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Carbon and man in the 21st Century: trees as a tool for climate manipulation towards a sustainable environment

Adiaha[1], M.S., Chude[1],V.O., Nwaka[2], G.I.C. , Oku[3] E. E. and Ojimiwe[4], K.O.

[1*]Department of Planning, Research, Extension & Statistics, Nigeria Institute of Soil Science
[2&3]Department of Soil Science, Faculty of Agriculture, University of Abuja
[4*]Inspectorate and Accreditation Department, Nigeria Institute of Soil Science

Abstract

A field experiment was conducted, where stratified random sampling was employed to delineate point were *Phoenix dactylifera*, and *Mangifera indica* was sampled. The experimental point was replicated twice, where moist soil was audited for its organic matter and organic carbon content before and after the experiment. The textural class of the area using the USDA textural model after laboratory analysis indicated soils of the University of Abuja ranging from loam to sandy-loam soils. Laboratory fractionalization indicated that the soils of the area had coarse sand value (1.8 g kg^{-1}), fine sand content ranging from (4.5 – 5.2 g kg^{-1}), silt content at (4.5 – 5.2g kg^{-1}), and clay content at (72 g kg^{-1}). Estimation analysis revealed that the organic matter and organic carbon content of the area are low to moderately low. The outcome of the study revealed that Phoenix dactylifera and Mangifera indica was able to sequester carbon in the form of CO_2, which was audited in the form of Soil Organic Carbon (SOC). The study thereby encourages the cultivation of *Phoenix dactylifera* and *Mangifera indica* which is not only economic trees that produce food or fuelwood but as a climate change tool that could be used to regulate climate change in the form of CO_2 sequestration

Keywords: Climate Manipulation; Sustainable environment; Man; CO_2; SDG

Corresponding Author's E-mail Address: mondaysadiaha@gmail.com.Phone:+234*8062627551*
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1.0 Introduction

The continual suffering of humans, animals and the environment due to the variation in the earth's climatic system is a far cry from sustainable development.
Climate Change (CC) has been recognized as one of the significant threats to food security, environmental sustainability, including human-health development in the twenty-first century (Seager *et al*., 2007; Adiaha *et al*., 2020), the Intergovernmental Panel on Climate Change (IPCC) concludes that climate has changed over the past century, in which human activities have had an influence on these changes, and that climate is expected to continue to change in the future (IPCC, 2007). Even under conservation scenarios, future climate change is likely to include a further increase in global mean temperature (above 2°C - 4°C) with significant drying in some regions (Seager *et al*., 2007), as well as an increase in frequency and severity of extreme droughts, hot extremes, and heat waves (IPCC, 2007).

Several reports including the work of Adiaha *et al*. (2020); FAO (2006); UNFCCC (2000) has stated integrated approaches including agroforestry, terrestrial carbon monitoring, and auditing as a strategy in tackling carbon emission in the form of carbon dioxide (CO_2) sequestration, as these could act as an approach to convert the problematic CO_2 that heat-up the earth for plant utilization, and beneficial soil utilization.
The use of trees as a tool for climate monitoring and regulation has been stressed in the work of UNFCCC (2000). Economic trees have been stressed to have significance to humans as a source of food, building materials, including been utilized for paper production (FAO-UN, 2015), and also as a green-approach to cut-down the impact of climate change in terms of sequestration of atmospheric CO_2 (UNFCCC, 2000), where different tree species has been reported having abilities to trap and store a certain amount of atmospheric carbon in the form of CO_2 in their biomass and the soil. This view was also amplified in the work of

Adiaha *et al*. (2020) where the researcher reported different tree species been able to trap, store, and carbon-related with the soil in the form of soil organic carbon. A similar view as expressed in the work of Adiaha *et al*. (2020) was reported in the work of Seager *et al*. (2007) where the Scientists stated green-technology as a strategy for reducing the temperature of the heating globe.

