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Carbon sequestration and assessment of fertility status of soil under different land uses for agronomic potentials in Abakaliki South Eastern Nigeria

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Abakaliki is predominantly agrarian but continuous cropping is largely practiced due to population pressure. Consequently, there is effort to evolve strategies that would ensure sustainable productivity. This necessitated a research which was carried out to study carbon sequestration and assessment of fertility status of soil for agronomic potentials under different land use systems. Six different land uses each of 20 m × 20 m equivalent to 0.04 ha were identified with Global Positioning System (GPS) and used for the study. Auger and Core samples were randomly collected at 0-15 cm depth in ten different points in each land use for determination of carbon sequestration and fertility assessment. Data were subjected to standard deviation. Results of standard deviation showed high carbon sequestration of 66.83±16.03, 43.73±5.69, 34.51±1.57 and 32.90±0.85 t ha^{-1} for alley cropping, forest, fallow and grazing land uses compared to 4.56±11.82 and 3.48±12.30 t ha^{-1} for mixed cropping and continuously cultivated soil. Bulk densities and total porosities were not limiting to soil fertility for alley cropping, forest, fallow and grazing land uses but moderately limiting for mixed cropping and continuously cultivated soil. Soil pH, available phosphorus, nitrogen, organic carbon, calcium, magnesium and exchangeable acidity were generally high and not limiting to fertility status in alley cropping, forest, fallow and grazing land uses but low and limiting in mixed cropping and continuously cultivated soil. Alley cropping, forest, fallow and grazing fell into grade 2 ranking while mixed cropping and continuously cultivated soil were in Grades 3 and 4 fertility ranking for agronomic potentials, respectively. Deep feeder crops are recommended for alley cropping, forest, fallow and grazing land uses while shallow and nitrogen fixers are suitable for mixed cropping and continuously cultivated soil. It is advocated that farmers adopt good and efficient land use management systems for high carbon sequestration, soil fertility sustainability and climate change mitigation.

Key words: Agronomic, assessment, carbon sequestration, fertility status, land uses.

INTRODUCTION

Carbon sequestration is the process involved in carbon capture and the long-term storage of atmospheric carbon dioxide (CO_2) in soil or other forms of carbon to either mitigate or defer global warming and avoid dangerous climate change (https://en.m.wikipedia.org, 2016). According to Lal (2008), the process removes carbon pool and is primarily mediated by plants through photosynthesis where carbon is stored in form of soil organic carbon. Since industrial revolution which is exacerbated by rapacious urbanization, there has been unusual conversion of natural ecosystem for agricultural use or other uses resulting in depletion of soil organic carbon to about 50 to 100 GT of carbon captured from the atmosphere (Lal, 2015). The reductions occur largely from plant roots and residues not returned to soil or through erosion (Lemus and Lal, 2005) leading to depletion of organic carbon stocks or carbon deficits in soil and sometimes through a variety of land mismanagement approaches. Other causes of low soil carbon storage include low carbon dioxide concentration with consequent poor carbon fixation by plants (Drake et al., 1997) as well as increased plant respiration, low moisture content and high microbial activity (Maracchi et al., 2005).

Land use and management have profound influence on quantity of carbon stored in soil (Abril and Bucher, 2001). For instance, forestation or reforestation, grassland restoration, continuous cultivation, conservation tillage, cover crops or amendment practices have their relative impacts on carbon storage and soil properties (Amalu, 2012). Similarly, Batjes (2011) noted that impact of land use on carbon stocks and soil properties in Nigeria and sub-Sahara Africa is challenging because of spatial heterogeneity of soils. The author further observed that climate management was not easy largely because of lack of data on soil carbon pools as obtained in most agro-ecosystems.

Land use might be a dominant factor influencing soil properties and behavior temporarily and spatially (Wang et al., 2001). Land use or management practices to a large extent determine available soil nutrients and could modify processes such as erosion, oxidation, leaching and rate of mineralization (Celik, 2005) especially, as land use are critical since it relates to soil nutrients availability and physicochemical properties. Since the current rise in atmospheric CO_2 is thought to be mitigated in part by carbon storage in agricultural soils, interest has increased in possible impacts of various agricultural management practices on soil organic carbon dynamics (Abril and Bucher, 2001) as well as of soil properties. This study has become imperative as population is increasing geometrically with a fixed land mass. In response, farmers now cultivate every available land space ignoring normal and recommended agricultural practices for sustainable soil productivity (Anikwe, 2015).

