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Influence of Different Depth of Tillage on Carbon Sequestration in the Soil of Rainforest Zone, Ekiti State

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***Abstract*:- One of the strategies accepted globally for mitigating a high concentration of carbon dioxide (CO_2) that causes global warming is carbon storage in the soil. Effect of Carbon storage in the soil and tillage practices are important in plant growth. Because of this, the research was based on determining the effects of different depths of tillage practice on carbon sequestration in the soil;the site was selected and cleared before the tillage practice operation was done at depth of 0cm (control) 10cm, 20cm, 30 cm. Two soil profiles of 1 m x 1m x1m were dug in each of the tillage depths, soil samples were collected from each horizon for laboratory analysis. Some physical and chemical properties of soil in each horizon were carried out and the organic carbon stocks (SOC) were determined. The Pearson correlation matrix showed a significant correlation between organic carbon (OC) and SOC at 0 cm (control) while there is no significant correlation between OC and SOC at 10 cm, 20 cm and 30 cm depth. This indicatesthat the Zero tillage level has the highest carbon storage in the soil, the more the depth of soil tillage the more the loss of soil organic carbon to the atmosphere. Zero tillage practice is therefore recommended to enhance the SOC sequestration, high yield of agricultural produces and to avoid the escape of carbon to the atmosphere which results in climate change problems.**

***Keywords:* Soil, Tillage, Organic, and Carbon Sequestration.**

I. INTRODUCTION

Carbon sequestration is the removal of carbon dioxide (CO_2) from the atmosphere (source) into green plants (sink) where it can be stored indefinitely. The sink can either be above ground, in the soil or the deeper subsurface environments (CO_2) occurs in the greatest concentration and its removal by terrestrial ecosystems through carbon sequestration and converting the sequestered carbon into soil organic carbon (SOC) has provided a great opportunity for shifting greenhouse gasses (GHG_S)emission to mitigate the climate change Paustian *et al*., (2002) observed that the soil is an ideal reservoir for storage of organic carbon due to a long in a stay of land misuse and inappropriate management.

Carbon is since it has depleted found in all living organisms and is the major building block for life on Earth. Carbon exists in many forms, predominately as plant biomass, soil organic matter, and as the gas carbon dioxide in the atmosphere and dissolved in seawater. Carbon sequestration is the long-term storage of carbon in oceans, soils, vegetation (especially forests), and geologic formations. Although oceans store most of the Earth's carbon, soils contain approximately 75% of the carbon pool on land three times more than the amount stored in living plants and animals. Therefore, soils play a major role in maintaining a balanced global carbon cycle (Sundermeier *et al*., 2005).

Carbon emission from agricultural activities contribute to the enrichment of atmospheric carbon sequestration in agricultural soil, through the use of proper management practices, while the soil inorganic carbon contributes approximately 25% of the overall soil carbon inventory, agricultural activities have a more profound influence on the change of soil organic carbon both in the short and the long term. Increasing soil organic carbon content enhances soil quality, reduces soil erosion and degradation, improves surface water quality, and increases soil water productivity(Sundermeier *et al*., 2005). Thus, the carbon in sequestration in soils, i.e, increasing soil organic carbon in agricultural soils through proper management provides a multitude of environmental benefits. The goal to sequester soil organic carbon is to create a win-win situation to improve soil productivity, reduce unnecessary inputs, and promote sustainability.

Soil organic carbon content of cropping soils is well below the potential protective capacity because it has been subjected to conventional tillage and burning practices, which cause substantial carbon losses (Lal, 2004). Therefore, tillage types have important impacts on soil organic carbon including controlling residue placement in soils (FAO, 2006). Deep tillage buries crop residue, but the residue is not mixed uniformly throughout the tillage depth (Lal, 2004). Moreover, tillage brings subsoil to the surface where it is exposed to atmospheric cycles (Lemus and Lal, 2005) and increases the decomposition of soil organic carbon. However, zero tillage provides minimum soil disturbance and promotes soil aggregation through enhanced binding of soil particles (FAO, 2004). The depletion of soil organic carbon stocks has created a soil carbon deficit that represents an opportunity to store carbon in the soil through a variety of land management approaches (Franzluebbers*et al*., 2000). An increase in soil organic carbon can be achieved by increasing carbon inputs and decreasing the decomposition of soil organic matter or both (Raich and Potter, 2012). Sundermeir*et al*. (2005) observed that the rate of organic carbon sequestration in the soil increase by each ton of residue applied was more for zero tillage than for plow-tilled cultivation.

