Ogbulu	***Trees:*** Cashew (*Anacardium occidentale*), Oil Palm (*Elaeis guineensis*), African Locust Bean (*Parkia biglobosa*), Mango (*Mangifera indica*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Cowpea (*Vigna unguiculata)*, Egusi/Melon (*Cucumeropsis mannii*).	7^{0}23’22”N	7^{0}3’20”E	Nearly flat	Textural class = Sandy Clay (59.52, 4.28, and 36.20 % of sand, silt, and clay respectively)
	Ugwolawo	***Trees:*** Teak tree (*Tectona grandis),* Oil Palm (*Elaeis guineensis*), Cashew (*Anacardium occidentale*), Mango (*Mangifera indica*), ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Groundnut (*Arachis hypogaea*), Okra *(Abelmoschus esculentus),* Egusi/Melon (*Cucumeropsis mannii*).	7^{0}23’22”N	7^{0}3’20”E	Nearly flat	
	Ejule	***Trees:*** Teak tree (*Tectona grandis),* Oil Palm (*Elaeis guineensis*), Cashew (*Anacardium occidentale*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Okra *(Abelmoschus esculentus),* Cowpea (*Vigna unguiculata)*.	7^{0}23’22”N	7^{0}3’20”E	Flat	
	Ochadamu	***Trees:*** Neem tree (*Azadirachta indica*), and Oil Palm (*Elaeis guineensis*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Egusi/Melon (*Cucumeropsis mannii*).	7^{0}23’37”N	7^{0}2’7”E	Undulating	
Olamaboro	Ejoka	***Trees:*** Oil Palm (*Elaeis guineensis*), Cashew (*Anacardium occidentale*), Mahogany (*Swietenia*), Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.), and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*) and Maize (*Zea mays)*.	7^{0}31’68”N	7^{0}62’67”E	Nearly flat	Textural class = Sandy Clay (59.52, 4.28, and 36.20 % of sand, silt, and clay respectively)

Local	Location of	Vegetation/Cultivated Crops (Agroforestry System)	Coordinate		Topography	Soil Textural
	Igoti Ade	***Trees:*** Oil Palm (*Elaeis guineensis*), Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.), Plantain (*Musa x paradisiaca*), Wild mango/Ogbono (*Irvingia gabonensis*), and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*), Yam (*Dioscorea spp*), and Maize (*Zea mays)*.	$7^0$24’05”N	$7^0$59’10”E	Nearly flat	Textural class = Sandy Clay (60.52, 4.28, and 35.20 % of sand, silt, and clay respectively)
	Unobe	***Trees:*** Cashew (*Anacardium occidentale*), Teak tree (*Tectona grandis),* Oil Palm (*Elaeis guineensis*), Plantain (*Musa x paradisiaca*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Okra *(Abelmoschus esculentus).*	$7^0$23’22”N	$7^0$3’20”E	Nearly flat	
	Ubalu	***Trees:*** Cashew (*Anacardium occidentale*), Oil Palm (*Elaeis guineensis*), Plantain (*Musa x paradisiaca*), and Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.) ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Yam (*Dioscorea spp*), Pigeon pea (*Cajanus cajan*).	$7^0$23’22”N	$7^0$3’20”E	Undulating	
Omala	Ajedibo	***Trees:*** Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.) and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, guinea corn (*Sorghum bicolor*), and Pigeon pea (*Cajanus cajan*).	$7^0$74’58”N	$7^0$61’04”E	Undulating	Textural class = Sandy Loam (64.12, 22.66, and 13.22 % of sand, silt, and clay respectively)
	Ajomakoji	***Trees:*** Oil Palm (*Elaeis guineensis*), Cashew (*Anacardium occidentale*), Mango (*Mangifera indica*), Mahogany (*Swietenia*), Teak tree (*Tectona grandis),* Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.), and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*) and Maize (*Zea mays)*.	$7^0$91’12”N	$7^0$51’62”E	Nearly flat	
	Odumukpo	***Trees:*** Teak tree (*Tectona grandis)* and African Locust Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays),* and Yam (*Dioscorea spp*),.	$7^0$54’35”N	$7^0$30’89”E	Nearly flat	
	Okugba	***Trees:*** Oil Palm (*Elaeis guineensis*), Mahogany (*Swietenia*), Iron Tree/Prosopis africana (Guill., Perrott, and Rich.) (Taub.), Plantain (*Musa x paradisiaca*), and African Locust	$7^0$43’82”N	$7^0$36’99”E	Undulating	

Local	Location of	Vegetation/Cultivated Crops (Agroforestry System)	Coordinate	Topography	Soil Textural
		Bean (*Parkia biglobosa*). ***Crops:*** Cassava (*Manihot esculenta*), Maize (*Zea mays)*, Egusi/Melon (*Cucumeropsis mannii*), and Pigeon pea (*Cajanus cajan*).			