Many diagnostic criteria and soil classifications are based on the colour of horizons. For this purpose Soil Scientists often use the Munsell colour system, identifying soil colour by visually comparing albums of colour chips with the colour of the soil sample. The precursor to these albums, The Munsell Atlas of Color, was published over 100 years ago in 1915. These albums, commonly called Munsell colour charts, have not changed significantly since the 1940s (Simonson, 1993). Building upon this technology, several advances in soil science and engineering have been recorded. For instance, the findings of Kirillova *et al*., (2018) have indicated that the Munsell Atlas of Color (Munsell Colour chart) could be used to estimate the amount of organic matter present in soil. This view was practically explained and presented in the work of FAO (2006) where the report indicated that at a specific soil textural class, the Munsell Colour chart could present the amount of organic matter present in soil (Table 1).

As a targeted strategy to contribute to the ongoing scientific approaches in combating the impact of climate change, this study seeks to present the interaction between man and carbon in terms of using economic trees as a tool for CO_2 sequestration. Building upon this expectation, the following objective arises:

I. Present the influence of Date palm (*Phoenix dactylifera)* tree in CO_2 sequestration in terms of influence in soil organic carbon
II. Present the influence of Mango (*Mangifera indica*) tree in CO_2 sequestration in terms of influence in soil organic carbon

Table 1: Estimation of organic matter content based on Munsell Soil Colour

Colour value	Munsell	Moist soil			Dry soil		
		S (%)	LS, SL, L	SiL, Si, SiCL, CL, SCL, SC, SiC, C	S	LS, SL, L	SiL, Si, SiCL, CL, SCL, SC, SiC, C
Light grey	7				< 0.3	< 0.5	< 0.6
Light grey	6.5				0.3–0.6	0.5–0.8	0.6–1.2
Grey	6				0.6–1	0.8–1.2	1.2–2
Grey	5.5			< 0.3	1–1.5	1.2–2	2–3
Grey	5	< 0.3	< 0.4	0.3–0.6	1.5–2	2–4	3–4
Dark grey	4.5	0.3–0.6	0.4–0.6	0.6–0.9	2–3	4–6	4–6
Dark grey	4	0.6–0.9	0.6–1	0.9–1.5	3–5	6–9	6–9
Black grey	3.5	0.9–1.5	1–2	1.5–3	5–8	9–15	9–15
Black grey	3	1.5–3	2–4	3–5	8–12	> 15	> 15
Black	2.5	3–6	> 4	> 5	> 12		
Black	2	> 6					

Source: FAO-UN (2006)

2.0 Materials and methods

2.1 Geography and Climate of the Study Area

Gwagwalada is a suburb of the Federal Capital Territory (FCT), Nigeria. It is situated along Abuja-Lokoja road at about 55 kilometers away from FCT main town and centrally located between latitudes 8°55' N - 9°00'N and longitudes 7°00'E - 7°04'E (Ishaya, 2013). With a population of about 157,770 at the 2006 census (FCDA, 2016). The region covered a a total landmass of about 65 km^2 out of the 8,000 km^2 of the total FCT landmass and was located at the centre of the very fertile area with an abundance of grasses (Ishaya, 2013). The area is bordered by Kuje area council to the East, Abaji area council to the West, Kwali area council to the south, and Abuja Municipal Area Council to the North-east and the North by Suleja Local Government Area of Niger State (Balogun, 2001). The area records about 60% of rainfalls during July to September, during which flood occurs within the area lying around the floodplain of River Usuma (Balogun, 2001). The highest rainfall is recorded in August with a rainfall amount of about 1400mm, while the least amount of rainfall is recorded in December, which records an average amount of 1mm. With an average of 258mm, with the most precipitation occurring in September. The variation in precipitation between the driest and wettest months is about 257mm annually (Balogun, 2001). The temperature of Gwagwalada is generally high during the day and falls sharply at night. Changes in temperature of about 17°C have been recorded between the highest and lowest temperature in a single day (Balogun, 2001). During the rainy season, the maximum temperature is lower due to dense cloud cover; the Diurnal annual range is also much lower sometimes not more than 7°C in July and August (Balogun, 2001). The mean maximum monthly temperature ranges between 28°C– 30°C and the mean minimum monthly temperature range between 25°C– 27°C (Balogun, 2001).