Intensity of land use has obvious impacts on soil physicochemical properties (Celik, 2005) and sometimes leads to productivity decline. In order to facilitate soil carbon storage and improve its physical, chemical and hydrological functions, the adoption of effective land uses management practices by farmers that would be enduring and sustainable cannot be overemphasized. The objectives of this study were to study effect of different land uses on soil carbon sequestration and assessment of fertility status of soil under different land use systems for agronomic potentials in Abakaliki agro environment.

MATERIALS AND METHODS

Study area

The study was carried out partly in Teaching and Research Farm of Faculty of Agriculture and Natural Resources Management, Ebonyi State University and adjoining areas near the Faculty. The Faculty lies by latitude 06° 4'N and longitude 08° 65'E while adjoining areas lie by latitude 06° 9'N and longitude 08° 69'E in the derived savanna area of the southeast agro ecological zone of Nigeria. The area experiences bimodal pattern of rainfall usually spread from April-July and September- November with dry spell in August. The rainfall ranges from 1700 to 2000 mm for minimum and maximum with mean annual rainfall of 1800 mm. Temperature varies from 27°C during cold (harmattan) period to 31°C for dry season normally between December and March. The relative humidity is highest (80%) during rainy periods but declines to 60% when the rains cease (ODNRI, 1989). The soils of the area are formed from sedimentary deposits from cretaceous and tertiary periods. It is associated with “Asu River” group as Abakaliki soil is believed to have been derived from shale residuum. The soil is unconsolidated up to 1 m depth and belongs to order ultisol and classified as typic haplustult (FDALR, 1985). The area is recently classified as derived savannah since it is characterized by growth of shrubs, herbs and common tropical grasses such as *Tridax procumbens, Imperata cylindrica, Panicum maximum, Elephant grass, (pennisetum purpurem), sporobulus pyramidalis* and *Sida acuta.* There are also traces of *centrosema* and *Pueriaria* as legume grasses. There are abundant palm trees but scanty economic trees like Obeche, Mahogany or “Afara”. The indigenes are mainly farmers specializing in crops, fishing and hunting as major means of livelihood. Due to state creation the area largely known for its agrarian nature has abandoned it for “greener pastures” and many of the people could now be found in different vocations and civil service (Figure 1).

Identification of different land uses and their description

Six different land uses were used for the study. The land uses were carefully identified and characterized for the experiment. Each land use type measured 20 m × 20 m equivalent to 0.04 ha and was located using a hand held Global Positioning System (GPS).

1. Forest land designated as FL is located at Azugwu adjacent to Faculty of Agriculture and Natural Resources Management, Ebonyi State University. The forest was established during the colonial era for preservation of forestry resources spanning for 50 years. *Gmelina aborea* is dominant tree among other vegetations in the forest. Hunting and farming activities are prohibited although poaching is not completely eliminated as people still encroach in the forest for faming related activities.
2. Fallow land (UC) was identified behind Bishop Otubelu convent about 2 km away from Faculty of Agriculture and Natural Resources

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Figure 1. Map of Abakaliki, Ebonyi State.

Management, Ebonyi State University. The fallow has lasted for more than 15 years without being put under cultivation. There are different types of vegetations covering the land but among major ones are herbs, shrubs and grasses while carpet grass appears to be predominant.

3. Alley cropping (AC) is located behind Faculty of Agriculture and Natural Resources Management of the University for Research Purposes. The alley was established by Department of Soil Science and Environmental Management and has spanned 23 years since establishment. The alley trees are *Gliricidia sepium and Leucena leucophella* interspersed with *Cajanus cajana*. Their leaves are pruned periodically and deposited on the soil or used to feed animals. It has been expanded recently to include *Gmelina aborea* and *Accia bartari.*

4. Continuously cultivated soil (CCS) is located behind Law Faculty of Ebonyi State University. The land has been under yearly cultivation for more than 10 years by staff of the university. Common crops grown in rotation include yam (*Dioscorea* spp.), Cassava (*Manihot* spp.) and maize (*Zea mays L.*). Farming practices employed is that of subsistence one which is devoid of scientific approach.

5. Grazing land referred to as GL is located behind Department of Animal Science of Faculty of Agriculture and Natural Resources Management, Ebonyi State University. The land is solely dedicated for cattle grazing in the Faculty. The land is grown with moderately tall trees, shrubs, herbs and dominated by short local grasses. Grazing has taken place in the land since the inception of the Faculty spanning for more than 18 years.

