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Effect of Intensive Vegetable Cultivation on Soil Organic Carbon Storage in Akwa Ibom State, Southeastern Nigeria

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Authors' contributions

This research work was carried out with the collaboration between authors EAA and PIO. Author EAA designed the study, carried out the field work, analyzed the data and wrote the manuscript. Author PIO provided valuable suggestions for the study design, supervised the data analysis, interpreted the results and reviewed the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

An empirical study was carried out to assess the effect of intensive vegetable cultivation on the amount of soil carbon stored in Abak, Onna, Uyo and Ikot Ekpene area of Akwa Ibom State, Southeastern Nigerian. The objectives of the study were to; assess the types of farming practices in the study area, characterize the physical and chemical properties of soils, quantify the amount and types of organic carbon stored as well as assessing the functional pool of soil organic carbon. Random and systematic sampling techniques were used for the collection of soil samples. Data was analyzed using descriptive and inferential statistics. The results showed that the average amount of soil carbon sequestered was similar among the study locations, ranging from 497.4 to $Mgha^{-1}$ in Abak to 576.7 $Mgha^{-1}$ in Uyo. The average amount of carbon stored in the uncultivated soil range from 417.3 $Mgha^{-1}$ in Uyo to 799.0 $Mgha^{-1}$ in Abak. On the average, the amount of carbon stored in the uncultivated soil was 575.6 $Mgha^{-1}$ greater than 535.2 $Mgha^{-1}$ in the cultivated area by about 7%. The results also showed that potential mineralized carbon (PMC) was also similar among the locations, ranging from 4.20 $MgC0_2$- C ha^{-1} in Uyo to 5.04 $MgC0_2$- C ha^{-1} in Ikot Ekpene cultivated area. In the uncultivated area, PMC range from 3.01 $MgC0_2$- C ha^{-1} in Onna to 5.24 $MgC0_2$- C ha^{-1} in Ikot Ekpene. Soil carbon storage can be improved by the application of organic manures and use of planted fallows in the cultivated areas.

Keywords: Vegetables; cultivation; intensive; farming practices; organic carbon; soil; climate change.

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1. INTRODUCTION

The role of agriculture in the economic development of a country cannot be overemphasized. It provides food, raw materials for industries as well as employment to a large proportion of the population. The world population involved in agriculture ranges from 2 per cent in the US to about 80 per cent in some parts of Africa and Asia [1]. The Word Bank [2] stated that the agricultural sector is the backbone of the economies of most developing countries. In most developing countries such as Nigeria and Cameroun, agriculture is dominated by smallholder farmers who operate on a subsistence basis often with low yield [3,4]. Since evolution of land husbandry, man has primarily been involved in the growing of crops and rearing of animals for the production of food. This is also known as farming. Wehmeir and Asby [5] define farming as the business of managing or working on a farm. It is an indisputable fact that the life supporting system on earth is food, which may come as raw, semi-finished or finished farm products.

Asthana and Asthana [6] also reported that technological advancement has come with modern intensive cultivation practices and increases in agricultural production but that are detrimental to the soil and the biotic community, and the traditional genetic resource base of cultivated plants. For instance, soils contain carbon (C) in the form of organic matter, or humus. Soil organic matter is derived from live plant roots, dead plant materials at various levels of decomposition, soil microbes, soil fauna, while soil organic carbon is derived from soil organic matter or in the form of inorganic carbonate [7].

Organic matter consist of different components and varies in proportions and are of many intermediate stages. These are active organic fractions including microorganisms and resistant or stable matter referred to as humus. Tate [8] and Theng [9] described organic matter in its form and classification. They are aboveground and belowground fractions. The aboveground organic matter comprises plant and animal residues while the belowground organic matter consists of living soil fauna and micro flora, particularly decomposed animal and plant residues as well as humic materials.

The total amount of organic matter in the soil is influenced by soil properties and by quantity of annual inputs of animal and plant residue in the soil ecological system. Upon decomposition, organic matter releases nutrient to plant and in order to maintain the nutrient cycle, the rate of organic matter addition must be equal to the rate of decomposition. Where the rate of addition is higher than the rate of decomposition, organic matter increases and vice versa.

Soil organic matter is commonly the largest fraction of soil organic biomass, and it is often subdivided into other fractions based on biological, chemical or physical properties. Soil carbon is also an important component of the overall global carbon cycle [10]. Soil can either be a source or sink for atmospheric carbon (iv) oxide depending on the land use and management of soil and vegetation [11]. The nature and quantity of soil organic carbon affect many of the physical, chemical and biological properties of the soil. Example, water infiltration, water retention, aeration, bulk density and resistance to erosion are influenced by soil organic carbon [12,13].

According to Morrison et al. [14], the amount of carbon in the soil could be a significant fraction of the overall carbon content in a forested ecosystem. They further reported that the amount of soil carbon accumulated in the forest floor and underlying mineral soil can vary significantly from one forest type to another within a locality and between regions. Organic carbon contributes to the soil's capacity to supply nutrients, buffer the movement of nutrients, pesticides and herbicides, improves the soil's water holding capacity and increases soil aggregation [15]. It also improves water quality, reduces soil erosion and sedimentation, and improves wildlife habitat.

Carbon constitutes approximately 50% of soil organic matter (SOM). It serves as both a structural and a functional material in soil. Both the soil inorganic carbon (SIC) and soil organic carbon (SOC) play a role in many geochemical and biochemical processes [15]. The soil organic carbon (SOC) pool constitutes one of the five (5) principal global carbon pools others being oceanic, geologic, atmospheric and biotic [16]. Soils of the tropics, constituting a major part of the soil C pool, have contributed considerably to the anthropogenic increase in atmospheric CO_2 pool. Lal [17,18,19] reported that the rate of depletion of SOC in soils of the tropics is exacerbated by the onset of soil degradative processes including decline in soil structure, leading to crusting/compaction and accelerated runoff and erosion, reduction in soil biotic activity, leaching of bases and depletion of soil fertility.

Dissolved carbon (iv) oxide and soluble carbonates in ground or surface water can move into the ocean where they may precipitate as solid carbonates, making the ocean bottom the largest sink of inorganic carbon. Biochemical oxidation of SOC can lead to emission of carbon (iv) oxide (CO_2) into the atmosphere making soil a source of atmospheric carbon. On the other hand, the humification process leads to sequestration of soil organic carbon.