2.2 Experimental Design

The experiment took an empirical survey method, where sites of the study were replicated twice:
Site A: Tree species 1 (*Phoenix dactylifera*)
Tree species 2 (*Mangifera indica*)
Site B: Tree species 1 (*Phoenix dactylifera*)
Tree species 2 (*Mangifera indica*)
The study sites were delineated through reconnaissance surveys.

2.3 Sampling Techniques

The experiment adopted a stratified random sampling method, where areas sampled were surveyed following a common element of interest.

- *Soil sampling:* Two sets of soil sampling was done: on -field sampling at 0-30 cm using a soil core was done, and was used to estimate the amount of organic matter in the moist soil. While the second sampling was taken to the laboratory for physical analysis

2.4 Laboratory analysis

2.4.1 Soil textural determination and Analytical procedures:

i. *Air drying of soil samples*: The soil samples collected were air-dried at room temperature.
ii. *Laboratory grinding*: The soil sample was ground using the laboratory pistol and muter
iii. *Sieving*: Sieving of the ground soil particles was done using a 2 mm sieve. The sieved particles were labeled accordingly to the various sites investigated to avoid error
iv. *Parameter determination*: The sand, coarse sand, fine sand, silt, and clay content in the soil particle's determined following the Bouycucos (1935) analytical procedure for the hydrometer method.
v. Soil textural class was determined using the USDA textural class system.

2.5 CO_2 Sequestration Potential Determination, and Soil Fertility Assessment

- *Organic Matter determination:*

The organic matter was determined following the procedures of the Munsell Colour Chart at moist soil condition

- *Organic Carbon Determination:*

The organic carbon content of the soil was estimated from the quantity of organic matter present in the soil. This procedure was done following the equation as presented by van Bemmelen, which presented a value of 0.58, as a standard for converting SOM to SOC, thus:

2.6 Data analysis and Statistical Application

- Field data were analyzed following Sorensen's Species Similarity Index:

$$Organic\ Carbon\ (OC)\% = Organic\ Matter\ (OM)\% \times 0.58 \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

a. Sorensen's Species Similarity Index

Sorensen's Species Similarity Index was obtained using the procedure by Sørenson (1948) as modified by Nath *et al*. (2005)for estimating Sorensen's Species Similarity Index between two locations was calculated, thus;
Where:
C = number of species in site a and b

$$Sorensen's\ Species\ Similarity\ Index\ (SI) = \left(\frac{2C}{a+b}\right) \times 100 \quad \ldots\ldots\ldots\ldots\ldots 2$$

a+b = number of species at site 1 and 2 respectively

Assumption: At Sorensen's Species Similarity Index of: 1000 (10%) = Very high, 200 – 400 (2-4%)= Moderate, 600 - > 600 (6% – > 6%) = High

b. Correlation Statistics:

The Pearson Product Moment Correlation (PPMC) Analysis was used to draw up a relationship and evaluate the performance of each Site (A and B) in terms of change in Soil Organic Carbon (SOC), where Coefficient of Determination (R^2) was utilized to present the percentage change in the amount of CO_2 the different tree species were able to sequester at each site.

$$r = \frac{n\,(\varepsilon XY) - (\varepsilon X)(\varepsilon Y)}{\sqrt{[n\,(\varepsilon X^2) - (\varepsilon X)^2][n\,(\varepsilon Y^2) - (\varepsilon Y)^2]}} \quad \ldots\ldots\ldots\ldots\ldots 3$$

r = Pearson's correlation coefficient
n = number of paired scores
X = score of the first variable
Y = score of the second variable
XY = the product of the two paired scores