2.5 Determination of Carbon Dioxide Emissions

The methods described by Herath et al. [38] for determination of carbon dioxide was used in this study. The reagents and equipment used include: 0.5 M sodium hydroxide (NaOH), 0.2 M hydrochloric (HCl) acid, 0.4 M Barium chloride ($BaCl_2$), Phenolphthalein indicator, 125 ml conical flasks, Burettes and Respiration flasks (1 litre air tight sealable Agee jars). In the laboratory, 50 g each of soil sample were placed in pre-weighed Agee jars. The weight of each soil sample and Agee jar was weighed so as to obtain the wet weight of the soil slice. 10 ml of 0.5M of sodium hydroxide (NaOH) solution was dispensed into 125 ml conical flask and placed inside each of the Agee jar containing the soil samples. A control made up of three blank Agee jars containing 125 ml conical flask of NaOH with no soil was set up. The lids of all the jars where screwed tightly and kept to incubate for fourteen days. The Agee jars where ventilated every three days for two minutes. On the fourteenth day, the conical flasks were removed and the amount of CO_2 produced were analysed by volumetric titration. 4 ml of 0.5M NaOH trapping solution from the control jar was pipetted into a 50 ml conical flask and 10ml of 0.4M barium chloride was added to the content of the flask followed by 4 drops of phenolphthalein indicator which now gives the content of the flak a yellow coloration. This was titrated with 0.2M hydrochloric acid solution until a colourless solution was obtained (end point). The volume of HCL acid used in the titration process was read from the burette and noted. This procedure was repeated for the other two blanks and for the trapping solution used in the other jars.

The carbon dioxide emitted per gram of wet soil slice (gCO_2 emitted/g wet soil slice) was computed as=

$$\frac{\text{moles of NaOH reacted with } CO_2}{2} \times 44g$$

2.6 Statistical Analysis

All measured variables were subjected to descriptive statistics (mean and standard deviation). Analysis of variance (ANOVA) was carried out on measured variables using GENSTAT Discovery Software while treatment means were separated using Duncan Multiple Range Test (DMRT) at ≤ 5 % probability level. GENSTAT® is a flexible general data analysis software applicable to all fields of research from VSNi. GENSTAT can be used to analyse experiments, ranging from one-way analysis of variance to complex designs with several sources of error variation, using a balanced-ANOVA or a REML approach (including the modelling of correlation structures) - see https://vsni.co.uk/software/genstat.

3. RESULTS AND DISCUSSION

3.1 Carbon Stock of Soils from Agroforestry Systems in Kogi East, Nigeria

The highest carbon stock was recorded from the soils from agroforestry systems in Dekina (334.43 Mg Cha^{-1}) while no significant difference in carbon stock was observed from the soils of AFS in Ankpa, Ofu, Olamaboro, and Omala LGAs (69.01, 159.21, 142.58, 117.33 Mg Cha^{-1} respectively) (Table 2). On the other hand, the maximum and minimum values of carbon stock in the study locations were 531.00 and 56.92 Mg Cha^{-1} respectively. Soil texture play significant role in soil carbon storage as it influences soil properties such as soil water and nutrient-holding capacity of soils [39,40]. Generally, fine-textured soils have been reported to have higher soil carbon stocks than coarse-textured soils [41-43]. Recent findings from Amhakhian et al. [34] of the study locations indicated that the soils of Dekina AFSs are loamy sand, Ankpa and Omala are sand and sandy loam respectively while Ofu and Olamaboro are sandy clay. Conversely, the results from this study indicated that the coarse textured soils (loamy sand) of agroforestry systems in Dekina LGA had higher carbon stock compared to sandy clay soils of Ofu and Olamaboro LGAs. Jami Al-Ahmadi et al. [43] reported negative relationship between soil carbon stocks and sand percentage while positive relationships were observed between soil carbon stocks with clay and silt percentages. Similarly, Zhang et al. [42] reported positive correlation of soil organic carbon concentration with the silt and clay content. Nonetheless, high soil organic carbon sequestration in Dekina LGA may depend on the soil C input and soil stabilization processes including tree species and density (broadleaves are higher sequesters compared to coniferous and deciduous trees). Plant root and rhizosphere inputs, in particular, make a large contribution to SOC [44]. Nair et al. [45] and Nair [11] posited that factors that can influence the total amount of carbon sequestered