The research is essential as tillage practice is common in farming activities both especially in mechanised farming to identify the best tillage practices that can enhance the best storage of carbon sequestration to improve our agricultural productivity.Given the need for any agricultural system to increase soil organic carbon content apart from those fixed by plants that grow on the soil. There is a need to use any opportunity in the area of soil tillage practice that will further increase soil organic carbon (carbon sequestration) both in the short and in the long term to improve soil productivity. **This research aims to know the effect of different depths of tillage practice on the carbon sequestration in soil. The respective objectives are; (1) determine the effect of different depths of tillage practice on carbon sequestration of the soil and (2) to know the depth or level of tillage that enhances the highest carbon storage in the soil (Carbon sequestration) to recommend the best tillage depth.**

II. THE STUDY AREA

The research was carried out at the Research Farm of The Department of Agricultural and Bio-Environmental Engineering, School of Engineering, The Federal Polytechnic, Ado-Ekiti, Ekiti State. The area lies on longitude 5^o 13’ 17.0004”E and latitude 7^o 37’ 15.9996” N in the tropical rainfall of southwestern Nigeria.

Climate: The area experiences a tropical climate with distinct rainy and dry seasons in March – November and November - March respectively. The temperature is uniformly high with little variation from a mean of 25.5-30.1^{0}C while the annual rainfall is about 1370 mm.

Land, Soil and Water: The study area is part of the nearly level to gently undulating plains and undulating land with scattered rock outcrops, inselbergs, hills and ridges on undifferentiated basement complex under forest vegetation. It has low water and nutrient retention capacities and highly erodible.

Geology: Metamorphic rocks of the basement complex underlie the area. The sequence of the geologic unit in the area is; older granite, quartzite, migmatite gneiss complex and charnokitic.

III. METHODOLOGY

Field Work

The fieldwork was carried during the rainy season of the year 2018. At the site, an area of 0.5 ha was chosen and cleared with a cutlass before the tillage practice operation was done at a depth of 0 cm (control) 10cm, 20cm, 30cm. Two soil profiles of 1m x 1m x1m were dug in each of the tillage depths, soil samples were collected from each horizon for laboratory analysis. Core sampler of 5cm x 5cm dimension was used to collect samples for the determination of bulk density and moisture content. The morphological characteristics of the soil profiles were described following the procedure in the soil Survey manual (Soil Survey Division Staff, 2014).

Laboratory Analysis

The soil samples collected from the profiles were properly labeled and taken to the laboratory, air-dried, gently crushed to break up the peds and sieved with a 2 mm sieve. Materials retained on the sieve were labeled ‘gravel’ (> 2 mm) while materials that passed through the sieve were labelled ‘fine earth’ (< 2 mm) fractions. The analysis was carried out at the Department of Soil Science, Ekiti State University, Ado-Ekiti, Ekiti State, Nigeria.

Particle-size analysis

Particle size distribution was determined by the method described by Day (1965). Sand, Silt and Clay were determined by the Bouyoucos hydrometer using a 5% Calgon (sodium hexametaphosphate) solution, by shaking on a reciprocating shaker for 24 hours to ensure complete dispersion of the soil and determining sizes and amount of particles settling at progressive time intervals. From the percent clay, silt and sand, the textural triangle was used to determine the actual soil texture.

Bulk density (BD)

This was determined by the oven-dry method. Undisturbed soil cores were taken with metal rings (5 cm diameter and 5 cm height) at each horizon, except the extremely gravelly and stony horizons. The weight of the peds was measured. These were then oven-dried at 105^{0}C for 10 hours and the final weight of the dry soil peds was used to calculate the bulk density.

$$\text{Bulk density } (\text{g/cm}^3) = \frac{\text{weight of oven soil (g)}}{\text{Volume of soil } (\text{cm}^3)} \text{Eqn 1}$$

Moisture content

Soil samples were collected into moisture cans and weighed with 0.001g accuracy (A). The soil was oven-dried at 105^{0}C with moisture cans lid removed. The cans were removed from the oven and closed with the lids and allowed to cool in a desiccator, the cooled sample was weighed (B).

Calculation:

The moisture content in wt. % (m/m) was obtained by:

$$\text{Moisture (wt \%)} = \frac{\text{A} - \text{B}}{\text{B} - \text{can}} \times 100 \qquad \text{Eqn 2}$$

Organic matter/Carbon determination

The acid-dichromate wet oxidation method of Walkey and Black as described by Nelson and Sommers (1982) was used in the determination of organic carbon.