3.0. Results and Discussion

Sorensen's Species Similarity Index

Applying the Equation of Sørenson (1948) as modified by Nath *et al*. (2005), then;

$$(SI) = \left(\frac{2C}{a+b}\right) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

$$SI = \left(\frac{2 \times 4}{2+2}\right) \times 100 = 600 \sim 6\% \quad \ldots\ldots\ldots\ldots\ldots 5$$

The result of the outcome of the Sorensen's Species Similarity Index indicated that the Similarity Index (*SI*)of the performance of the tree species that exist between the two locations is (600 or 6%), which was ranked with a standardized value presented by Nath *et al*. (2005) to be high, indicating a view that the two tree species in the area acted similarly in their ability to sequester and look-up atmospheric carbon dioxide (CO_2). Building upon this ability, it could be stated that the tree species used statistically responded positively in their ability to act as a sink for the atmospheric pile-up of CO_2. This view expressed through the ability of the tree species used to sequester CO_2confirms the work of UNFCCC (2000); IPCC (2000) including Adiaha *et al*. (2020), which stated tress as a clean mechanism for atmospheric CO_2 sequestration while acting as a green approach for environmental sustainability.

3.1 Soil Physical Properties Behavior Relating to Soil Organic Matter and Soil Organic Carbon Determination

3.1.1 Behavior of Soil Physical State at Site A

Soil physical analysis at the start of the CO_2 sequestration monitoring (Table 2) indicated that the soils at the points where the two tree species were are loam for (the point at the location of Species 1) and Sandy-loam for (the point at the location of Species 2). With coarse sand content of (1.8g kg^{-1}), Fine sand content of (4.5g kg^{-1}), Silt content in the 50 g soil sample was obtained at (424g kg^{-1}), while the sand content was observed at (497.7g kg^{-1}). At the point where the Mango tree was a soil physical property of sand was obtained at (650.4g kg^{-1}), coarse sand content of (12.1g kg^{-1}) was obtained. The fine sand content at the point of species 2 was (21.5g kg^{-1}), while the silt and clay content of the 50g soil sample was observed at (274g kg^{-1} and 42g kg^{-1} respectively). This range of value obtained for the soils of this location confirms the work of FAO (2006) including the work of Oku *et al.* (2015) that that stated textural class of soil of the tropics been a factor to soil fertility due to their easy degradation because of it a textural class that often contain a high content of sand among other factors.

Table 2: Site A Soil Physical Properties at the start of CO_2 sequestration monitoring

Site A Soil Physical Properties at the start of CO_2 sequestration monitoring

	Sand (g kg^{-1})	**Coarse sand (g kg^{-1})**	**Fine sand (g kg^{-1})**	**Silt (g kg^{-1})**	**Clay (g kg^{-1})**	**USDA Textural Class**
Date palm (Spp 1)	497.7	1.8	4.5	424	72	Loam
Mango (Spp 2)	650.4	12.1	21.5	274	42	Sandy-loam

Spp = Species

Site A Soil Physical Properties after 5 months of CO_2 sequestration monitoring (Table 3)indicated a view that the soil textural class did not change; instead, a slide reduction was observed in Sand content at the point of specie A where (497g kg^{-1}) was obtained. An increase in the fine sand content was observed for fine sand, which was obtained at a value of (5.2g kg^{-1}) which stands over the value of (4.5g kg^{-1}) obtained at the beginning of the experiment. At the point of Specie B (Mango), a reduction was obtained for the sand content at a value of (650.1g kg^{-1}). An increase was observed for the content of fine sand (21.8g kg^{-1}) and (27.5g kg^{-1}) for silt content respectively. Although there was an increase in some of the textural parameters, the textural class of the soil did not change, this unchanged soil textural status confirms the work of FAO (2006) that indicted that soil textural change is very slow or may not change. The work of Oku *et al.* (2005) also validates this finding, where the researchers indicated that soil textural change might seem impossible or extremely slow, especially in problematic soils.