Table 2. Carbon stock of soils from agroforestry systems in Kogi East, Nigeria

Local Government Area	C stock per hectare (Mg Cha-1)	Statistics		
		Max	**Min**	**SEM**
		531.00	56.92	24.98
Ankpa	69.01b			
Dekina	334.43a			
Ofu	159.21b			
Olamaboro	142.58b			
Omala	117.33b			

Note: Means in a column with different letters are statistically significant at probability level of 5 % (p = 0.05), Max= Maximum, Min = Minimum, Mg Cha-1 = Mega gram carbon per hectare

Table 3. Carbon dioxide emissions of Soils from Agroforestry Systems in Kogi East, Nigeria

Local Government Area	Carbon dioxide Emissions (gCO_2 emitted/50g wet soil slice)	Statistics		
		Max	**Min**	**SEM**
		195.80	84.04	9.62
Ankpa	104.15cd			
Dekina	186.23a			
Ofu	159.40b			
Olamaboro	138.51bc			
Omala	88.88d			

Note: Means in a column with different letters are statistically significant at probability level of 5 % (p = 0.05), Max= Maximum, Min = Minimum, CO_2 = Carbon dioxide, and gCO_2 = grams of carbon dioxide

include previous land use, tree species and density (broadleaves are higher sequesters compared to coniferous and deciduous trees), the type of agroforestry system (nature of components), age of perennials like trees (mature stands of trees have the capacity to storage more carbon compared to young stands), ecological region.

3.2 Carbon dioxide emissions of Soils from Agroforestry Systems in Kogi East, Nigeria

The soils from agroforestry systems in Dekina LGA had highest carbon dioxide emissions (186.23 emitted/50g wet soil slice) followed by and Ofu and Olamaboro LGAs (159.40 and 138.51 gCO_2 emitted/50g wet soil slice respectively) (Table 3). The lowest CO_2 (104.15 and 88.88 gCO_2 emitted/50g wet soil slice) were recorded from the soils of Ankpa and Omala LGAs respectively. Furthermore, the maximum and minimum values of carbon dioxide emissions in the study locations were 195.80 and 84.04 gCO_2 emitted/50g wet soil slice respectively. Highest carbon dioxide emissions from soils of AFSs in Dekina LGA can be attributed to its coarse texture. Coarse soils are considerably more susceptible to releasing their carbon. The absence of variation in CO_2 emission levels in some of the locations studied can be attributed to similar land management practices like tillage, bush burning and soil fertility management. This could contribute to increase or decrease in carbon emissions as well as soil organic carbon [46].

4. SUMMARY AND CONCLUSIONS

This study was conducted to assess the below ground carbon sequestration- C stock per unit land area (Mg Cha-1) and carbon dioxide emissions (gCO_2 emitted/50g wet soil slice) of agroforestry systems in Kogi East (Ankpa, Dekina, Ofu, Olamaboro, and Omala) Nigeria. Stratified random sampling was used to select study locations that gave a good representation of the AFS in the Kogi East Nigeria. The results from the analysis revealed that highest carbon stock was recorded from the soils of AFSs in Dekina while no significant difference in carbon stock was observed from the soils of AFSs in Ankpa, Ofu, Olamaboro, and Omala LGAs. The highest carbon sequestration recorded from soils of AFSs in Dekina LGA may depend on the soil C input and soil stabilization processes including tree species and density.

Furthermore, the results indicated that the soils from AFSs in Dekina had highest CO_2 emissions followed by Ofu LGA while the lowest CO_2

emissions were recorded from Ankpa and Omala LGAs. Highest carbon dioxide emissions from soils of AFSs in Dekina LGA can be attributed to its coarse texture. Coarse soils are considerably more susceptible to releasing their carbon. The absence of variation in CO_2 emission levels in some of the locations studied can be attributed to similar land management practices like tillage, bush burning and soil fertility management. This could contribute to increase or decrease in carbon emissions as well as soil organic carbon.

ACKNOWLEDGEMENTS

This work was funded by grant under Tertiary Education Trust Fund (TETFund) institutional based research (2014-2015 merged intervention), Kogi State University Anyigba, Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/88439