Exploring Soil Exchangeable Cations and Auditing the Potential of *Phoenix dactylifera* and *Mangifera indica* in CO_2 Sequestration into Soil Biomass in Naturally occurring tree patches

Exploración de los cationes intercambiables del suelo y auditoría del potencial de Phoenix dactylifera y Mangifera indica en el secuestro de CO_2 en la biomasa del suelo en una parcela arbóreo de origen natural

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Revista Iberoamericana de Bioeconomía y Cambio Climático
Universidad Nacional Autónoma de Nicaragua, León, Nicaragua
ISSN-e: 2410-7980
Periodicity: Semestral
vol. 9, no. 17, 2023
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Received: 05 January 2023
Accepted: 07 June 2023

URL: http://portal.amelica.org/ameli/journal/394/3943882005/

DOI: https://doi.org/10.5377/ribcc.v9i17.16207

Funding
Funding source: Sustainability Grant for "CO2 Sequestration modality projects" was issued through the reserved funds of Late S. A. Adiaha under ADISON Ventures.
Contract number: 004.
Award recipient: Monday Sunday Adiaha
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Abstract: **Background:** The experiment investigated soil Exchangeable Cations (EC) and audited the potential of Phoenix dactylifera and Mangifera indica in CO_2 sequestration into soil biomass in other acts as remediating-factor for the sustainability of agriculture.
Methodology: The study utilized to a stratified sampling research design where Infrared Gas Analyzer (IRGA) was utilized to sample stratified locations within the experimental landmass for CO_2 captured in the soil biomass within a five (5) month period. Sorensen's Species Similarity Index was applied in the study to x-ray and validate the performance of the two tree species for CO_2 sequestration potential similarity performance.
Results: Results indicated that there exists a potential for the two tree species to sequester atmospheric CO_2 at a value of 1.25 ± 0.13 and 0.47 ± 0.19 for Phoenix dactylifera and Mangifera indica respectively at a five (5) monthly interval. **Conclusions**: The distribution of exchangeable cation of Ca^{2+}, Mg^{2+}, K^+, and Na^+ indicated that there exist an increase of the exchangeable cations in the soil solution at the end of the five (5) months with a Coefficient of Variation (CV=101%). An increase was observed in the Cation Exchange Capacity (CEC) of the soil from 7.3 cmolkg^{-1} at the start of the experiment to 7.47 cmolkg^{-1} at the end of the experiment, indicating increased fertility status of the soils.

Keywords: Exchangeable Cations, tree-CO_2 potential, CO_2 Sequestration, Soil Biomass, Tree Patches.

Resumen: Antecedentes: El experimento investigó los cationes intercambiables (EC) del suelo y auditó el potencial de Phoenix dactylifera y Mangifera indica en el secuestro de CO_2 en la biomasa del suelo y en otros actos como factor de remediación para la sostenibilidad de la agricultura.
Metodología: El estudio utilizó un diseño de investigación de muestreo estratificado en el que se utilizó el analizador de gas infrarrojo (IRGA) para muestrear ubicaciones estandarizadas

dentro de la masa terrestre experimental para detectar el CO_2 capturado en la biomasa del suelo en un período de cinco (5) meses. El índice de similitud de especies de Sorensen se aplicó en el estudio para obtener una radiografía y validar el rendimiento de las dos especies de árboles para el rendimiento de similitud potencial de secuestro de CO_2. Resultados: Los resultados indicaron que existe un potencial de las dos especies de árboles para secuestrar CO_2 atmosférico en un valor de 1.25± 0.13 y 0.47±0.19 para *Phoenix dactylifera y Mangifera indica* respectivamente en un intervalo de cinco (5) meses. Conclusiones: La distribución de cationes intercambiables de Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} indicó que existe incremento de los cationes intercambiables en la solución del suelo al final de los cinco (5) meses con un Coeficiente de Variación (CV=101%). Se observó un aumento en la capacidad de intercambio de cationes (CEC) del suelo de 7,3 cmolkg^{-1} al comienzo del experimento a 7,47 cmolkg^{-1} al final del experimento, lo que indicó un aumento en el estado de fertilidad de los suelos.

Palabras clave: Cationes intercambiables, potencial árbol-CO_2, secuestro de CO_2, biomasa del suelo, parcelas arbóreos.