Emission of carbon (iv) oxide (CO_2) from oxidation of soil organic matter is the largest source of CO_2 in the atmosphere [20].

Interest in SOC has greatly increased in recent years because of the role it plays in understanding the effect of carbon emission on global climate change. Anthropogenic activities have caused large losses of C from the soil and from aboveground biomass. In many cases, these activities especially those involving poor planning, development of marginal lands, and use of tillage methods that sacrifices SOC and SIC have caused land degradation and the failure of the overall system. Agriculture and forestry have been part of the problem. In fact, Lal et al. [10] stated that agricultural and forestry activities were the major contributors to the increase of atmospheric CO_2. It is now recognized and known that agricultural and forestry practices are becoming part of the solution. Agricultural practices cannot by themselves solve the greenhouse gas flux problem, but adoption of Best Management Practices (BMPs) and other agricultural strategies can decrease the overall flux and can stash a significant part of the currently emitted C into the soil.

In Nigeria, farming was the mainstay economic activity before the oil boom. Subsistence agriculture with the associated bush fallow was the rule. It conserves the soil, improving soil quality and with minimal impact on the environment. However, the geometric increase in population with attendant pressure on agricultural lands for food production, industrialization and urbanization necessitated intensive continuous agriculture with negative effects on soil and environmental quality. Senjobi and Ogunkunle [21] noted that the intensification of cultivation exposes the topsoil to the element of degradation and alter the natural ecological balance. There is therefore, a growing concern about the sustainability of soil as a resource. Intensive agriculture has slowly been consuming the very resource base that sustains the human society, by causing soil and environmental degradation through loss of soil physical, chemical and biological quality.

Anthropogenic and natural release and sequestration of carbon has taken an increased significance in recent years due to its potential impact on global climate. According to Rosenberg et al. [22] soil (pedosphere) is considered an active and significant component in global carbon emission and sequestration potential In fact, soil carbon sequestration is considered a bridge to the future in controlling increased levels of atmospheric CO_2. Therefore, the impact of intensive vegetable cultivation on the organic carbon sequestration potential of soils in Akwa Ibom State is of great importance to the overall carbon status.

Consequently, this study is aimed at examining the effect of intensive vegetable cultivation on soil organic storage with the following objectives

i. To assess the types of farming practices in the study area,
ii. To characterize the physical and chemical properties of cultivated and uncultivated soils to vegetable crops,
iii. To quantify the amount and type of organic carbon stored, and
iv. To assess the functional pool of soil organic carbon in both cultivated and uncultivated areas.

The following hypotheses were considered

1. **H_0:** There is no significant relationship between intensive vegetable cultivation and soil organic carbon sequestration.
2. **H_0:** There is no significant relationship between the physical and chemical properties of cultivated and uncultivated soils.

1.1 Description of the Study Area

Akwa Ibom State is located between latitudes 4^{o} 32^{I} and $5^{o}\,53^{I}$ N and longitudes $7^{o}\,25^{I}$ and $8^{o}\,25^{I}$ with a landmass of 8,412 square kilometers. According to the National Population Commission [23], the population of Akwa Ibom State is 3,920,208.The study was conducted in Uyo, Abak, Ikot Ekpene and Onna areas of Akwa

Ibom State, Southeastern Nigeria. The population of Abak is 139,090; Ikot Ekpene = 143,077; Onna =123,373, and Uyo = 309,573. The choice of these locations was based on the fact that market gardening of vegetables is intensively cultivated in the areas for several years now as a profitable farming activity.

The state is located in the hot humid climate zone; the climate is marked by two distinct seasons, the dry season, which lasts from November to March, and the wet season, which lasts from April to October [24]. Mean annual rainfall is 2,200 mm in the north and 3,500 mm in the south of the state. Sunshine varies between 1,400 and 1,500 hours per year, while average temperature ranges from 23°C to 31°C, which allows for favorable cultivation and extraction of agricultural products.

Akwa Ibom State is underlain by the sedimentary geological formation, the tertiary coastal plain sands [25]. The landscape is dominated by the undulating to gently rolling topography. The soils are derived from the weak unconsolidated coastal plain sand parent material. The soils are structurally unstable, low in organic matter and fertility status, and generally susceptible to accelerated erosion.