6. Mixed cropping (MC) is located behind Law Faculty of the university. The land is used to grow mixture of crops which are intercropped on yearly basis. Common crops intercropped are maize (*Z. mays L.*), Yam (*Dioscorea* spp.), Cassava (*Manihot* spp.), Cocoyam (*Colocasia esculentum*), Cowpea (*Vignia urnguiculata*), Bambara (*Phaseolus vulgaris*) and sweet potato (*Ipomea batata*). This practice is in vogue in the land and commonly accepted practice within the agro environment.

Soil sampling

A hand held global positioning system (GPS) was used in determining positions for collection of soil samples in each land use. Auger and Core soil samples were collected at 0-15 cm depth in each land use believed to be within plough layer since local hoe is commonly used for cultivation. Samples were collected at ten points per each land use. Auger samples were composited after being air dried at 26°C, ground and sieved with 2 mm sieve and used for determination of soil chemical properties. The mean of core samples after laboratory determinations were used to evaluate soil physical properties.

Soil carbon sequestration determination

Total carbon sequestered in soil was calculated using procedure used by Mbah and Idike (2011). The procedure is as follows:

$$\text{Carbon sequestered in soil} = \frac{\%C}{100} \times \text{Soil BD (mgm}^{-3}\text{)} \times \text{area of land (m}^{2}\text{)} \times \text{soil depth (cm)} \quad (1)$$

Where %C = percent carbon; BD = bulk density (mgm^{-3}); area = area of land used for study equivalent to 1 ha (m^{2}), and soil depth = 0.15 cm.

Rating index for agronomic potentials

Soils under different land uses were rated based on their individual suitability for sustaining arable crops according to Storie Index (1953) rating as corroborated by Akamigbo (2010) which is based on the following characteristics related to crop growth and yield.
These soil characteristics include:

Soil characteristics	**Factor**
Soil profile depth-	A
Texture of surface soil-	B
Sloppiness-	E
Other factors (drainage, salts, alkali and erosion)-	X

Each factor is evaluated on the basis of 100%. A rating of 100% implies most favourable or ideal condition and lower percentage ratings are for less favourable conditions for crop production (Akamigbo, 2010). The index rating for individual factors for alley cropping, forestry, grazing and fallow land uses are 90% since they did not impose limitation for crop production. Mixed cropping has 90% for factors A-E and 60% for X while 70% was assigned to continuously cultivated soil for factors A-E and 50% for X, respectively. Where A, B, E are 90% for AC, FL, GL and UC and A,B,E are 90% and X is 60% for MC while A, B, E are 70% and X is 50% Grades for suitability for intensive production of crops were based on summation of values for factors A × B × E × X.

Laboratory methods

Particle size distribution was determined using Gee and Or (2002) hydrometer method. The result of particle size distribution was reported in percentages while the textural class determination was determined using USDA textural triangle (Obi, 2000). Bulk density was evaluated using core method as follows:

$$\text{Bd} = \frac{\text{Weight of oven dry soil (Mg)}}{\text{Volume of Core } (\text{M}^3)} \qquad (2)$$

Where Bd = bulk density (Mgm^{-3}).
Whereas total porosity value was obtained as described by Obi (2000) using the formula:

$$\text{Total porosity} = \left(\frac{1\text{-Bd}}{\text{P}_\text{p}}\right) \text{ x } \frac{100}{1} \qquad (3)$$

Where, Bd = bulk density (mgm^{-3}), and Pp = particle density assumed to be 2.65 Mgm^{-3}.

Soil pH determination was done using soil/water suspension ratio of 1:2.5. The pH values were read using electrode pH meter. Organic carbon was determined by the method described in Page et al. (1982). Total nitrogen determination was done using the modified macro-Kjedahl method (Bremner and Mulvancey, 1982). Exchangeable calcium, magnesium, potassium and sodium were extracted using the method described by Mba (2004). The values of potassium and sodium were obtained using flame photomertry method. Available phosphorus was determined by colorimetric method of Page et al. (1982). Exchange acidity was determined using titrimetric method of Mclean (1982).

Data analysis

Data from the study were subjected to standard deviation analysis according to Obi (2002). Chart was used where possible to further illustrate the results.

RESULTS

Soil carbon sequestration

Soil carbon sequestration under different land uses is presented in Table 1 and Figure 2. The results showed strong variations in carbon sequestration among the different land uses. The results of carbon sequestration in different land uses ranged from 3.48±12.30-66.83±16.03t ha^{-1} for the land uses. The variations recorded in carbon sequestration for the alley cropping, forest land, grazing land and fallow land were 54, 29, 6 and 10% higher from their mean values, respectively. On the other hand, continuously cultivated soil and mixed cropping land uses had 88 and 85% lower variations of carbon sequestration from their mean values. The order of value of carbon sequestration for the different land uses is AC > FL > UC > GL > MC > CCS.