Table 3: Site A Soil Physical Properties after 5 months of CO_2 sequestration monitoring

Site A Soil Physical Properties after 5 months of CO_2 sequestration monitoring

	Sand **(g kg^{-1})**	Coarse sand **(g kg^{-1})**	Fine sand(g **kg^{-1})**	Silt **(g kg^{-1})**	Clay **(g kg^{-1})**	**USDA Textural Class**
Date palm (Spp 1)	497	1.8	5.2	424	72	Loam
Mango (Spp 2)	650.1	12.1	21.8	275	41	Sandy-loam

Spp = Species

3.1.2. Behavior of Soil Physical State at Site B

The physical status of the soils at Site B (Table 4) indicated that the soil has sand content of (598.5g kg^{-1}), coarse content of (7.9g kg^{-1}), fine sand content of (17.6g kg^{-1}), silt content of (334g kg^{-1}) and clay particle observed at (42g kg^{-1}), the range of values observed in this soil indicated that the soil is a Sandy-loam soil. The same textural class was observed for the soil found at the point of specie 2, although, a little variation was observed at this point, where it was found that the sand particle valued at (578.5g kg^{-1}), the coarse sand particle was obtained at (8.8g kg^{-1}), fine sand content was found to be (16.7g kg^{-1}), while silt and clay content was obtained at (324g kg^{-1} and 72g kg^{-1} respectively).

Table 4: Site B Soil Physical Properties at the start of CO_2 sequestration monitoring Soil

Site B Soil Physical Properties at the start of CO_2 sequestration monitoring Soil

	Sand (g kg^{-1})	**Coarse sand (g kg^{-1})**	**Fine sand (g kg^{-1})**	**Silt (g kg^{-1})**	**Clay (g kg^{-1})**	**USDA Textural Class**
Date palm (Spp 1)	598.5	7.9	17.6	334	42	Sandy-loam
Mango (Spp 2)	578.5	8.8	16.7	324	72	Sandy-loam

Spp = Species

Site B Soil Physical Properties after 5 months of CO_2 sequestration monitoring (Table 5) revealed that the soil still maintains the textural class of sandy-loam soils after five (5) months of study, this reveals that fact that soil does not easily change its texture, this view is in-line with the assertion of Adiaha (2016) who confirms no-change in soil textural class after physical and chemical soil manipulation with mineral fertilizer. Although there was no change in the soil textural class, slide decrease was found in the sand content at the point of Species 1 recorded at (595.5g kg^{-1}), while a little increase in coarse sand content was observed at a value of (10.9g kg^{-1}). At the point of Specie 2, a reduction to the tune of (576.5g kg^{-1}) was observed. An increase at a value of (10.8g kg^{-1}) was observed for coarse sand. An increase to (18.7g kg^{-1}) was observed for fine sand content, while a reduction in the silt content was noticed at a value of (322g kg^{-1}). This increase and decrease in the different soil fragments indicated that a variation occurred in the different soil ped for five (5) months. This view agrees with the work of FAO (2006) who reported variation in the system over a while due to interaction of soil with the ecosystem, including the atmosphere.

Table 5: Site B Soil Physical Properties after 5 months of CO_2 sequestration monitoring

Site B Soil Physical Properties after 5 months of CO_2 sequestration monitoring

	Sand (g kg^{-1})	Coarse sand (g kg^{-1})	Fine sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	USDA Textural Class
Date palm (Spp 1)	595.5	10.9	17.6	334	42	Sandy-loam
Mango (Spp 2)	576.5	10.8	18.7	322	72	Sandy-loam

Spp = Species

3.2 CO2 Sequestration Ability of Phoenix dactylifera and Mangifera indica for Modification of the Earth Climatic System, and Soil Fertility Improvement