1. Introduction

The increasing frequency of drought, hunger, migration, malnutrition including societal unrest has been linked with cases of soil degradation, environmental fragmentation, and pollution, climatic change hazard aggravation including the intensive decline in soil carbon resources which maintains the soil living system (Adiaha *et al*., 2022; FAO, 2016). Empirical statistics has indicated about 80% stress the increasing frequency in the decline of soils potentiality (FAO, 2016), this threat has been projected by the Food and Agricultural Organization of the United Nations to be worse as the century progresses, especially with the increasing variability posed by the Earth climatic system (Adiaha *et al*., 2020). Hazards due to climatic impacts and its various setbacks on environment, economy including agricultural and socioeconomic development has been amplified in the works of Morales-Casco *et al*. (2016); Barahona-Mejia *et al.* (2022); Iglesias and Martin (2009); Rueda and Garcia (2002); Sol-Sanchez *et al*. (2017); Sierra-Figueredo and Durán-Zarboso (2022); Inter-American Development Bank (IDB) (2016); Tovar-Cabañas, *et al*. (2022); Vázquez-Montenegro *et al*. (2015); Sierra-Figueredo *et al*. (2019)

Exchangeable cations or anions are the ions that balance out in the soil system. The outer-sphere complexes with the charged surfaces, in which waters of hydration exist between the charged ion and the oppositely charged mineral surface in the soil system, are formed by exchangeable cations, including anions. Cation exchange capacity (CEC) measures the soil's capacity to hold positively charged ions by measuring exchangeable cations or anions. Exchangeable cations remain a very important soil property influencing soil productivity processes including structure stability, nutrient availability, soil pH and the soil's reaction to ameliorants and fertilizers (Hazleton and Murphy 2007).

Trees play a critical role in soil health improvement (Adiaha *et al*., 2020). Different part of trees has the potential for modulating the climate-environment nexus impact towards sustainability, for instance, tree

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root enhances soil water absorption and prevent erosion risk. Fallen leaf litter contributes to the buildup of organic matter in the system (Isha Foundation Outreach, 2021). The relationships between rainfall and trees including tree impact on climatic management as investigated by Suárez (1960); Nataren Velazquez *et al*. (2020); Duarte *et al*. (1994); Hernández *et al*. (2017); Harrison (1976) have presented trees as a critical tool for ecosystem and environmental regulation. The important role tress plays in climatic and environmental modulation, sustainability and management has been indicated by Sierra-Figueredo *et al.* (2021) including Granados *et al*. (2002) to be beneficial in the management of the plant Earth and her resources. Trees reduce soil temperature and provide shade, both of which help to regulate the Earth's climate. Trees recycle nutrients by pulling them up from deeper layers of the ground and bringing them up to the surface through the decomposition of leaf and plant litter to form soil organic matter (Adiaha *et. al*., 2020). Tree canopies play a critical role in trapping atmospheric nutrients, Greenhouse Gas (GHG) including the problematic CO_2heating up the globe (Adiaha *et al*., 2020). The contribution of trees to soil and food security has been researched by Dehollain (1995); Rebolledo-Martínez *et al*. (2019) including Curti *et al*. (2012), indicating trees including economic trees being among the sustaining factors for the production of food-feed-environmental biomass and also serving as a climatic modulation tool. Dios-Palomares *et al*. (2015) and Mercado (2016) experimentation proves that environmental stainability is critical for climatic wellbeing, hence creating bioeconomic approach towards sustainability (Mercado, 2016). Paz *et al*. (2013); Frioni (1990); Gama-Rodrigues and Gama Rodrigues (1999); Giri *et al*. (2010); Castilhos *et al*. (2004); Da Silva *et al*. (2006); Vallejo (2013) explained that social economy could be enhanced through farming involvement with application of economic trees, soil biomass including forestry and agroforestry practices utilizing trees.

Soils play critical role in environment and ecosystem climate regulation (Galantini and Suñer, 2008; Leguia *et al*. 2004). Soil chemical properties have been x-rayed by Muthanna, *et al*. (2016) to have played a critical role in global weather cycle modulation and solar activity variations, hence playing a sustainable role to human-environmental survival nexus. The ecological impact of soil remediation in-other to enhance soil fertility/productivity experimented by Adiaha (2022) including Jarquín-Hernández *et al*. (2019); Matias, *et al.* (2008); CENTA (2002), proves plant biomass as a sustainable tool for eco -remediation and for environmental-climatic nexus management and quality. The contribution of trees to soil nutrition and environmental nutrition as explained by Teixeira *et al*. (2003) indicates that *Cocos nucifera* L. cultivation increased soil fertility and environmental nutrition. Colque-Arispe and Ruiz-Alderete (2019) further explained that microbial biomass from trees and other carbon-producing products influenced soil residues. Beltran *et al*. (2006) prove that the incorporation of plant leaves including green manure holds great potential in soil carbon increase and soil productivity. Also, Fernández *et al*. (2004) views gave a critical point for the great benefit in plant biomass for soil fertility management.