Table 1. Carbon sequestration under different land uses.

Land use	Carbon storage (t ha^{-1})
Alley cropping	66.83± 16.03
Forest land	43.73 ±5.69
Uncultivated land	34.51±1.57
Grazing land	32.90±0.85
Mixed cropping	4.56±11.82
Continuous cultivation soil	3.48±12.30
Mean	31.00

Soil physical properties under different land uses

Table 2 and Figure 3 show soil physical properties under different land uses. Particle size distribution ranged from 55-69, 10-34 and 15-24%, respectively for sand, silt and clay fractions in the land uses, respectively. Generally, percent sand, silt and clay varied in the land uses with sand being predominantly higher. Clay fraction was dominant in alley cropping land use compared to corresponding values in other land uses. Textural class was sandy loam for the different land uses. Bulk density and total porosity ranged from 1.29±0.03-1.52±0.14 Mgm^{-3} and 42.75±2.39-51.75±1.64% and varied from their mean values in the land uses. Lowest values of bulk density were obtained in forest and grazing land uses while highest value was recorded in continuously cultivated soil. Total porosity followed the trend obtained in bulk density for the different land uses.

Chemical properties of soil under different land uses

Chemical properties of soil under different land uses are presented in Table 3. Results showed that chemical properties of soil generally varied from one land use to another and from their mean values with highest values obtained under alley cropping, forest, grazing and fallow land uses compared to their counterparts in mixed cropping and continuously cultivated soil. The values of soil pH obtained under different land uses ranged from

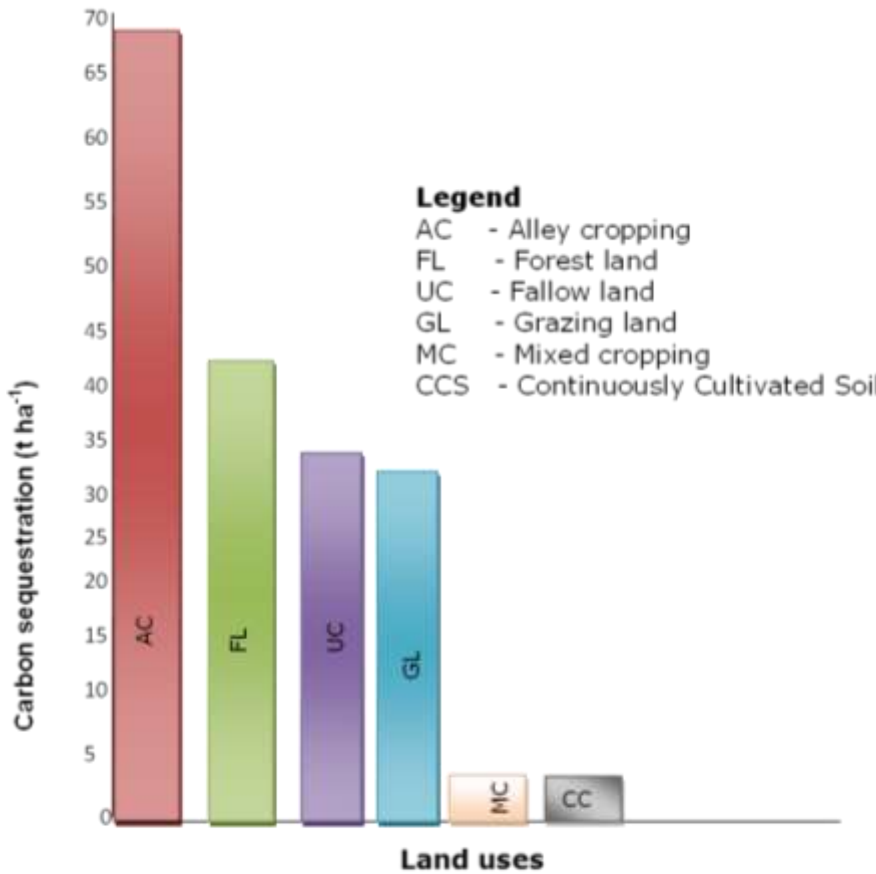

Figure 2. Carbon sequestration under different land uses.