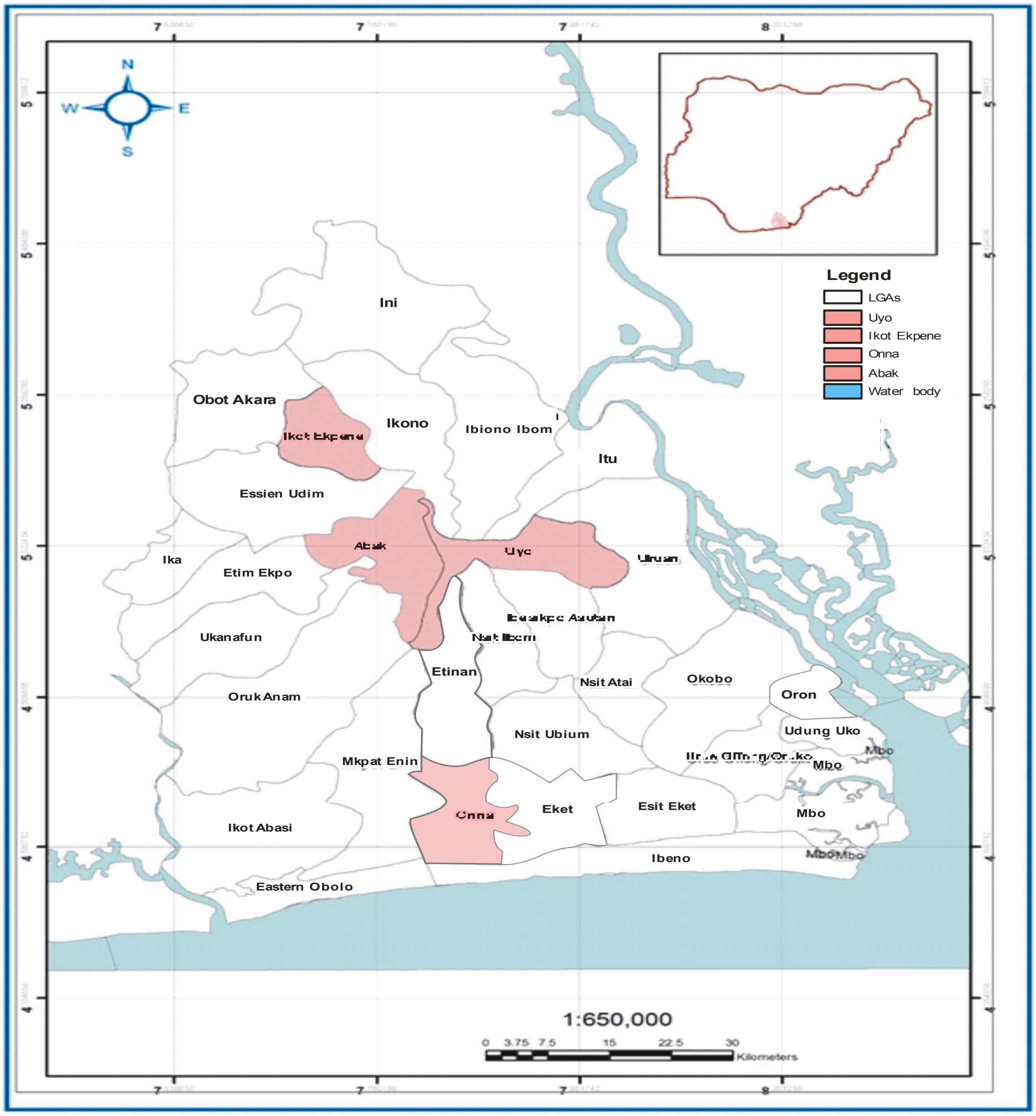

Fig. 1. Map of the study area

The state falls in the rainforest zone of Nigeria, with the native vegetation has almost been replaced by secondary forest of mainly wild oil palm trees and woody shrubs as well as various grass undergrowth [25]. The predominant land use is the cropping bush fallow system operated with primitive hand tools of hoes and machetes. Tahal [26] described this as a sedentary form of shifting cultivation. The farmers are restricted to their own farmlands. The average farm size is less than half hectare, and a farmer could have several small farms scattered over a wide area. The principal food crops grown are yams, cassava, maize and cocoyam with oil palm as the dominant tree crop.

2. RESEARCH METHODOLOGY

The study utilized the guidelines for site selection and soil survey to characterize the soils, especially to quantify types and amount of organic carbon stored in the cultivated and fallow soils. The study made use of primary data, which included qualitative information on reconnaissance survey. It also included quantitative soil data (physical, chemical and biological) from the cultivated and fallowed (control) soils. Random sampling technique was used in the uncultivated area, while systematic sampling technique was used in the cultivated area.

A soil pit was dug at each sample point, to determine the depth of the A-horizon. In each location, three transects were established in the cultivated area, along which soil core and auger samples were collected from the ends and middle of each transect and random sampling in the adjacent uncultivated (control) area, all at depth intervals of 0-10, 10-20 and 20-30 cm. In other words, both systematic (in the cultivated area) and random (in the adjacent, control area) sampling techniques were used. Three replicate samples from the same depth zone on each transect or random points in the control area constituted the bulk sample, while the soil core samples were collected with metal cylinders 5cm in height and 5cm internal diameter.

Samples were taking to make sure they represent a uniform layer. This is because the laboratory data that would be generated will only be as accurate as the sample collected. During sampling, the organic carbon pools were carefully taken into consideration. These included the litter – microorganic matter e.g. crop residues that lies on the soil surface, light fraction – plant residues and their partial decomposition product that resides within the soil. Others are microbial biomass i.e. cells of living organism notably bacteria, actinomycetes and fungi, faunal biomass (invertebrates such as earthworms) as well as the stable humus i.e. humid acids which is humified remains of plant and animal tissues that have become stabilized by microbial action.

Samples collected for biological analysis was placed in a cooler with ice packs (to prevent microbial deterioration) while those for physical and chemical analysis was collected without refrigeration. A total of 96 samples (48 bulks and 48 cores) were collected, labeled and transported for laboratory analysis. The physical and chemical analysis of the soil samples were done using standard soil survey laboratory methods [27]. Samples collected for biological analyses were analyzed for Mass Carbon (MC) and Potentially Mineralized Carbon (PMC). MC was calculated using the correction factor (k=0.33) of Sparling and West [28] while PMC were determined using the procedures outlined by Drinkwater et al. [29].

The data were subjected to multivariate analysis to simultaneously analyze correlated variables. The soil attributes were therefore grouped into statistical factors on the basis of their correlation structure using SAS Institute [30]. Factor analysis was used to describe the interrelationship among many correlated variables. This was done using principal component analysis as a method of factor extraction because it does not require prior estimates of the amount of variation in each soil attribute explained by the factors. Each sample number is a mean value of three samples. Analysis of variance (ANOVA) was used to describe the variation that exists among the locations.

3. RESULTS AND DISCUSSION

3.1 Farming Practices and Cropping History

In all the locations, the predominant farming practice is continuous cropping with waterleaf as the principal crop grown. Other major crops include fluted pumpkin and cassava. The plots were segregated into individual holdings with each family member cultivating the parcel of land on a yearly basis. Simple tools such as the hoes and machetes are commonly in use in the study areas except in Onna where tractors mechanically do land preparation and irrigations in some areas. Farmers in Onna also have an easy access to farm inputs such as fertilizers from Cross River Basin Development Authority.

3.2 Effect of Cultivation on Soil Physical Properties

3.2.1 Particle-size distribution

The results on Table 1 show that average values of coarse sand range from 50.4% in Ikot Ekpene to 65.0% in Abak, and with very low variability, the highest being 7.2% across the locations. Similar results were obtained for fine sand (FS) and total sand (TS). Comparisons with data from the adjacent uncultivated area show close values of the sand fractions.