Soil organic carbon (SOC) is the most important component in maintaining soil quality because of its role in improving the physical, chemical, and biological properties of the soil (FAO, 2016;Armida *et al*., 2005). The benefit of carbon-organic matter in soil suitability as experimented by Merchant (2001); Mercante *et al.* (2008) have indicated that the carbon-organic matter nexus plays a critical role in soil dynamics for microbial-ecological-climatic functionality nexus and beyond. Also, from a bioeconomic perspective, Toruño *et al.* (2022) and Sol-Sánchez *et al*. (2022) presented views indicating carbon-organic matter nexus as a key in productive paths of bioeconomy sustainability and for the development of mangroves for agricultural-climatic sector management and wellbeing. Environmental mismanagement including agricultural land malpractices often influence both the quantity and quality of SOC and its turnover rates (FAO, 2016), as such, stagnation or decline in yields has been observed in intensive cropping systems and in agro-plantations including plantation patches in the latest decennia (Bhandari *et al*., 2002), and has been attributed to the poor quality and quantity of SOC and its impact on nutrient supply and soil biophysical wellbeing (Bhandari *et al*., 2002). The level of SOC at a point in time reflects the long-term balance between addition and losses of SOC, particularly C, and N, under continuous cultivation (Manna *et al*., 2005; Cochrane and Barber, 1993). Soil organic carbon over the years has been influenced by climatic changes, which has caused a decline in terrestrial carbon stock in ecosystems and with the view of continuing anticipated changes being expected (IPCC, 2007). Research survey statistics of IPCC (2020) including the findings of Adiaha *et al.* (2020) has indicated that increase in global climatic changes will impact more on Africa among other vulnerable regions of the Earth due to its position and composition. For instance, Africa being one of the driest continents has faced and has been projected by Scholars including the recommendations of IPCC (2007) to face intense drought among other negative natural phenomena, building upon this impending threats projected then it becomes necessary for sustainable actions towards the sustainability of our environmental systems which over centuries has provides us the basic necessities of life (food, shelter and clothing) among other luxuries humanity has enjoyed. As a sustainable strategy to combating environmental degradation and for building up of soil organic matter and soil organic carbon for sequestration of the problematic CO_2 which among other greenhouse gases heating-up the globe the utilization of economic tress such as *Phoenix dactylifera* and *Mangifera indica* becomes imperative, then could serve as low-cost green technology and as a sustainable bio-tool for ecological and environmental transformation, it is on this basis that the following Research Hypothesis has been developed:

1. There exists the potential of *Phoenix dactylifera* and *Mangifera indica* to sequester CO_2 in the form of Soil Carbon ec1.

$$Y_j = Y_1 \quad \text{[Ec 1]}$$

Where;

Yj = potential of tree species to capture and lock CO_2 *in soil biomass*

Y1= time (1---i)

2. *Phoenix dactylifera* and *Mangifera indica* does not have the potential to sequester CO_2 in the form of Soil Carbon ec 2.

$$Y_j \neq Y_1 \quad \text{[ec 2]}$$

Where;

Yj = potential of tree species to capture and lock CO_2 *in soil biomass*

Y1= time (1---i)

Note: Yj = Y1 Yj ≠Y1 was modified and adopted for hypothesis testing following the methodology proposed by Leite and Olivera (2002) for analyzing hypothetical computations with a gas analyzer.

In other to serve a mitigative and adaptive strategy towards the management of climate change, and for the realization of low-cost green technology for CO_2. sequestration, the following objectives arise:

1. Determine the potential of Date palm (*Phoenix dactylifera*) in CO_2. sequestration and the influence on soil organic carbon.
2. Identify the performance of Mango (*Mangifera indica*) in CO_2. sequestration and building up soil organic carbon.
3. Audit soil exchangeable cations in the *Phoenix dactylifera* and *Mangifera indica* naturally occurring plantation.

2. Materials and methods

2.1. Study Site

The study was conducted within naturally occurring tree patches found within Latitude 8.981833°. and Longitude 7.190139°. and at Latitude 8.981639°. and Longitude 7.193583°. The area lies within Gwagwalada Area Council, a suburb of the Federal Capital Territory (FCT) (FCDA 2000). Gwagwalada is part of the Abuja Municipal Area Council of the FCT, Nigeria (Balogun, 2001; Adakayi, 2000; Ishaya, 2013) (Figure. 1).