Carbon Sequestration Estimation

The potential of the soil to sequester carbon was assessed by estimating soil organic carbon (SOC) stock. Carbon sequestration was estimated by using the soil mapping approach whereby the various carbon content resulting from changes in soil properties. The following equation (Batjes, 1996) was used in the determination of the carbon sequestration.

$$\boldsymbol{S}\mathrm{OC} = \sum_{i}^{i}([(\mathrm{BDi} \times (\mathrm{THi}\ \times 0.01) \times [1 - \frac{\mathrm{CRi}}{100}]) \times \mathrm{Ci}] \times 100) \qquad \text{Eqn 3}$$

Where:

SOC (Mg/ha) = Organic carbon stock in a full profile

n = total numbers of horizons in a full profile

BDi (g/cm^3) = bulk density of the horizon i

THi (cm) = thickness of the horizon i in cm

CRi (vol.%) = volume of coarse fragments by horizon

Ci (%) = percentage of organic carbon in horizon i

Statistical Analysis

Pearson Correlation was carried out on the result of carbon estimation using Statistical Package for Social Sciences (SPSS).

IV. RESULT AND DISCUSSION

Table 1: Physical and Chemical Properties of Soil Sample (Research Farm of ABE)

	Horizon	BD (Kgm^{-3})	Depth (cm)	% Coarse Sand	% Fine sand	% Sand	% Silt	% Clay	% OC
Control (Upper level)	A	1.00	20.00	23.82	63.97	87.80	9.12	3.08	0.687
	B	1.40	23.00	35.90	49.89	85.80	10.12	4.08	0.753
	C	1.50	28.00	35.02	54.77	89.80	7.12	3.08	0.678
Control (Lower level)	A	1.00	20.00	31.86	48.93	80.80	13.12	31.86	0.690
	B	1.70	29.00	24.02	64.77	88.80	8.12	3.08	0.860
	C	1.60	22.00	32.61	55.18	87.80	5.12	7.08	0.229
10 cm (Upper level)	A	1.40	20.00	28.37	61.42	89.80	83.30	3.08	0.980
	B	1.70	43.00	31.86	54.43	89.80	8.12	5.08	0.716
	C	1.00	10.00	39.80	43.49	83.30	8.12	9.08	0.753
10 cm (Lower level)	A	1.40	26.00	29.80	60.99	90.80	7.12	2.08	0.678
	B1	1.60	16.00	23.13	66.66	89.80	7.12	3.08	0.229
	B2	1.70	15.00	28.97	63.82	92.80	5.12	2.08	0.716
	C	1.30	17.00	25.01	60.78	85.80	8.12	6.08	0.226
20 cm (Upper level)	A	1.30	20.00	23.53	63.20	86.80	16.28	3.08	0.603
	B	1.60	33.00	27.74	60.65	88.40	6.52	5.08	0.791
	C	1.50	14.00	33.04	47.75	80.80	5.12	14.08	0.301
20 cm (Lower level)	A	1.50	23.00	24.66	64.13	88.80	9.12	2.08	0.226
	B	1.70	23.00	22.88	67.91	90.80	6.12	3.08	0.678
	C	1.70	14.00	23.56	68.23	91.80	5.12	3.08	0.640
30 cm (Upper level)	A	1.60	19.00	23.01	63.78	86.80	10.12	3.08	1.010
	B1	1.30	24.00	29.45	58.34	87.80	16.28	4.08	0.450
	B2	1.50	24.00	31.11	57.66	88.80	7.12	4.08	0.340
	C1	1.40	11.00	31.40	50.39	81.80	6.12	12.08	1.150
	C2	1.20	11.00	59.33	11.46	70.80	7.12	22.08	0.490
30 cm (Lower level)	A	1.90	32.00	33.40	50.39	83.80	11.02	9.12	0.940
	B1	1.70	14.00	30.57	58.82	89.40	6.52	4.08	0.791
	B2	1.60	18.00	26.67	62.12	88.80	15.28	4.08	0.370
	C	1.70	21.00	37.54	37.25	74.80	9.12	16.08	0.180

Table 2: Estimation of Carbon Sequestration (Research Farm of ABE)