The low variability and similarity in values of the sand fractions across the locations indicate that the soil in all locations was formed from similar lithological parent material, the coastal plain sands. Such soils are liable to erosion especially under intensive cultivation. The moderate mean values of the fine sand fraction indicate that surface sealing and slaking may be important in the soil. Average values of the silt fraction were generally low, and except in Abak and Onna, the variability was equally low. The highest mean was 8.2% at Ikot Ekpene, and lower value in Abak. Similarly, the content of the clay fraction and its variability were low. This is in disagreement with the work of Taye and Yifru [31] who recorded high variability in clay properties between cultivated and uncultivated soils. They attributed this to the variations in the degree of eluviation-illuviation processes. Generally, contents of the silt and clay fractions indicate that the soil is derived from highly weathered parent material, or due to prolonged cycles of erosion. Soil texture was therefore dominated by the sand fraction, and soil texture class was loamy sand.

Table 1. Effect of cultivation on soil physical properties

Sample no	Particle-size distribution					Bd	f	Ksat	AWC
	%CS	%FS	%TS	%Silt	%Clay	Mgm^{-3}	(m^3/m^3)	(cm/h)	(cm)
AC/1	61.95	27.44	89.39	3.94	6.67	1.43	0.46	20.83	7.75
AC/2	66.31	23.71	90.02	2.65	7.33	1.39	0.48	27.10	9.46
AC/3	66.67	21.72	25.99	4.27	7.34	1.36	0.49	26.56	7.06
$\bar{x}$	**65.00**	**24.30**	**89.30**	**3.62**	**7.11**	**1.39**	**0.48**	**24.83**	**8.09**
Sd±	2.36	2.90	0.82	0.86	0.38	0.04	0.02	3.47	1.24
CV%	4.0	12.0	0.9	23.6	5.4	2.5	3.2	14.0	15.3
AUC	**68.68**	**22.01**	**90.69**	**2.65**	**6.66**	**1.38**	**0.48**	**32.39**	**8.67**
OC/1	54.06	30.67	84.73	5.94	9.33	1.51	0.43	3.67	5.91
OC/2	58.18	29.82	88.00	3.39	8.61	1.38	0.48	7.09	6.44
OC/3	62.50	24.16	86.66	4.73	8.61	1.58	0.40	5.06	6.21
$\bar{x}$	**58.20**	**28.21**	**86.46**	**4.69**	**8.85**	**1.49**	**0.43**	**5.37**	**6.19**
Sd±	4.20	3.54	1.64	1.28	0.42	0.10	0.04	1.72	0.27
CV%	7.2	12.5	1.9	27.2	4.7	6.8	9.2	32.6	4.3
OUC	**67.39**	**19.28**	**86.67**	**5.39**	**7.94**	**1.44**	**0.46**	**4.75**	**5.43**
UC/1	64.52	21.48	86.00	6.73	7.27	1.43	0.43	1.18	5.47
UC/2	62.94	22.39	85.33	6.06	8.61	1.46	0.45	3.86	6.23
UC/3	58.07	26.60	84.87	6.73	8.60	1.38	0.48	7.93	6.05
$\bar{x}$	**61.84**	**23.49**	**85.4**	**6.51**	**8.16**	**1.42**	**0.45**	**4.32**	**4.92**
Sd±	3.36	2.73	0.57	0.39	0.77	0.04	0.03	3.40	0.40
CV%	5.4	11.6	0.7	5.9	9.4	2.8	5.6	78.6	6.7
UUC	**55.53**	**29.80**	**85.33**	**5.39**	**9.28**	**1.07**	**0.59**	**14.85**	**3.67**
IC/1	50.05	28.01	78.06	8.60	13.34	1.47	0.44	1.93	6.63
IC/2	51.52	27.81	79.33	8.00	12.67	1.61	0.39	2.09	8.23
IC/3	49.65	28.34	77.99	8.00	1.401	1.40	0.47	2.43	5.07
$\bar{x}$	**50.41**	**28.05**	**78.46**	**8.20**	**9.14**	**1.49**	**0.43**	**2.51**	**6.64**
Sd±	0.98	0.27	0.75	0.35	6.70	0.11	0.04	0.26	1.58
CV%	2.0	1.0	1.0	4.2	5.0	7.2	9.3	11.9	23.8
IUC	**52.16**	**29.50**	**81.66**	**7.00**	**11.34**	**1.27**	**0.52**	**14.41**	**5.72**

Source: Field survey, 2010

CS = Coarse Sand; FS = Fine Sand; TS = Total Sand; Bd = Bulk Density; f = Total porosity; Ksat = Hydraulic conductivity; AWC = available water capacity; AC, OC, UC and IC = Abak, Onna, Uyo and Ikot Ekpene cultivated respectively; AUC, OUC, UUC and IUC = Abak, Onna, Uyo and Ikot Ekpene uncultivated respectively

3.3 Bulk Density and Total Porosity

Mean values of bulk density range from 1.39 Mg/m^3 in Abak to 1.49 Mg/m^3 in Onna and Ikot Ekpene, and are generally moderate, with very low variability across the locations ranging between 2.5 – 7.2 per cent (Table1). Bulk density was moderately higher in cultivated soils than the uncultivated (control) indicating compaction of soil as result of external loading arising from the continuous intensive cultivation activities. This is in agreement with the work of Eludoyin and Wokocha [32] who concluded that bulk density is higher in cultivated sites than non-cultivated ones. Similarly, mean values of total porosity were moderately lower in the cultivated than uncultivated soils. The observed values reflected the values of soil bulk density which followed the normal trend of the higher the Bd, the lower the porousity (f). Also, Bd and f followed the same pattern of variability ranging from 2.5 – 7.2 per cent and 3.2 – 9.3 per cent respectively. Values in cultivated and control were similar.

3.4 Hydraulic Conductivity, Ksat

Average values of saturated hydraulic conductivity, the rate at which the soil medium conducts water, range from 2.51 cm/h in Ikot Ekpene to 24.83 cm/h in Abak, and range from low to very rapid (Table1) whether cultivated or control. The variability of Ksat also varied widely across the locations, ranging from 11.9% in Ikot Ekpene to 78.6% in Uyo. Ksat usually varies greatly and is greatly influenced by even small variations in soil physical conditions (soil texture and soil structure) and land use, and management practices (cultivation etc.).

3.5 Available Water Holding Capacity, AWC

Data of available water, water that can be stored and easily extracted by plant roots, range from 4.92 cm in Uyo to 8.09 cm in Abak (Table 1), varying from very low to moderate. Low values were also obtained in the uncultivated, control area. The range of values obtained may be due to the coarse texture of the soil and moderately high values of total porosity (pore space), which both facilitates and enhances rapid movement of water in the soil.