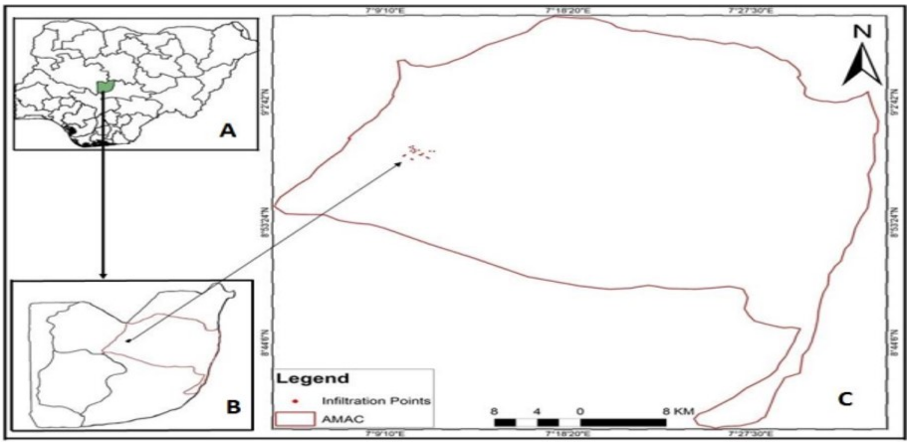

FIGURE 1
Study Area/Location
A=Nigeria, B= Abuja, C=Gwagwalada

2.2. Study site

The Geography, Climate and Soils at the Experimental Area is as preseted in Table I

TABLE 1
Geography, Climate and in Soils at the Experimental Area

	Selected Species composition	Tree species	Latitude	Longitude	Temperature	Highest Annual Rainfall	Highest Relative humidity	Soils of the Area
Site A	Tree species 1	Phoenix dactylifera			25oC-27oC	1632mm	20%	deep, weakly to moderately structured, sand to sandy clay in texture with gravel and concretionary layers in the upper or beneath the surface layers
	Tree species 2	Mangifera indica	8.981833o	7.190139o				
Site B	Tree species 1	Phoenix dactylifera						
	Tree species 2	Mangifera indica	8.981639o	7.193583o				

Table 1 indicates the general information on study sites that were delineated through reconnaissance surveys.

Soils and species composition in Site A and Site B: The upland soils under the basement complex formation are generally deep, weakly to moderately structured, sand to sandy clay in texture with gravel and concretionary layers in the upper or beneath the surface layers. The area at Site A and Site B are only naturally occurring patches with few appearances of different species of *Phoenix dactylifera* and *Mangifera indica* among other tree types.

2.3 Experimental Design

A correlational research design was applied in the study, this design was done following the protocol as described by Adiaha *et al.* (2022) for the relationship between two or more variables.

· *The infrared gas analyzer Sampling Design*

A stratified Random sampling procedure was adopted, where sites of the study were replicated twice. The areas sampled were surveyed for the appearance of the naturally occurring *Phoenix dactylifera* and *Mangifera indica* tree patches. The procedure was followed according to the recommendations of the IPCC (2007).

2.4 Laboratory Chemical Analytical Procedures

Available phosphorus was determined following the Bray 1 method prescribed for tropical soil as outlined by Page *et al.* (1982). Exchangeable cations were determined by the Ammonium acetate extraction method as described by Udo *et al.* (2009). Nitrogen was determined by the Macro Kjeldahl digestion method as described by Udo *et al.* (2009).

2.5 Ratings for interpreting selected soil properties

The procedure for the Coefficient of Variation (CV) variability Class (Table 2) as presented by Wilding (1985) as cited in Adiaha *et al.* (2019) was followed to determine the variability influence in the study.

Table 2: Coefficient of Variation Variability Classes

TABLE 2
Coefficient of Variation Variability Classes

CV%	Class
< 15	Low
16 - 35	Moderate
> 35	High

Source: Wilding, (1985) as cited in Adiaha et al. (2019)

2.6 In-situ Determination Procedure for Measuring Amount of CO_2 Trapped in the Soil

Infrared gas analyzer (IRGA) measurement was done at the start of the experiment and at five (5) months of the experiment. The result generated from the gas analyzer was subjected to statistical analysis for testing the research hypothesis. The infrared gas analyzer (IRGA) measurement was done following the procedure of Davidson *et al.* (2002). The IRGA apparatus (Licor LI-6400-09) has a gas retention chamber of 991 cm., covering a soil surface area of 71.6 cm., an infrared irradiator, and a measurement chamber, also described as an optical path and filter plus a detector. The infrared signal traverses the measurement chamber, which is filled with the sampled gas and is measured by the detector. The CO_2 emission is calculated by the linear regression of the increase in CO_2 concentration inside the chamber along with the measurement period. Before beginning measurement, the CO_2 concentration near the soil surface was registered (about 350 μmol mol^{-1}), and this value was introduced in the software system of the apparatus to function as a reference value.

2.7 Computation and Statistical Analysis

Descriptive statistics of Mean, Standard deviation including Coefficient of Variation (CV) were applied in the study to analyze the outcome of the experimental data.