	Horizon	**The thickness of Horizon (cm)**	**Bulk Density**	**% of Coarse Sand**	**Organic Carbon**	**SOC (MgCha^{-1})**
Control (Upper Level	A	20.00	1.00	23.82	0.687	10.470
	B	23.00	1.40	35.90	0.753	15.540
	C	28.00	1.50	35.02	0.678	18.500
	Total					**44.510**
Control (Lower Level)	A	20.00	1.00	31.86	0.980	30.050
	B	29.00	1.70	24.02	0.867	32.480
	C	22.00	1.60	32.61	0.229	5.430
	Total					**67.960**
10 cm (Upper Level)	A	40.00	1.40	28.37	0.980	19.660
	B	23.00	1.70	31.86	0.716	35.660
	C	10.00	1.00	39.80	0.753	4.530
	Total					**59.850**
10 cm (Lower Level)	A	26.00	1.40	29.80	0.678	31.490
	B1	16.00	1.60	23.13	0.229	4.510
	B2	15.00	1.70	28.97	0.716	12.970
	C	17.00	1.30	25.01	0.226	3.750
	Total					**52.710**
20 cm (Upper Level)	A	20.00	1.30	23.53	0.603	11.990
	B	33.00	1.60	27.74	0.791	9.690
	C	14.00	1.50	33.04	0.301	4.510
	Total					**26.190**
20 cm (Lower Level)	A	23.00	1.50	24.66	0.226	27.420
	B	23.00	1.70	22.88	0.678	20.440
	C	14.00	1.70	23.56	0.640	11.640
	Total					**59.500**
30 cm (Upper Level)	A	19.00	1.60	23.01	1.017	23.800
	B	24.00	1.30	29.45	0.452	9.950
	B2	11.00	1.50	31.11	0.339	8.410
	C1	11.00	1.40	31.40	1.152	12.170
	C2	11.00	1.20	59.33	0.490	2.630
	Total					**56.960**
30 cm (Lower Level)	A	32.00	1.90	33.40	0.942	38.140
	B1	14.00	1.70	30.57	0.791	13.070
	B2	18.00	1.60	26.67	0.376	7.940
	C	21.00	1.70	37.54	0.178	3.960
	Total					**63.110**