The implication is that intensive and more profitable crop production cannot be practiced in the area without supplementary water supply and soil surface management, involving the application of mulch (plant materials spread over the soil surface to reduce evaporation from the surface and minimize losses of soil water due to soil material drainage especially during the dry period). Supplementary water application or irrigation is practiced at Onna, but bare cultivation is the rule in all locations, as is common in the traditional food production systems in the state.

3.6 Effect of Cultivation on Soil Chemical Properties

Mean pH values range from 6.2 in Onna and Ikot Ekpene to 6.5 in Uyo. pH values in uncultivated soil were similar to the cultivated soil. The pH values were generally slightly acidic. The pH values obtained had very low variability both within and across the study locations, and reflect the “acid” sand parent material from which the soils derive. Values of electrical conductivity (EC) were generally low and indicate that the salt concentration of the soil solution is low.

The amount of carbon sequestered range from 497.4 Mgha^{-1} in Abak to 576.7 Mgha^{-1} in Uyo (Table 2). In the uncultivated soil, the amount of carbon stored was higher in Abak and Onna than in Uyo and Ikot Ekpene locations. The results show that large quantities of carbon were sequestered in all locations, but variability in the amount of carbon stored was moderately high in Abak and Onna, and low in Uyo and Ikot Ekpene. On the average, the amount of carbon sequestered in uncultivated soil was greater than in the cultivated soil. Carbon sequestration in uncultivated soil was probably enhanced by growing fallow vegetation compared to the cultivated areas where crops are grown and harvested with little or no residues left on the surface. Unsustainable farming practices such as annual slash and burn, tillage and lack of use of cover crops may also account for low carbon sequestration in the cultivated area. However, the higher amount of carbon sequestered in cultivated areas than the uncultivated ones experienced in Uyo and Ikot Ekpene may be as a result of the heavy use of animal manure and mulching as witnessed on these locations. In general, that similar and large amount of carbon were sequestered in all locations indicates that the soil was benefiting somehow from the cultivation activities, and that the soil has the capacity for carbon sequestration when properly managed and conserved through the adoption of best management practices (BMPs), such as planted fallow, agro forestry, mixed cropping and green manuring.

Table 2. Effect of cultivation on soil chemical and biological properties

Sample no	pH	EC Ds/m	MC Mgha^{-1}	PMC MgCO$_2$	Total N (%)	Av.P (mg/kg)	Exchangeable Bases				EA	ECEC	BS (%)
							Ca.	Mg	Na	K			
							cmol/Kg						
AC/1	6.4	0.034	652.1	4.22	0.070	14.21	2.657	1.147	0.047	0.080	2.027	5.99	66.4
AC/2	6.4	0.028	554.6	4.22	0.053	11.57	2.803	1.367	0.053	0.067	2.353	6.64	64.5
AC/3	6.5	0.366	285.6	3.67	0.033	13.02	2.420	1.133	0.037	0.073	1.920	5.58	65.7
x̄	**6.4**	**0.140**	**497.4**	**4.04**	**0.052**	**12.93**	**2.630**	**1.283**	**0.050**	**0.070**	**2.100**	**6.070**	**65.5**
Sd	0.06	0.19	189.8	0.32	0.02	1.32	0.19	0.13	8.08	0.00	0.23	0.53	0.96
CV%	0.9	135.6	38.20	7.9	35.6	10.2	7.3	10.8	17.7	8.9	10.7	8.8	1.5
AUC	**6.1**	**0.028**	**799.0**	**3.42**	**0.077**	**7.00**	**2.380**	**1.067**	**0.047**	**0.073**	**1.760**	**5.33**	**66.9**
OC/1	6.1	0.072	534.5	4.88	0.050	16.59	2.230	0.967	0.047	0.060	2.027	5.33	61.9
OC/2	6.3	0.057	372.6	4.91	0.037	16.41	2.533	1.133	0.033	0.070	1.493	5.26	71.5
OC/3	6.2	0.059	658.9	4.03	0.053	12.34	2.817	1.000	0.037	0.063	1.973	5.89	66.3
x	**6.2**	**0.060**	**522.0**	**4.61**	**0.05**	**11.78**	**2.53**	**1.030**	**0.04**	**0.060**	**1.830**	**5.49**	**66.6**
Sd	0.10	0.00	143.6	0.50	0.00	2.40	0.29	0.09	0.00	0.00	0.29	0.35	4.81
CV%	1.6	13.0	27.5	10.8	18.2	15.9	11.6	8.5	18.5	8.0	16.1	6.3	7.2
OUC	**5.9**	**0.025**	**651.6**	**3.01**	**0.057**	**6.42**	**2.267**	**1.233**	**0.050**	**0.083**	**1.600**	**5.23**	**69.4**
UC/1	6.4	0.065	583.4	4.33	0.063	25.5	2.353	1.200	0.037	0.073	1.813	5.48	66.5
UC/2	6.5	0.088	525.6	5.57	0.053	29.14	2.307	1.153	0.043	0.070	1.547	5.12	69.9
UC/3	6.5	0.072	621.0	2.71	0.060	28.46	2.200	1.033	0.047	0.093	2.133	5.51	61.6
x̄	**6.5**	**0.08**	**576.7**	**4.20**	**0.06**	**27.70**	**2.870**	**1.130**	**0.049**	**0.080**	**1.830**	**5.37**	**66.0**
Sd	0.06	0.01	48.1	0.99	0.00	1.94	0.08	0.09	5.03	0.01	0.29	0.22	4.17
CV%	0.9	15.7	8.3	22.4	8.7	6.9	3.4	7.6	11.9	15.9	16.0	4.0	6.3
UUC	**6.4**	**0.061**	**417.3**	**3.03**	**0.057**	**27.60**	**2.160**	**0.903**	**0.037**	**0.057**	**1.443**	**4.60**	**68.6**
IC/1	6.3	0.043	608.5	4.88	0.067	14.43	2.207	0.827	0.043	0.057	1.83	4.97	63.5
IC/2	6.1	0.025	521.6	4.47	0.047	15.80	2.307	0.953	0.040	0.060	1.760	5.12	65.6
IC/3	6.2	0.036	504.0	4.76	0.053	20.12	2.450	0.973	0.040	0.070	1.653	4.99	66.1
x̄	**6.2**	**0.030**	**544.7**	**5.04**	**0.060**	**16.78**	**2.330**	**0.920**	**0.041**	**0.060**	**1.740**	**5.03**	**65.1**
Sd	0.1	0.00	55.9	0.21	0.01	2.97	0.12	0.08	0.00	0.00	0.09	0.08	1.38
CV%	1.6	26.2	10.3	4.5	18.4	17.7	5.3	8.6	4.2	10.9	5.1	1.6	2.1
IUC	**6.1**	**0.053**	**434.6**	**5.24**	**0.053**	**8.32**	**2.540**	**1.133**	**0.050**	**0.080**	**2.027**	**5.80**	**65.1**