2.8 Sorensen's Species Similarity Index

The Sorensen's Species Similarity Index (SI) was applied to find and compare similarities that may exist in the ability of *Phoenix dactylifera* and *Mangifera indica* in CO_2 gas sequestration, this procedure was done following the equation of Sorenson (1948), modified by Nath *et al.* (2005) and utilized by Adiaha *et al.* (2022). Thus, Sorensen's Species Similarity Index (SI) between two locations was given as ec 3;

$$(SI) = \left(\frac{2c}{a+b}\right) \times 100 \qquad [ec\ 3]$$

Where:

C = number of species in sites a and b

a+b = number of species at sites a and b respectively

Assumption: At Sorensen's Species Similarity Index of: 1000 (10%) = Very high, 200 – 400 (2-4%) = Moderate, 600 - 1/4 600 (6% 1/4 6%) = High

a. **Correlation Statistics**

Correlation analysis following the protocol of Adiaha *et al.* (2022) was applied in the research to draw up the relationship and evaluate the performance of the field data at each of the Site (A and B) in regard to the two tree species ability for CO_2 sequestration.

3. Result and discussion

3.1 Potential of *Phoenix dactylifera and Mangifera* indica trees to Sequester CO_2. into the soil biomass

Data presented in Table 3 indicated that *Phoenix dactylifera* and *Mangifera indica* was able to contribute to the trap of CO_2 into the soil biomass, where a value of 1.25 ± 0.13 and 0.47 ± 0.19 was obtained as the increase (difference) that existed in CO_2 flux in the soil at a five (5) months interval in the patches. The outcome of the result confirms the work of Adiaha *et al.* (2022); Adiaha *et al.* (2020) which indicated the ability of tree species in playing remediation strategy in terms of sequestration of atmospheric CO_2. Outcome of the studies further confirms the report of IPCC (2007) which indicated forestation strategies including the utilization of trees as one of the measures for achieving the adaptations modalities against climatic hazard vulnerability.

TABLE 3

Potential of *Phoenix dactylifera and Mangifera indica* trees to Trap CO_2 into the soil biomass

Mean of five points in suit IRGA measurement						
IRGA	Time		e-s	Statistical test for Hypothesis		Conclusion
	Start	End		Yj = Y1	Yj ≠Y1	
Areas for Specie a (Phoenix dactylifera)	2.22 ± 1.34	3.47 ± 1.21	1.25 ± 0.13	YES	NO	Yj = Y1
Areas for Specie b (Mangifera indica)	2.69 ±1.48	3.16 ±1.29	0.47 ± 0.19	YES	NO	Yj = Y1

s= start of the CO_2 monitoring, e= end of the CO_2 monitoring

e-s = value at the end – value the at start of the CO_2 monitoring

Note: Trapped $CO_{2.}$ data taken around five (5) sampling points within the patches where naturally occurring *Phoenix dactylifera* and *Mangifera indica* trees were found was summed to obtain the value for start and end for the CO_2 monitoring program

3.2. *Phoenix dactylifera* and *Mangifera indica* Influence on the Soil Fertility

The outcome of the experiment as indicated in Table 4 presented that the available P in the soil increased from 13 (mg kg^{-1}) to 18 at a five (5) month interval. The N content in the soil was influenced to a rise at 0.01

to 0.05 (g kg^{-1}) at a five (5) month interval. The Exchangeable acidity of the soil was influenced from 1 to 1.11. Outcome observed in the fertility status of the soil following the CO_2 sequestration program presents views that the existence of the tree contributed to the observed increase in the fertility potential of the soil. Views expressed in the outcome is in line with the work of Kekong *et al.* (2016) who expressed increase in soil fertility status following the presence of organic material contributed to soil from organic sources and surrounding tree patches. It could be stated that a high Coefficient of Variation (CV= 129%) at the end of the CO_2 sequestration monitoring observation indicated that the presence of the patches contributed to the soil fertility status.

TABLE 4
Soil fertility impact of *Phoenix dactylifera and Mangifera indica*

Chemical Characteristics of the soil			
START		END	
N (g kg-1)	0.01	N (g kg-1)	0.05
Available P (mg kg-1)	13	Available P (mg kg-1)	18
Exchangeable Acidity	1	Exchangeable Acidity	1.11
Mean	4.68	Mean	6.37
STD	5.89	STD	8.23
CV (%)	126	CV (%)	129
SE	3.40	SE	4.75

3.2.1 impact of Individual tree species on Soil Chemical properties at Start of the Project

Result output presented in Table 5, Table 6 and Figure 2 indicated a view that the tree species at location and A and B contributed significantly to the build-up of the soil chemical wellbeing of the area. Outcome of the result presented in Table 7 and Table 8 shows 95.0% confidence intervals for the means and standard deviations of each of the variables. Each of the two tree species: *Phoenix dactylifera and Mangifera indica* stands statistically significant at the 95% probability level of the P-statistics indicating a view that the individual tree species has high potential for influencing the chemical regulation of soils of the area. Outcome of this finding indicated that the two tree species has an influence in the fertility status of the soils of the area, the findings explained in this outcome confirms the work of Adiaha *et al.* (2022) who expressed trees being a contributor to soil carbon build-up.