Applying Equation 1, as described by van Bemmelen, soil organic matter (SOM) at Site A was found to be 3%, and Soil Organic Carbon (SOC) was found to be 1.74% indicating a view that the soil contains relatively low to the minimal quantity of soil organic matter and organic carbon. At Site B, it was observed that the soil contains 4%OM and 2.3 organic carbon. There was an increase in the amount of soil organic matter to the tune of (SOM% = 4) at Site A at the end of five (5) months of carbon sequestration and auditing. An increase in Organic carbon was also observed at a value of (SOM% = 2.32). This finding presents a view that the Date palm (*Phoenix dactylifera*) tree can act like a clean strategy or mechanism that could be harnessed for modification of the atmospheric CO_2 and regulation of soil fertility. This finding agrees with the research findings presented by UNFCCC (2000), which stated trees as been statistically fix and economically stable in acting like a green-approach for climate regulation and CO_2 sequestration. The findings of Adiaha *et al*. (2020) also reported a similar outcome presented in this result, where their indicated various tree species been able to capture and lock atmospheric CO_2 into tree biomass and the soil system.

Table 6: CO_2 Sequestration Ability of *Phoenix dactylifera* and *Mangifera indica* for Modification of the Earth Climatic System, and Soil Fertility Improvement

Differences that occur in the amount of CO2 trapped in the soil

	START Location		END Location	
	SITE A	SITE B	SITE A	SITE B
Tree Spp	**OM (%)**	**OC (%)**	**OM (%)**	**OC (%)**
Date PalmTree (Spp 1)	3	1.74	4	2.32
Mango Tree (Spp 2)	4	2.32	3	1.74

OM=Organic matter, OC=Organic carbon

3.3 Auditing of CO_2 sequestered as a result of the change that occurred in the amount of CO_2trapped into the soil

Building upon the behavior of the soils at Site A and Site B, it was observed that there was a change at (1%) in organic matter content and a (0.58%) change in the amount of organic carbon in the form CO_2 that the tree-soil system was able to trap, thereby indicating that *Phoenix dactylifera* is practically fit for capturing $CO_2$and for climate regulation. It was observed that *Mangifera indica* also captured (1%) organic matter and (0.58%) organic carbon, indicating a view that the Mango tree is also fit for climate regulation in terms of carbon capture, and storage into the soil-atmospheric system. The increase that occurred in the carbon trapped indicated that the two economic trees acted productively and positively in climate-soil regulation. The findings of this study agree with the research of Adiaha *et al*. (2020) that stated trees, including economic trees as a clean mechanism for atmospheric CO_2 sequestration. The work of IPCC (2000); UNFCCC (2000) is also in-line with the findings of this research, where their report indicated both economic trees and all green-plant as a sink for CO2 concentration in the atmosphere.

Table 7: Change that occurs in the amount of CO_2 trapped in the soil

Change that occurred in the amount of CO2 trapped in the soil	
Change in trapped CO_2(%)	Change in trapped CO_2 (%)
SITE A	SITE B
OM 2-OM1	OC2-OC1
1	0.58
1	0.58

OM=Organic matter, OC=Organic carbon

3.4 Relationship of Organic Matter and Organic carbon in Climate Regulation

The result indicated a perfect correlation between organic matter and organic, with a coefficient of Determination at ($R^2 = 1$) for Site A and Site B, respectively. Percentage analysis indicated that 100% interaction existed in the climate-soil interaction. The view of this finding supports the research of UNFCCC (2000) that indicated that a strong correlation exists between tree species and the climate, presenting a view that trees are targeted tools for moderating atmospheric temperature, and as a tool for CO_2 sink.