Source: Field Survey, 2010; EC = Electrical Conductivity; MC = Mass of Carbon; PMC = Potentially mineralizable carbon; Total N = Total nitrogen; Av.P = Available phosphorous; EA = exchangeable Acidity; ECEC = Effective Cation Exchange Capacity; BS = Base Saturation

The storage of carbon in the soil will also reduce its storage in the atmosphere and its adverse effect on climate. Ultimately, it is the soil that will be benefited in terms of the attributes that will enhance plant productivity and environmental quality, such as improvement in soil structure, soil water holding capacity, and improved biological health.

Data of potential mineralizable carbon (PMC), as a pool for soil organic carbon, show moderately high values and generally low variability in the cultivated soil, and also generally higher than in the uncultivated soil. The organic carbon in the soil of the study area was more in the mineralizable form. Thismay be related to the favorable temperature and moisture conditions, which facilitated rapid decomposition and mineralization in the area. According to FAO [33], the transformation and movement of materials within soil organic matter pools is a dynamic process influenced by climate, soil type, and vegetation and soil organisms.

The labile soil organic matter pool regulates the nutrient supplying power of the soil, particularly of nitrogen (N), whereas both the labile and stable pools affect soil physical properties, such as aggregate formation and structural stability [33]. When crops are harvested or residues burned, organic matter is removed from the system. The loss can be minimized by retaining plant roots in the soil and leaving crop residues on the surface. Organic matter can also be restored to the soil through sustainable farming practices such as green manuring, agroforestry and the addition of compost.

Available P was moderately high and moderately variable in all locations (Table 2). Mean values of available P were generally lower in the control (uncultivated) soil than in the cultivated, probably due to the use of mineral fertilizers. Already, the farmer admitted using soil amendments including chemical and mineral fertilizers. This finding agrees with the work of Edmeades et al. [34]. They reported high level of P due to fertilizer application on the soil.

Total N was moderately high and also varies in all the locations (Table 2). The mean value was lower in cultivated than the cultivated soils. This was probably due to the amount being used up by crops and consequent depletion as a result of intensive and continuous cropping systems notwithstanding the use of soil amendments of mineral fertilizers. Intercropping with nitrogen-fixing plants can be encouraged instead of mineral fertilizers.

Average values of the effective CEC were generally low in the soil (Table 2), and similar in all the locations, whether cultivated or not. The low values observed may be due to leaching losses and erosion of the nutrient elements in the soil. The implication is that more intensive and successful crops production in the areas require the use of appropriate and adequate amounts of fertilizers including organic fertilizers, not only to supply plant nutrients but also to contribute to other soil quality attributes such as physical and biological properties. Base saturation, (BS) was generally greater than 60%, indicating that the exchange sites were slightly dominated by the exchangeable bases.

3.7 Effect of Cultivation on Variability of Soil Properties

The variability of some soil parameters with location of study is shown in Table 3. Out of twenty-two parameters analyzed, ten differed significantly ($p<0.05$) with cultivation, while twelve were similar among the locations. The ten significant parameters are CS, TS, silt, clay, Ksat, AWC, pH. Av.P, ECEC and BS. CS was significantly higher in Abak, Onna and Uyo than Ikot Ekpene. The silt fraction differed among the locations being greater at Ikot Ekpene, followed by Uyo, Onna and Abak. Clay was significantly greater in Ikot Ekpene, followed by Uyo, Onna and Abak. Ksat was significantly greater in Abak and similar among Onna, Uyo and Ikot Ekpene. The trend in AWC was similar to Ksat. Although there were differences in soil pH, the soil was generally slightly acidic, that is, cultivation had little or no effect on soil reaction, in terms of soil acid status.

Av.P was significantly greater at Uyo and similar among Abak, Onna and Ikot Ekpene locations. Effective CEC was significantly greater in Abak and similar among Onna, Uyo and Ikot Ekpene. BS was greater in Onna and similar in Abak, Uyo and Ikot Ekpene.

The analysis shows that intensive cultivation did not seen to have widespread effect on soil properties because even among those parameters that are significantly different, the effect may be in only one location.

Table 3. Effect of cultivation on variability of soil properties

Soil parameters	Abak	Onna	Uyo	Ikot Ekpene
CS %	65.90 ^{a}	60.53 ^{a}	60.27 ^{a}	50.85 ^{b}
FS %	23.72 ^{a}	25.98 ^{a}	25.07 ^{a}	28.41 ^{a}
TS %	89.62 ^{a}	86.52 ^{b}	85.33 ^{b}	79.26 ^{c}
Silt %	3.38 ^{d}	4.86 ^{c}	6.23 ^{b}	7.90 ^{a}
Clay %	7.00 ^{c}	8.62 ^{b}	8.44 ^{b}	12.84 ^{a}
Bd	1.39 ^{a}	1.48 ^{a}	1.34 ^{a}	1.44 ^{a}
f	0.48 ^{a}	0.44 ^{a}	0.49 ^{a}	0.46 ^{a}
Ksat	26.72 ^{a}	5.14 ^{b}	6.96 ^{b}	5.22 ^{b}
AWC	8.35 ^{a}	5.98 ^{b}	5.40 ^{b}	6.38 ^{b}
pH	6.35 ^{a}	6.13 ^{b}	6.45 ^{a}	6.18 ^{b}
EC	0.11 ^{a}	0.53 ^{a}	0.07 ^{a}	0.04 ^{a}
MC	572.8 ^{a}	531.9 ^{a}	356.8 ^{a}	517.1 ^{a}
PMC	3.63 ^{a}	4.16 ^{a}	3.91 ^{a}	5.01 ^{a}
Total N	0.06 ^{a}	0.05 ^{a}	0.06 ^{a}	0.06 ^{a}
Av.P	11.45 ^{b}	12.94 ^{b}	27.68 ^{a}	13.42 ^{b}
Ca	2.57 ^{a}	2.46 ^{a}	2.31 ^{a}	2.38 ^{a}
Mg	1.18 ^{a}	1.08 ^{a}	1.07 ^{a}	0.97 ^{a}
Na	0.0.5 ^{a}	0.04 ^{a}	0.04 ^{a}	0.04 ^{a}
K	0.07 ^{a}	0.07 ^{a}	0.07 ^{a}	0.07 ^{a}
EA	2.02 ^{a}	1.77 ^{a}	1.73 ^{a}	1.81 ^{a}
ECEC	5.89 ^{a}	5.43 ^{b}	5.18 ^{b}	5.17 ^{b}
BS	65.88 ^{a}	67.28 ^{a}	66.65 ^{a}	65.08 ^{a}