TABLE 5
95.0% confidence intervals of individual performance of *Phoenix dactylifera and Mangifera indica* at the Start of the Programme

	Mean	Stnd. error	Lower limit	Upper limit
Site A (Phoenix dactylifera)	2.58	1.30181	1.03442	6.19442
Site B (Mangifera indica)	2.58	1.30181	1.03442	6.19442

TABLE 6
Sigma strength of individual performance of *Phoenix dactylifera and Mangifera indica* at the Start of the Program

	Sigma	Lower limit	Upper limit
Site A (Phoenix dactylifera)	2.91094	1.74404	8.36474
Site B (Mangifera indica)	2.91094	1.74404	8.36474

TABLE 7
Correlations performance of individual *Mangifera indica* at the Start of the Program

	Site A (Phoenix dactylifera)
Site A (Phoenix dactylifera)	
Site B (Mangifera indica)	1.0000
	(5)
	0.0000

TABLE 8
Correlations performance of individual *Phoenix dactylifera* at the Start of the program

	Site B (Mangifera indica)
Site A (Phoenix dactylifera)	1.0000
	(5)
	0.0000
Site B (Mangifera indica)	

* *P-values below 0.05 indicate statistically significant non-zero correlations at the 95.0% confidence level. The following pairs of variables have P-values below 0.05: Site A (Phoenix dactylifera) and Site B (Mangifera indica) *Table 8 and 9 shows the Pearson product-moment correlations between each pair of variables. These correlation coefficients range between -1 and +1 and measure the strength of the linear relationship between the variables. Also shown in parentheses is the number of pairs of data values used to compute each coefficient. The third number in each location of the table is a P-value which tests the statistical significance of the estimated correlations.

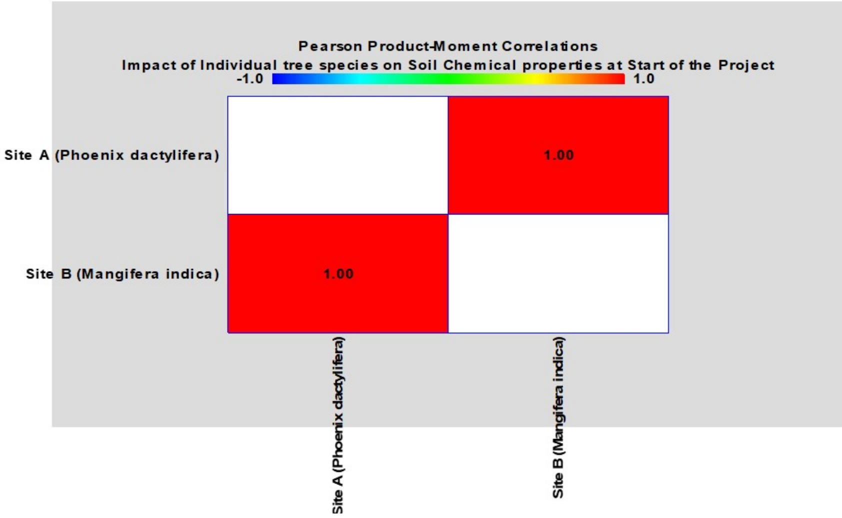

FIGURE 2
Impact of Individual tree species on Soil Chemical properties at Start of the Project

3.2.2 Impact of Individual tree species on Soil Chemical properties at End of the Project

Analytical computational outcome presented in Table 9 shows 95.0% confidence intervals for the means and standard deviations of each of the variables. The intervals in Table 10 indicates that the populations from which the samples come from possess a normal distributions. Analytical computational output presented in Table 11, Table 12 and Figure 3 indicated the Pearson product moment correlations between each pair of variables, where result of the output indicated a view that there exist a high significant difference at 95% probability level of the P-Statistics in the potential of *Phoenix dactylifera* and *Mangifera indica* to play a role in the build-up of soil chemical nutrients of the area. It could be stressed that both *Phoenix dactylifera* and *Mangifera indica* performed at similar potential in its contribution to the soil chemical fertility of the area. The Findings presented in this outcome confirms the work of Kekong *et al.* (2016) who expressed increase in soil fertility status with organic materials of trees and animal origin.