Table 2. Physical properties of soil under different land uses.

Land uses	Sand (%)	Silt (%)	Clay(%)	Texture	BD (Mgm^{-3})	TP (%)
Alley cropping	58	18	24	SL	1.33±0.22	50.25±0.96
Forest land	68	16	16	SL	1.29±0.03	51.50±1.53
fallow land	64	18	18	SL	1.39±0.01	47.54±0.59
Grazing land	69.	10	21	SL	1.29±0.03	51.75±1.64
Mixed cropping	55	27	18	SL	1.45±0.03	45.50±1.20
Continuous cultivated soil	61	20	19	SL	1.52±0.14	42.75±2.39
Mean	**45**	**34**	**20**		**1.38**	**48.08**

BD, bulk density; TP, total porosity; SL, sandy loam.

5.50±0.18 to 6.20±0.13 and slightly varied from their corresponding mean values. The respective values of available phosphorus ranged from 14.00±3.53 to 31.60±4.34 mgkg^{-1} under alley cropping, forest, grazing and fallow land uses and were comparable with their mean values more than values obtained for continuously cultivated soil and mixed cropping land uses. There were higher deviations in values of available phosphorus under continuously cultivated soil and mixed cropping systems when compared to their counterparts recorded for other land use systems except for forest land. Nitrogen values 0.08±0.01 to 0.16±0.02% in alley cropping, forest fallow and grazing land uses were higher than their mean values and varied from those of fallow land, continuously cultivated soil and mixed cropping systems. The values of organic carbon in alley cropping and forest land uses were higher than their mean values and differed from values in continuously cultivated soil, fallow and mixed cropping land uses, respectively. The values of organic carbon ranged from 0.20±0.60 to 3.35±0.08% for the