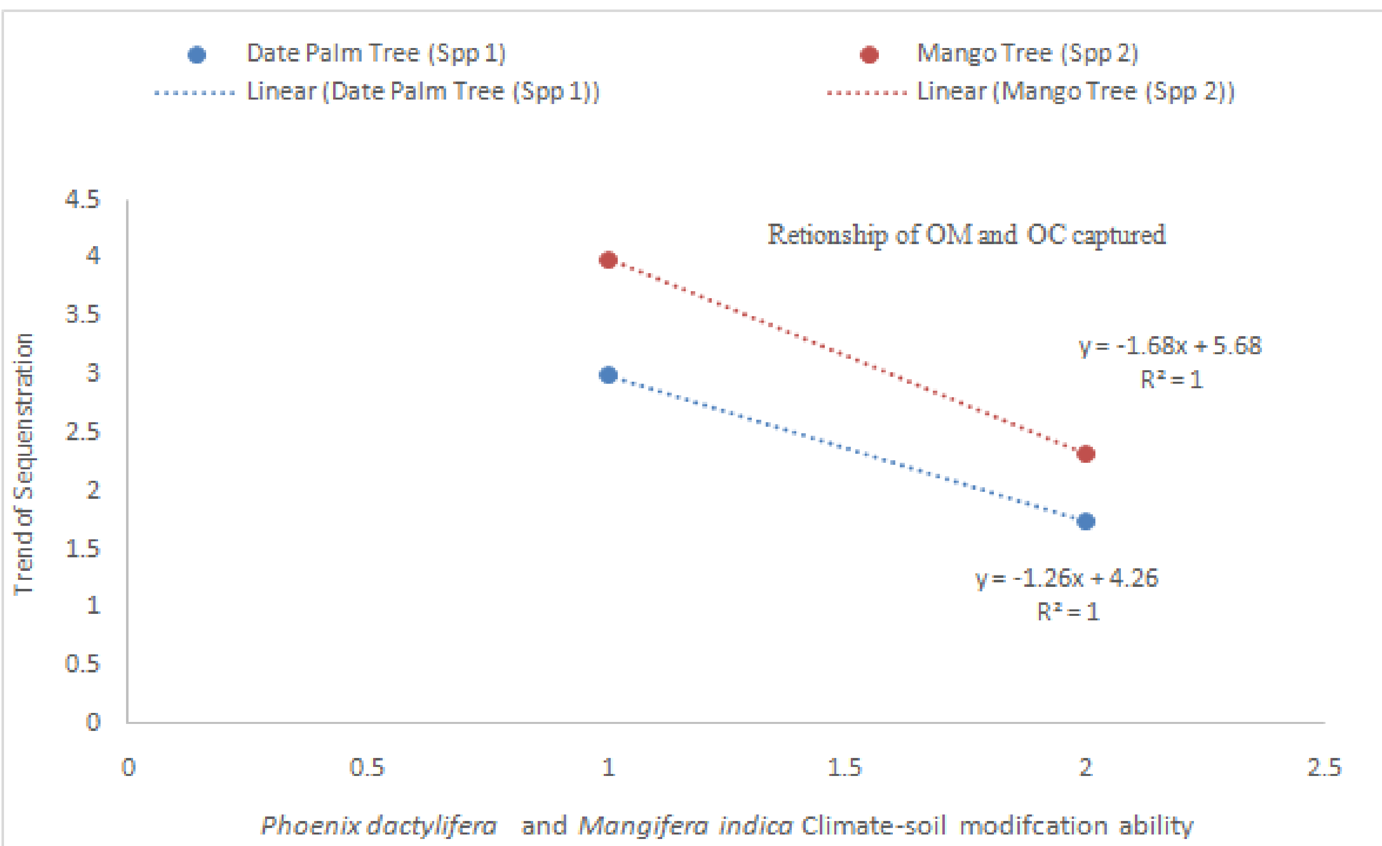

Figure 1: Climate manipulation Ability of Economic Trees in terms of Soil fertility development at Site A