TABLE 9
95.0% confidence intervals of individual performance of
Phoenix dactylifera and Mangifera indica at End of the program

	Mean	Stnd. error	Lower limit	Upper limit
Site A (Phoenix dactylifera)	2.746	1.30025	-0.864079	6.35608
Site B (Mangifera indica)	2.746	1.30025	-0.864079	6.35608

TABLE 10
Sigma strength of individual performance of *Phoenix dactylifera and Mangifera indica* at the End of the program

	Sigma	Lower limit	Upper limit
Site A (Phoenix dactylifera)	2.90744	1.74195	8.3547
Site B (Mangifera indica)	2.90744	1.74195	8.3547

TABLE 11
Correlations performance of individual *Mangifera indica* at End of the program

	Site A (Phoenix dactylifera)
Site A (Phoenix dactylifera)	
Site B (Mangifera indica)	1.0000
	(5)
	0.0000

TABLE 12
Correlations performance of individual *Mangifera indica* at End of the program

	Site B (Mangifera indica)
Site A (Phoenix dactylifera)	1.0000
	(5)
	0.0000
Site B (Mangifera indica)	

* *P-values below 0.05 indicate statistically significant non-zero correlations at the 95.0% confidence level. The following pairs of variables have P-values below 0.05: Site A (Phoenix dactylifera) and Site B (Mangifera indica)
** Table 11 and Table 12 show the Pearson product-moment correlations between each pair of variables. These correlation coefficients range between -1 and +1 and measure the strength of the linear relationship between the variables. Also shown in parentheses is the number of pairs of data values used to compute each coefficient. The third number in each location of the table is a P-value which tests the statistical significance of the estimated correlations.

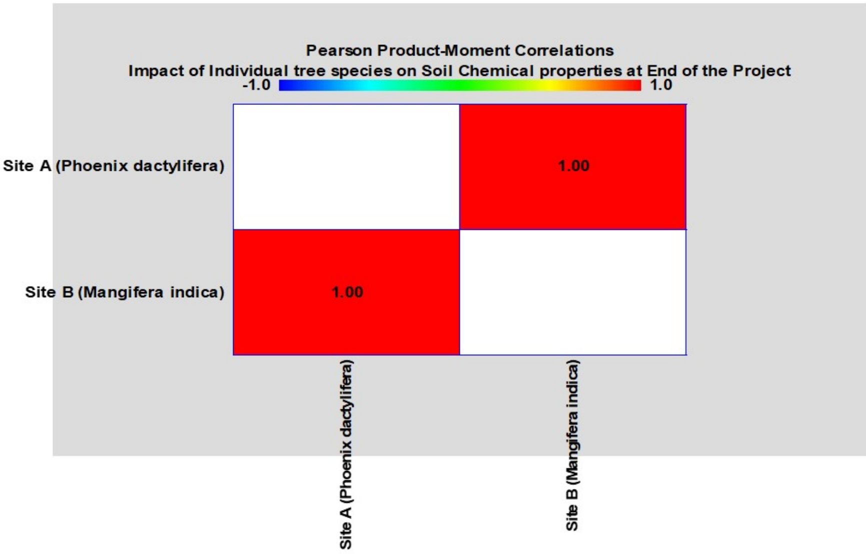

FIGURE 3
Impact of Individual tree species on Soil Chemical properties at End of the Project

3.3 Impact of *Phoenix dactylifera* and *Mangifera indica* on the soil Exchangeable cations

It was observed that there exist an increase of the exchangeable cations in the soil of the area at the end of five (5) month of the CO_2. monitoring experiment as presented in Table 13, where Ca^{2+} increased from 2.2 to 2.4 (cmol kg^{-1}) and Mg^{2+} from 2.99 to 3.11, K^{+} from 0.31 to 0.35 (cmol kg^{-1}), Na^{+} from 0.1 to 0.4 (cmol kg^{-1}) respectively. Outcome of the study is in line with the research outcome of Kekong *et al.* (2016) who reported organic materials from sources including tree sources being influence chemical composition of soils. Findings of Adiaha (2022) who surveyed trees ability to sequester atmospheric CO_2 also validate outcome of this study.

TABLE 13
Impact of *Phoenix dactylifera and Mangifera indica* on the soil Exchangeable cations

Exchangeable Cations (cmol kg-1)			
START		END	
Ca2+	2.2	Ca2+	2.4
Mg2+	2.99	Mg2+	3.11
K+	0.31	K+	0.35
Na+	0.1	Na+	0.4
ECEC	7.3	ECEC	7.47
Mean	2.58	Mean	2.746
STD	2.60	STD	2.60
CV (%)	101	CV (%)	95
SE	1.16	SE	1.16

3.3.1 Comparing The Performance of ***Phoenix Dactylifera and Mangifera Indica*** **to other tree species**

Although other tree species have been utilized in soil fertility programs like in the case of *Acacia albida, Acacia senegalensis, Combretum aculeatum,* and *Piliostigma reticulatum*) which increased soil ammonium-N^+, P, Na^{2+}, K^+, Ca^{2+}, and Mg^{2+} in the semi-arid West African states as presented by Oumarou (2016), but *Phoenix dactylifera* and *Mangifera indica* utilization remain of the greatest potential because of its availability and wide distribution across all the agro-ecological zone of the country among other mangrove and tropical distribution of the world apart from being economic trees that serve as food, fuelhood and contributes towards micro-macro climate modulation (figure 4).