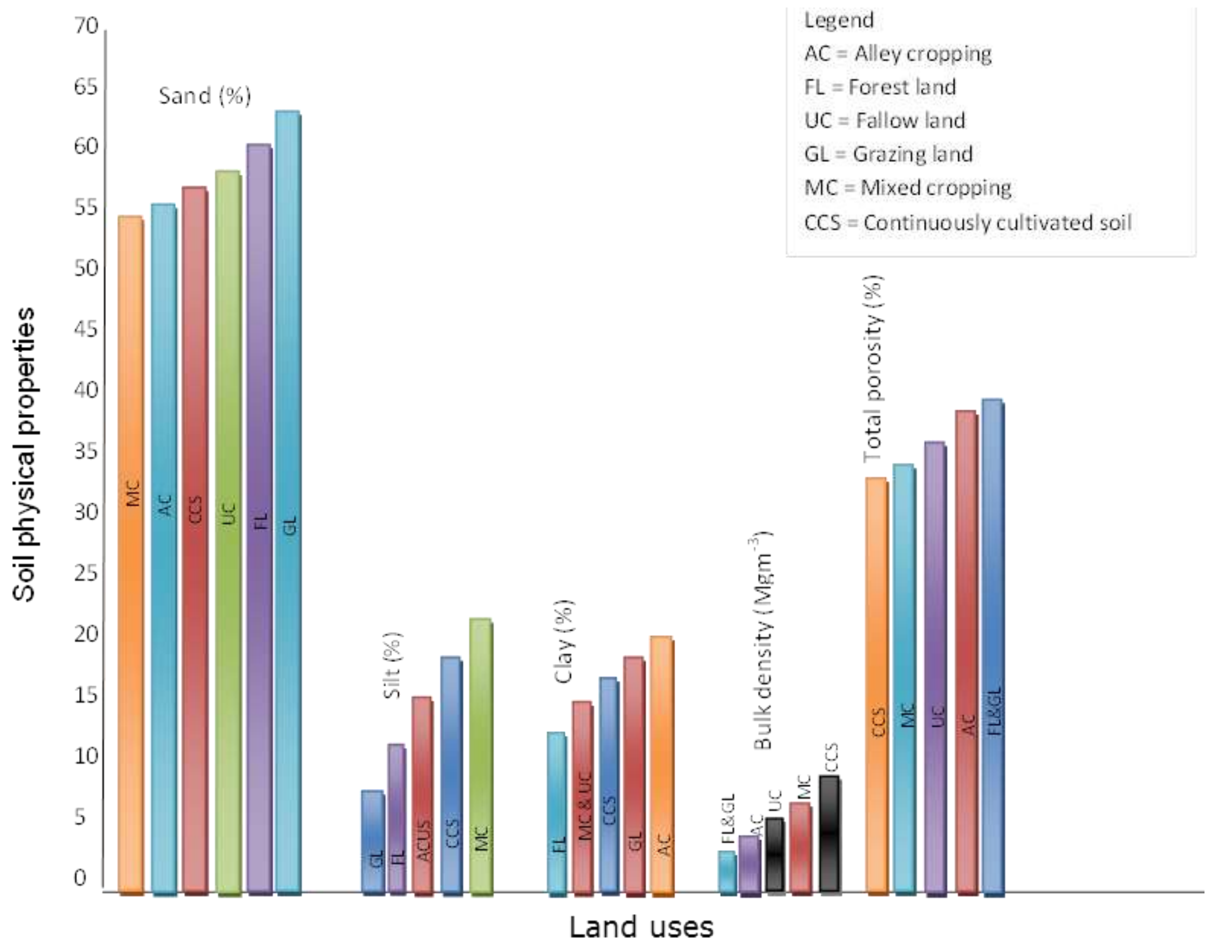

Figure 3. Soil physical properties under different land uses.

different land use systems. Generally, exchangeable cations of calcium and magnesium predominantly dominated exchange complex of soil in the land uses than potassium and sodium. The values of exchangeable cations ranged from 2.40±0.57-4.80±0.51, 1.20±0.21-2.46±0.33, 0.05±0.04-0.18±0.02 and 0.15±0.01-0.23±0.02 cmolkg-1 respectively for calcium, magnesium, potassium and sodium. Exchangeable acidity ranged from 0.16±0.18-1.20±0.29 cmolkg^{-1} and was higher under continuously cultivated soil more than in any other land use system. In contrast, least value of exchangeable acidity was obtained under alley cropping land use relative to other land uses. The respective fertility ranking for the different land use systems is in the order of AC > GL > FL > UC > MC > CCS (Table 1).

DISCUSSION

The highest carbon sequestered under alley cropping, forest, fallow and grazing land uses compared to their counterparts obtained under continuously cultivated soil and mixed cropping land uses could be attributed to efficiency or effectiveness of vegetations and/or trees which trapped and sequestered carbon in the soil. This implies that adoption of forestation, fallowing or conservation farming could have purifying effect on the atmosphere through carbon iv dioxide removal and its consequent storage in soil. This could lead to mitigation of climate change and global warming. This finding is in tandem with reports of Anikwe (2015) which made similar observations and corroborated by Lal (2008) that trees trapped carbon dioxide of the atmosphere and sequestered it in plants' parts and finally as soil carbon. Sloughed off parts' of plants as well as death and decomposed plants parts form soil carbon (Oelkers and Cole, 2008). Highest carbon sequestration obtained under alley cropping land use compared to other land uses could be linked to higher efficiency of legume trees in conversion of carbon dioxide to soil carbon pool. This finding is supported by Mbah and Idike (2011) and Okonkwo et al. (2011) who reported that alley cropping system had higher carbon sequestration potential compared to other types of land uses. Low level of

Table 3. Chemical properties of soil under different land uses.

Land uses	pH (kcl)	P (mgkg^{-1})	N (%)	OC (%)	Ca	Mg	K	Na	EA
							Cmolkg^{-1}		
Alley cropping	6.20±0.13	24.50±1.16	0.16±0.02	3.35±0.08	4.40±0.33	2.46±0.33	0.18±0.02	0.23±0.02	0.16±0.18
Forest land	6.20±0.13	31.60±4.34	0.14±0.03	2.26±0.30	4.80±0.51	1.66±0.04	0.17±0.02	0.17±0.04	0.40±0.07
Grazing land	6.00±0.04	24.30±1.07	0.11±0.00	1.70±0.01	42.0±0.15	1.60±0.03	0.16±0.01	0.17±0.04	0.32±0.07
fallow land	6.00±0.04	21.80±0.02	0.10±0.09	1.62±0.03	3.20±0.21	1.60±0.03	0.10±0.01	0.17±0.04	0.5±0.09
Mixed cropping	5.90±0.00	15.10±3.04	0.08±0.01	0.20±0.60	3.20±0.21	1.60±0.03	0.09±0.02	0.17±0.04	0.32±0.01
Continuously cultivated soil	5.50±0.18	14.00±3.53	0.08±0.01	0.16±0.60	2.40±0.57	1.20±0.21	0.05±0.04	0.15±0.01	1.20±0.29
Mean	5.9	21.9	0.11	1.55	3.67	1.67	0.13	0.18	0.56