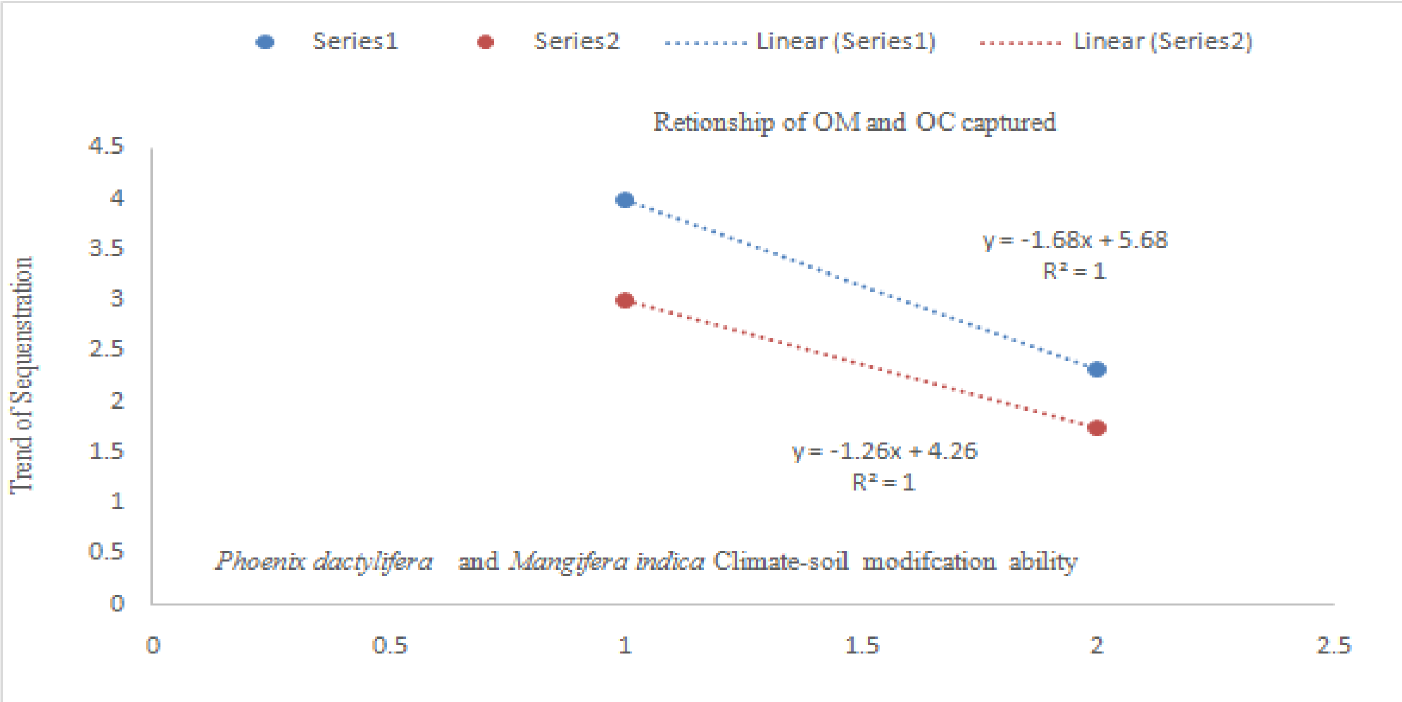

Figure 2: Climate manipulation Ability of Economic Trees in terms of Soil fertility development at Site B

4.0 Conclusion

The study indicated that *Phoenix dactyli*fera and *Mangifera indica* could productively capture atmospheric CO_2 and store as soil organic carbon and soil organic matter. The modification ability of the economic tree species indicated that the trees have most of the required ability to be included as a clean development mechanism tree for combating local variation in the climate as climate change. Five (5) months period is productive in atmospheric CO_2 sequestration ability of *Phoenix dactyli*fera and *Mangifera indica* in regards to soil fertility improvement for agricultural, soil, and environmental sustainability.

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