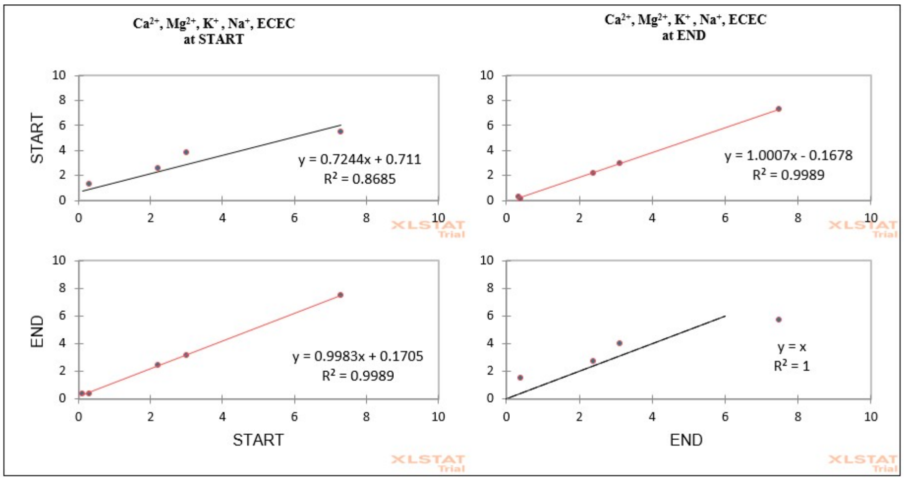

FIGURE 4
Exchangeable Cations performance in the CO_2 experimental evaluation

3.4 *Sorensen's Species Similarity Index*

From the protocol of Adiaha *et al.* (2022) in utilizing the equation of Sorenson (1948), modified by Nath *et al.* (2005), thus ec 4, ec 5;

$$(SI) = \frac{2c}{a+b} \times 100 \quad [ec4]$$

$$(SI) = \frac{2 \times 4}{2 \times 2} \times 100 = 200{\sim}2\,\% \qquad [ec\ 5]$$

Sorensen's Species Similarity Index of *Phoenix dactylifera* and *Mangifera indica* indicated that there exist Similarity Index (SI) of 2% between the two locations, hence, SI = 200 or 2%. This outcome was ranked using a standardized value presented of Nath *et al.* (2005) as described by Adiaha *et al.* (2022) to be moderate, further indicating a CV of 95 %, which validated that the two tree species (*Phoenix dactylifera* and *Mangifera indica*) acted similarly in their sequestering capacity towards the environmental CO_2 decline for the achievement of soil-environmental-climatic wellbeing. The outcome of this work totally confirms the findings of Adiaha *et al.* (2022) which indicated the potential of trees in acting similar in toward eco-wellbeing. Findings of UNFCCC (2000); IPCC (2000) also align with the outcome of the SI potentials of *Phoenix dactylifera* and *Mangifera indica* in the studied ecosystem which remains a key for Agric-Climate-Environmental Transformation Nexus.

4. Conclusion

Experimental results have indicated that there exists the potential of P*hoenix dactylifera* and *Mangifera indic*a to sequester atmospheric CO_2 at a value of 1.25± 0.13 and 0.47±0.19 respectively at five (5) monthly intervals. The outcome of the study further indicates that there is an increase in the distribution of exchangeable cations of Ca^{2+}, Mg^{2+}, K^+, and Na^+ after a five (5) months interval following the CO_2 sequestration program at a Coefficient of Variation of (CV=101%). Cation Exchange Capacity (CEC) of the soil increased from 7.3cmolkg^{-1} at the start of the experiment to 7.47 cmolkg^{-1} at the end of the five (5) months of CO_2 auditing experiment which indicated increased in the fertility status of the soils, thereby enhancing the soil toward agri-climate-environmental-ecological transformation nexus.

Recommendation

1. Since *Phoenix dactylifera* and *Mangifera indica* falls into group of commonly found economic trees in the area and similar global geography, hence it intensive utilization for soil biochemical modification is advocated.

2. Survey into 150cm -200 cm depth of soil profile could give more outlook into the nutrient and carbonic behavior of the area, hence advocated.

Acknowledgments

Thanks to the Nigeria Institute of Soil Science for providing internet facility to enhance the literature search, manuscript type-setting and for providing enabling environment for data analysis and interpretation. I am grateful to the Institute of Biopaleogeography named under Charles R. Darwin, Poland for providing models and statistical software and packages.

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