P, phosphorus; N, nitrogen; OC, organic carbon; Ca, Mg, K, Na, exchangeable cations; EA, exchangeable acidity.

sequestered carbon under continuously cultivated soil could be due to losses as a result of dissipation, high mineralization and exposure to high temperatures, hazards of erosion and harvesting of crops without replacement. Low value of carbon sequestered under mixed cropping is attributable to competition of the crops as well as low ratio of leaves to plants which hampered carbon fixation in soil. These findings are supported by the report of Thompson and Kolka (2005) that land uses and management have large influence on local temperature, erosion and sediment deposition all of which ultimately controlled carbon inputs variation in soils. For instance, increased temperature might have impact on soil carbon balance reducing rate of photosynthesis (Zak et al., 2000). As a result, poor land use and management have the negative consequence of elevated carbon dioxide concentration in the atmosphere leading to global warming and climate change which is adverse to soil productivity. The carbon storage in alley cropping, forest, fallow and grazing land uses are high (Mbah and Idike, 2011) while value obtained under mixed cropping and continuously cultivated soil are low. Crops which make use of high efficiency of carbon such as C3 and C4 (maize and cow pea) plants could perform optimally in soils under high carbon storage.

High clay fractions under alley cropping and grazing land uses are attributable to effective rooting network system of vegetation which allowed for high concentration of clay fraction in the soil. This observation was corroborated by Okonkwo et al. (2011) that clay fraction was higher under alley cropping system compared to non-alley system. Furthermore, sandy loam texture obtained in all the land uses could be linked to good distribution of particle sizes in the soil due to management practices. Sandy loam texture has good attribute of high aeration propensity and sustenance of yields of arable crops, because of its high water and nutrients supply potentials (Nwite et al., 2016). The predominance of sand fraction in different land uses could be attributed to parent material rather than influence of land uses. Soils of Abakaliki area is reported (FDALR, 1987) to have been formed from unconsolidated deposits from sandstone. Low clay fraction under forest land is expected since tree roots could create channels for clay eluviations.

The lower bulk densities and higher total porosities in forest, grazing and alley cropping land uses could be adduced to be effect of animal droppings and leaf litter as well as recycling of nutrients to upper horizons of soil due to pedoturbation. The bulk densities except under continuously cultivated soil ranged from non-limiting to moderate values according to Anikwe (2006), Obi (2000) and Grossman and Berdanier (1982) that enhance soil productivity. Several researchers including Ohaekwiro (2016), Anikwe et al. (2007) and Mbah et al. (2009) corroborated that continuous cultivation and cropping increased soil compaction and hindered root proliferation which limited soil productivity. Similarly, total porosity ranged from non-limiting values for alley cropping, forest fallow and grazing land uses to moderate values in mixed cropping and continuously cultivated soil (Obi, 2000). Bulk density and total porosity have reciprocal relationship and their negative effects could affect nutrient retention and supply, water supply, root proliferation, leaching and nutrient losses all of which could severely limit soil productivity. Consequently, alley cropping, grazing, forestation and fallow system management could have high agronomic potentials.