Source: Field survey, 2010; Critical value of t = 2.26216 = 2.26; Level of significance = 0.05
Error of degree of freedom = 9; Means with the same letter are not significantly different at the 5% level

3.8 Correlation Matrix of Soil Properties

The Pearson Correlation matrix of soil properties is shown in Table 4. The result shows eighteen pairs of data were positively significant while seventeen were negatively significant. Csand was positively significantly correlated with Tsand (r = 0.87**) and Mg (r = 0.71**) and negatively correlated with Fsand (r = - 0.84**), silt (r = - 0.75**), clay (r = - 0.89***) and PMC (r = - 0.52*). The implication is that Csand dominates the Tsand fraction and the greater the value of Csand the less the value of Fsand, silt and clay fractions. This is also demonstrated by the negative significant relationship with silt (r = - 0.94**) and clay (r = - 0.96**). Tsand was however positively significantly (r = 0.67**) correlated with Ksat, indicating that water movement in the soil is favored by the dominance of soil texture by the sand fraction. The silt and clay fractions were negatively significantly (r = - 0.74** and r = - 0.55, respectively) correlated with Ksat.

Soil Bulk density (Bd) was significantly (r = - 0.99**) correlated with total porosity (f), because as the soil becomes dense, usually the pores tend toward the micropores.

Soil pH was significantly (r = 0.66**) correlated with Av.P, because the latter usually is more available with increasing acidity. Mass of carbon (MC) was significantly (r = 0.85**) with Total N. Usually, soil N content increases with soil organic carbon or soil organic matter content.

Ca and Mg were also significantly (r = 0.80** and r = 0.68**, respectively) correlated with ECEC, because the greater the content of the former the greater the ECEC, as well as the Base Saturation (BS). These relationships, although few compared with the total pairs of data are nonetheless important in terms of soil management for intensive crop production.

3.9 Principal Component Analysis of Soil Attributes in the Study Area

Principal component analysis was used to reduce the twenty-two soil properties to seven orthogonal components with eigenvalues greater than unity (Table 5). These seven components accounted for over 90 percent of the total variance within the variables. Component 1 explained 31 percent of the total variance and had significant loadings (±0.30) on Csand, Tsand, silt and clay. This component was termed the soil texture factor. It also had moderate positive loadings for Ksat and exchangeable Mg.

Table 4. Correlation matrix among soil properties

	Csand	Fsand	Tsand	Silt	Clay	Bd	F	Ksat	AWC	pH	EC	MC	PMC	Total N	Av.P	Ca	Mg	Na	K	EA	ECEC	BS
C sand	1.00																					
F sand	-0.84**																					
Tsand	0.87**	-0.47																				
Silt	-0.75**	0.31	-0.94**																			
Clay	-0.89**	0. 55*	-0.96**	0.81**																		
Bd	0.01	-0.20	-0.16	0.19	0.13																	
f	-0.07	0.27	0.14	-0.20	-0.08	-0.99**																
Ksat	0.54	-0.23	0.67**	-0.74**	-0.55*	-0.41	0.44															
AWC	0.39	-0.28	0.39	-0.47	-0.29	0.41	-0.36	0.58*														
pH	0.15	-0.03	0.22	-0.12	-0.28	-0.28	0.26	0.19	0.06													
EC	0.26	-0.25	0.20	-0.14	-0.23	-0.13	0.14	0.30	0.07	0.44												
MC	0.24	-0.26	0.15	-0.09	-0.18	0.38	-0.40	0.06	0.30	-0.23	-0.59											
PMC	-0.52*	0.37	-0.51*	0.42	0.54*	0.25	-0.29	-0.46	-0.14	0.04	-0.07	-0.31										
Total N	0.12	-0.15	0.06	0.02	-0.13	-0.04	-0.00	0.14	0.07	-0.11	-0.56 *	0.85 **	-0.30									
Av.P	-0.17	-0.13	-0.15	0.29	0.09	-0.15	0.11	-0.39	-0.42	0.66**	0.05	-0.11	0.08	-0.03								
Ca	0.34	-0.17	0.40	-0.48	-0.31	0.20	-0.21	0.29	0.39	0.09	-0.06	0.11	0.21	-0.07	-0.36							
Mg	0.71**	-0.57*	0.63*	-0.57*	-0.64*	-0.03	-0.00	0.39	0.37	0.11	0.07	-0.06	-0.05	-0.11	-0.24	0.55*						
Na	0.15	-0.14	0.13	-0.11	-0.13	0.01	0.02	0.32	0.34	-0.28	-0.33	0.41	0.11	0.43	-0.42	0.01	0.38					
K	0.36	-0.33	0.28	-0.13	-0.38	-0.11	0.10	0.18	0.02	0.07	0.06	0.13	-0.29	0.16	-0.07	0.06	0.50*	0.40				
EA	0.13	-0.01	0.19	-0.16	-0.20	0.22	-0.20	0.34	0.51*	0.14	0.06	0.25	-0.04	0.10	-0.28	0.46	0.30	0.57*	0.25			
ECEC	0.48	-0.27	0.54*	-0.54*	-0.50*	0.23	-0.23	0.46	0.62**	0.18	0.06	0.21	-0.04	0.00	-0.37	0.80**	0.68**	0.44	0.29	0.82**		
BS	0.32	-0.25	0.29	-0.33	-0.23	-0.21	0.18	-0.02	-0.19	-0.05	-0.05	-0.25	0.02	-0.18	0.03	0.10	0.28	-0.41	-0.04	-0.76**	-0.28	1.00

Source: Field Survey, 2010

** - Significant at the 0.05 probability level; ** - Significant at the 0.01 probability level*

Component 2 loaded significantly on Bd, f, and MC, and is termed the soil (bulk) density factor, and explained over percent of the total variance. It had significant loading of over (±0.30). This component explained that the higher the bulk density the greater the amount of carbon sequestered.