Table 3: Tillage depths and the soil organic carbon sequestration

Tillage depth (cm)	**SOC (MgCha^{-1})**
0	67.96
10	52.71
20	59.50
30	63.12

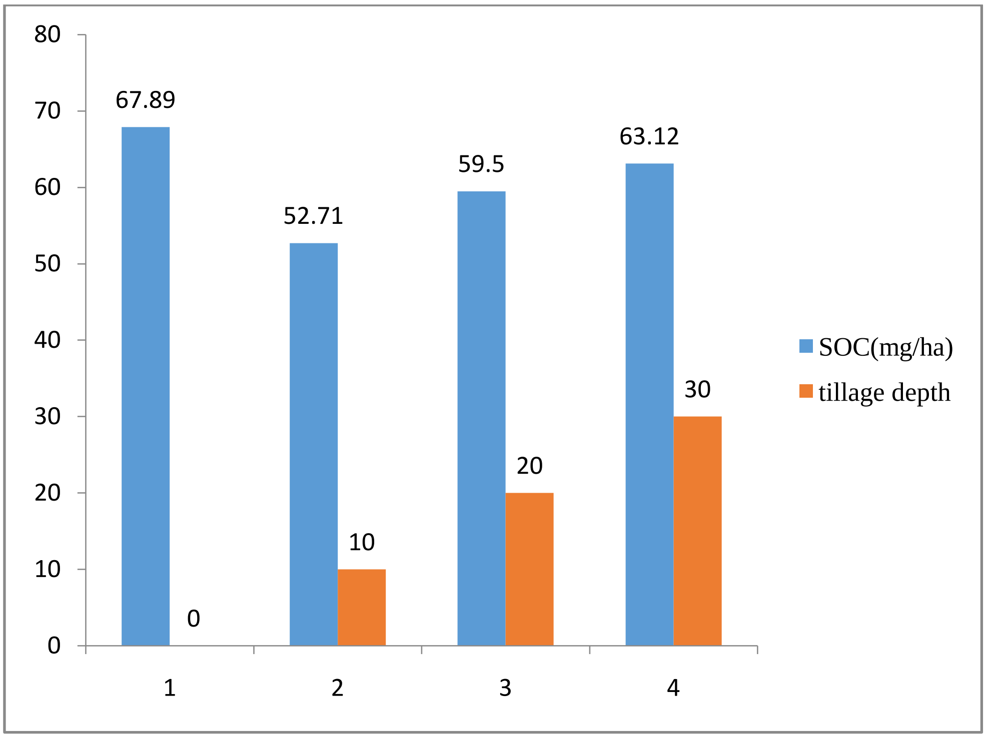

Figure 1: Relationship between Tillage Depth and Soil organic carbon

Table 4: Pearson Correlation matrix for the variable which influences SOC

	BD	% Coarse	OC	% of Fine Sand	% of Sand	% of Silt	% of Clay	SOC
BD	1							
% of Coarse	-.325	1						
OC	.011	-.207	1					
% of Fine Sand	.172	-.885*	-.060	1				
% Sand	-.177	-.204	-.469	.636	1			
% of Silt	-.079	-.001	.833*	-.399	-.840*	1		
% of Clay	.337	.169	.425	-.571	-.919**	.712	1	
SOC	.472	-.227	.847*	.015	-.345	.561	.439	

* Correlation is significant at the 0.05 level
* * Correlation is significant at the 0.01 level

Discussion

Table 1 presents the physical and chemical properties in each of the soil horizons at O cm, 10 cm, 20 cm, and 30 cm. There is variation in the bulk density concerning organic carbon. The clay content increase with depth in the profiles, which is probably linked with the migration of clay within the study area.The increase in the clay content with the depth may be the reason while the SOC sequestration also increases with depth. This assertion has supported the report of Jobbagy and Jackson (2000); Daniel Kane (2015) that clay particles form strong bonds effectively protecting carbon molecules from microbial attack and thereby explain why higher carbon content and clay are correlated.

Table 2 shows the estimation of carbon sequestration in each of the soil horizons at O cm, 10 cm, 20 cm, and 30 cm. The properties of the soil are sufficient to estimate carbon sequestration in each tillage depth. Table 3 shows that zero tillage has the highest value of carbon sequester 67.96 MgCha^{-1} especially when the lower level is taken into consideration for the estimation of carbon sequestration. Also, Figure 1 shows the relationship between the SOC and tillage depth which shows that zero tillage has the highest carbon sequestration.

Table 4shows, there is a high ($P>0.05$) positive correlation between Organic Carbon (OC) and Soil Organic Carbon (SOC) in all the tillage depths except at 20cm Organic carbon diminish with depth at 10cm downward. Also, there is a high positive correlation between silt and organic carbon (OC) which indicates that an increase in the content of silt in the soil will also result in higher SOC. The Predominance of sand on the surface was attributed tothe preferential removal of clay and silt by soil erosion (Ojanuga, 1978) and the influence of the parent material. The distribution of individual soil particles shows some level of significance in relationship with carbon Sequestration. The result was consistent with the finding of Abera (2012). Who reported that soil texture influences several characteristics of the soil microenvironment such as soil moisture, organic matter, and soil organic carbon content. The particle size distribution showed a positive and negative correlation with SOC sequestration and this revealed that SOC sequestration increased or decreased with the same trend of increasing or decreasing sand, silt and clay in the study area.

V. CONCLUSION AND RECOMMENDATIONS

Conclusion

The factors contributing to carbon sequestration were mostly soil properties in the study area. These factors are therefore needed to be considered in taking an appropriate approach to enhance carbon sink in agricultural practices suitable for mitigating CO_2 release to the atmosphere in the study area. It is concluded that the zero tillage level has the highest carbon storage in the soil with a value of 67.96 (mg/ha)

Recommendations

It is therefore recommended that the farmers should practice zero tillage operation in their farming system. In a situation whereby zero tillage is impossible, the tillage level should not be more than 10 cm to avoid the escape of carbon to the atmosphere which resultsin climate change problem, and zero tillage can be promoted among the peasant farmers by:

- Improves air quality:-Crop residue left on the surface improves air quality because it: Reduces wind erosion, thus it reduces the amount of dust in the air; Reduces fossil fuel emissions from tractors by making fewer trips across the field, and Reduces the release of carbon dioxide into the atmosphere by tying up more carbon in organic matter.
- Improves water quality: - Crop residue helps hold soil along with associated nutrients (particularly phosphorous) and pesticides on the field to reduce runoff into surface water. Residue can cut herbicide runoff rates in half. Additionally, microbes that live in carbon-rich soils quickly degrade pesticides and utilize nutrients to protect groundwater quality.
- Reduces soil erosion: -Crop residues on the soil surface reduce erosion by water and wind. Depending on the number of residues present, soil erosion can be reduced by up to 90% compared to an unprotected, intensively tilled field.

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