Slightly different values of pH of the soil under different land uses could be attributed to effect of land use management practices prevalent in the study area. Low soil pH values obtained under continuously cultivated soil and mixed cropping systems compared to their counterparts from other land uses could be due to continuous cultivation, utilization of nutrients by crops and inorganic fertilizer application commonly practiced by farmers. However, soil pH between 5.50 and 6.20 do not constitute limitation to soil productivity (Schoenerberger et al., 2002) as most soil major nutrients such as nitrogen, phosphorus, potassium, sulphur and magnesium are precipitated and made available to crops (Anikwe, 2006; Asadu and Nweke, 1999). Moderate values of available phosphorus (FMARD, 2002) obtained in alley cropping, grazing, forest and fallow land use systems compared to values from continuously cultivated soil and mixed cropping land uses could be attributed to recycling of nutrients by roots of plants, decomposition and mixing of decomposed leaf litter through microbial action (Kaur et al., 2005). The phosphorus status in alley cropping, grazing, forest and fallow land uses is at critical levels that is limiting to soil productivity (Asadu and Nweke, 1999). Low nitrogen status under different land uses could be attributed to rapid mineralization under tropical condition (Asadu, 1990) as obtained in Abakaliki Nigeria and other subsaharan environment and is limiting to soil productivity (Raju et al., 2006). The organic carbon ranged from low to moderate values under different land uses and this could be linked to influence of different land use systems. Alley cropping, grazing, forest and fallow land use systems have potentials for nutrient recycling more than continuously cultivated soil and mixed cropping as corroborated by earlier findings of Anikwe (2015) and Okesiji et al. (2012) that conservation practices increased organic carbon status of soil. The high and dominant values of exchangeable calcium and magnesium under alley cropping, forest, grazing and fallow land uses relative to continuously cultivated soil and mixed cropping systems are attributable to improvements arising from improved pH conditions of the soil (Table 3) and moderate available phosphorus and organic carbon (Asadu et al., 2012). High exchangeable calcium and magnesium is advantageous as it could skew up soil fertility status as they improve soil pH, reduce soil exchangeable acidity and precipitate release of nutrients such as available phosphorus, nitrogen and potassium. Essentially, calcium and magnesium except potassium and sodium (Asadu and Nweke, 1999) are not limiting to soil productivity. Sodium generally is not important in plant nutrition but could improve both base saturation and cation exchange capacity of soil. Trend of exchangeable acidity obtained under different land uses could be due to improvements from soil pH and nutrient status in the land use systems. High exchangeable acidity in continuously cultivated soil system could be linked to effect of nutrient depletion, low acidity and poor base saturation of the soil. High soil pH is favourble for stimulation and precipitation of exchangeable Al^{3+} saturation of soil. It is advocated that management practices which could ensure and promote forestation or reforestation, fallowing and farming could be revolutionary and a step towards sustainable soil productivity (Ezeaku, 2011). Higher deviations obtained in values of available phosphorus in CCS and MC land uses could be due to error in handling and calculation of samples as the values in those land uses except in fallow land use were even lower (Table 3).

Agronomic potentials of different land uses

The different land uses have great agronomic potentials based on their fertility status ranking. Individual capability or suitability ratings for sustaining crop production was calculated based on Storie (1953) rating and used to characterize land uses for agronomic potentials. The land uses were further grouped into grades as determined by favourable conditions or otherwise that could enhance and sustain crop production or limit it. Based on this, land uses such as alley cropping, forest, grazing and fallow fall into grade 2 implying soils which are good and could support intensive and high production of arable crops such as yam (*Dioscorea* spp), Cassava (*Manihot* spp), Maize (*Zea mays* L.), Cocoyam (*Colocasia esculenta*), Amaranthus, garden egg (*Solanum* spp) and fluted pumpkin (*Occidentalis* spp.). Mixed cropping land use is grouped under grade 3 which means that the soil is fairly well suited for production of yam (*Dioscorea* spp), cassava (*Manihot* spp), Maize (*Z. mays* L.), groundnut (*Arachis hypogea*), Bambara nut (*P. vulgarise*), cowpea (*V. unguculata*), *Cajanus cajan* and pepper (*Capasicum annum*). Continuously cultivated soil has grade 4 which implies that such soil is poorly suited for crop production. The soil could support production of arable crops such as maize (*Z. mays* L.) although not at economical level, cowpea (*V. vulgarise*) and groundnut (*A. hypogea*). These three grades of soil could also be suitable for production of economic tree crops such as oil palm (*Ealeis guinensis*), coconut, orange tree, mango (*Magnifera indica*), cashew and guava at economical and productive levels (Obi, 2000).

Conclusion

The results of this study have shown that carbon sequestration could be high under vegetation cover than bare soil condition and continuously cultivated soil. The sequestrated soil carbon could play strategic role in climate change mitigation and global warming reduction as well as enhance crop production. Furthermore, bulk density and total porosity were ideal for soil productivity in alley cropping, forest grazing and fallow land uses but limiting in continuously cultivated soil and mixed cropping land uses. Similarly, soil pH, nitrogen available phosphorus, organic carbon, exchangeable bases and exchangeable acidity do not impose limitation to soil productivity in AC, FL, UC, and GL land use. Alley cropping, forest, fallow and grazing land use could support intensive crop production just as mixed cropping is fairly well suited and continuously cultivated soil is poorly suited for arable crop use. Essentially, different land uses have different capacities for agronomic uses and potential. Generally, conservative farming such as practice of alley cropping, forestry, fallowing, and grazing land rather than mixed cropping, slash and burn or and continuously cultivated soil management practices are restorative measures on soil nutrients and physicochemical properties. The latter practices are depletive on soil nutrients and deteriorate physical properties. A good and effective land management practice such as alley cropping and forestry are advocated for enhanced carbon sequestration, climate change mitigation, sustained soil fertility status and increased productivity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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