The third component was termed the potential mineralizable carbon factor because it had high positive loadings on PMC and high negative loadings on MC and Total N (Table 5). This factor explained over 12 percent of the total variance, and that as potential mineralizable carbon increases, the total amount of carbon that is stored and total N decrease.

The fourth component was termed the exchangeable acidity factor because it had high positive loadings on EA (Table 5). It also had a high positive loadings on f and Fsand but high negative loadings on Bd and BS. This factor explains over 10 percent of the total variance. Total porosity highly negatively significantly ($p < -0.99$) correlated with Bd (Table 4), and as f increases leaching losses of exchangeable bases increases, which may increase the EA (exchangeable acidity).

The fifth component was terms the soil P factor because it had high positive loadings on Av.P and soil pH (Table 5), and explained over 8 percent of the total variance. These two attributes had a large positive correlation on each other (Table 4).

The sixth component was termed the soil nutrient factor because it had high positive loadings on K and Mg, and moderate positive loadings on PMC (Table 5). This factor explained over 6 percent of the total variance. K and Mg were positively correlated ($p < 0.5$; Table 4).

The seventh component was termed the soil Ca factor because it had high positive loadings on Ca, moderate positive loadings on Fsand, and high negative loadings on EC and K (Table 5) and explains over 6 percent of the total variance.

Table 5. Principal component analysis of soil attributes in the study area

Soil attributes	1	2	3	4	5	6	7
MC	0.108	**0.327**	**-0.351**	-0.148	0.164	-0.078	0.223
CS	**0.336**	-0.111	-0.047	-0.232	0.100	-0.015	-0.093
FS	-0.231	0.022	0.041	**0.341**	-0.178	-0.055	**0.312**
TS	**0.340**	-0.161	-0.040	-0.070	0.002	-0.074	0.129
Silt	-0.39	0.151	-0.001	0.026	0.179	0.167	-0.208
Clay	**-0.327**	0.155	0.069	0.099	-0.145	-0.006	-0.056
Bd	-0.000	**0.366**	0.234	**-0.337**	0.139	-0.129	-0.072
f	-0.006	**-0.353**	-0.219	**0.376**	-0.177	0.089	0.064
Ksat	0.281	-0.112	-0.078	0.275	-0.145	-0.282	0.024
AWC	0.236	0.203	0.151	0.038	-0.017	**-0.333**	0.036
pH	0.055	-0.225	0.168	0.189	**0.502**	0.061	0.294
EC	0.062	-0.259	0.308	0.105	0.206	-0.259	**-0.394**
PMC	0.174	0.104	**0.357**	0.004	-0.128	**0.315**	0.206
TN	0.059	0.201	**-0.486**	-0.002	0.130	0.023	0.238
Av. P	-0.140	-0.192	-0.019	-0.038	**0.543**	0.161	0.271
Ca	0.211	0.111	0.294	-0.022	-0.178	0.168	**0.368**
Mg	0.295	-0.041	0.133	-0.064	-0.093	**0.431**	-0.075
Na	0.151	0.266	-0.216	0.253	-0.106	0.231	-0.210
K	0.163	-0.006	-0.137	0.075	0.144	**0.487**	**-0.360**
EA	0.183	0.284	0.156	**0.378**	0.156	0.022	-0.023
ECEC	0.297	0.185	0.232	0.157	0.009	0.133	0.131
BS	0.026	0.297	-0.020	**-0.413**	-0.29	0.156	0.154
Eigen value	6.87	3.78	2.56	2.26	1.74	1.35	1.33
Var%	31.20	17.16	11.65	10.26	7.92	6.12	6.04
Cum var%	31.20	48.31	60.02	70.28	78.19	84.31	90.35

Source: Field survey, 2010

From the foregoing, for Hypothesis 1, since there is a relationship between intensive vegetable cultivation and organic carbon storage, the null hypothesis (H_O) is discarded and (H_1) upheld. Similarly, for Hypothesis 2, since there is a relationship between the physical and chemical properties of cultivated and uncultivated soils, the null hypothesis (H_O) is discarded and (H_1) upheld.

4. CONCLUSION

Agriculture is greatly influenced by the fertility status of the soil and also on the farming practices employed as the agricultural method. The need to increase food production in the face of a dwindling land resource necessitated agricultural intensification. This study was conducted to evaluate the effect of intensive vegetable cultivation on the amount of soil organic carbon stored in Akwa Ibom State, Southeastern Nigeria. The locations of study were, in the first place almost similar in other soil properties analyzed. The locations were also similar in the amount of carbon sequestered. However, the result showed that uncultivated soils sequestered larger amount of carbon compared to the cultivated soils.

The study further revealed that there is a relationship between physical, chemical and biological properties of the soil and its organic matter. The organic matter affects soil structure and porosity, moisture holding capacity of soils, nutrient availability and the biodiversity of soil organisms. In order words, organic matter influences soil properties and vice versa and is therefore an important variable that determine soil fertility and agricultural productivity. Therefore, the maintenance of soil organic matter levels and nutrient cycling optimization are essential to sustainable agricultural system.

The study concluded that cultivated soils sequester carbon, but the quantity of the carbon sequestered depends on the type of farming system that is being practiced. Also, the SOC pools between the cultivated and uncultivated soils varied due to cropping systems, management practices, land use and growing season climate.

Mixed cropping, organic manuring and fallowing are some of the methods suggested in mitigating CO_2 emission thereby reducing global warming and its deleterious activities. Reintroduction of local extension officers is also strongly recommended to educate the local farmers on the innovative methods of farming that are both sustainable and environmental friendly. This is a long-term goal and it's technically feasible but also requires education of policy makers and the general public about the importance of adopting science-based ecologically compatible systems of land use and crop management.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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