Estimating The Carbon Sequestration Potential of Trees Within Rivers State University Main Campus

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Key words: Carbon Sequestration Potential, Spatial Distribution

SUMMARY

The carbon sequestration potential (CSP) of the trees within River's State University Main Campus was determined, using the non-destructive method, and allometric equation. A total of 1,865 trees were measured. The trees were categorized as Recently Planted, Old, Fallen, and Dead without Leaves (DWL). 24.2 % of the entire tree population were recently planted, 5.2 % of the trees were Fallen, 1.0 % were dead without leaves, this could be due to natural occurrence and about 70% of the tree population were old trees that were previously planted. The total carbon sequestered by the trees within the study area is 13603.43Kg, approximately 13.60 Metric Tons. The previously planted (Old) trees (1297 trees), and the recently planted trees (453 trees), sequestered approximately 13,034.92kg and 478.973kg carbon respectively. This accounts for about 96.5% and 3.5% of the entire carbon sequestered within the studied area. Individually, the most carbon was sequestered by the Teak tree (Tectona grandis), followed by Kashmir tree (Gmelina arborea) and Gum tree (Eucalyptus spp.), with CSP rate of 73.78kg, 52.77kg, and 43.19kg respectively. The coefficient of residual, R-squared, showed that 95% of the dependent variable was explained or accounted for by the explanatory variables, and the explanatory variables were statistically significant. Spatial distribution analysis and hot spot analysis were carried out to determine the spread of the top 3 trees that sequestered more carbon, and the spatial distribution of CO_2 within the study area. Based on the CSP rate of the trees within the studied area, the school could be considered as a carbon trading site, seeing the number of available trees; old and recently planted within the campus. Although the volume of carbon sequestered is low, this could be increased by good Agricultural management practices, effective policy, and regulatory framework, geared towards intentional tree planting of high carbon sequestering tree species, and minimizing afforestation.

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1. INTRODUCTION

The process of extracting and storing carbon dioxide (CO_2) from the atmosphere to lessen the consequences of climate change is known as carbon sequestration (CS). The increasing concentration of CO_2 in the atmosphere, primarily caused by burning fossil fuels, is a major contributor to global warming. Carbon sequestration offers a potential solution to this problem by removing excess CO_2 from the atmosphere and storing it in a variety of long-term storage options, such as underground geological formations and oceans.

Many methods have been explored over the years, in a bid to reduce CO_2 emitted into the atmosphere, some of those methods are Direct Air Capture (DAC), Carbon Capture and Storage, Afforestation and Reforestation, Enhanced Weathering, Carbon Farming, Ocean Fertilization, Carbon Capture and Utilization (CCU), Biochar, etc., while some have been successfully implemented around the world, others are still in their early stages of research and development. For example, Biochar, Afforestation, and reforestation, Carbon farming have been adopted and used for a long period of time, DAC, CCS, CCU, Enhanced Weathering, Ocean Fertilization are still in their early stage of research and development, and they have not yet been demonstrated at pilot scale.

Plant biomass can be measured or quantify either by direct (destructive) or indirect (non-destructive) Shi L. & Liu S. (2017). Direct techniques are the most suitable for estimating biomass and assessing the Carbon Sequestration, while some research blends the two (Eisfelder et al. 2012). Destructive biomass estimation entails harvesting all plants, dividing them into constituent parts (e.g., stem, branches, leaves, flowers, fruits, and roots), and then calculating the carbon content of each constituent part analytically or (indirectly) as a percentage of the measured biomass (i.e., drying and weighing the biomass) (Harrison, 1992).

Due to their destructive character, time, cost, and labor intensity, the destructive techniques of biomass assessment are the most direct and accurate method, but they are only applicable to a small region. Furthermore, because the direct techniques depend on measurements from the ground, they may harm forests and have an adverse effect on the ecosystem. (Salem et al. 2020). Non-destructive (indirect) methods of biomass estimation are based on allometric equations, where physical variables such as stem diameter (DBH, Diameter at Breast Height) height of the tree, crown area, number of stems or number of plants, vegetation cover and stand height (plot biomass) (Eisfelder et al. 2012) or methods that uses Remotely Sensed dataset and Geographic information system (GIS) based models, where LiDAR (Light Detection and Ranging), Moderate Resolution Imaging Spectroradiometer (MODIS), medium resolution multispectral imageries like Landsat datasets are used. (Shashikant, et al 2010).

Carbon sequestration is important for mitigating climate change because it can help reduce the concentration of CO_2 in the atmosphere, which will reduce the warming effect of greenhouse gases. This can be done through a variety of methods, including afforestation (planting trees and reforestation (replacing trees that have been cut down), soil carbon sequestration (storing CO_2 in soil), and geological sequestration (injecting CO_2 into underground rock formations).

This research estimated the carbon sequestration potential of trees on the Rivers State University (RSU) Main Campus, with the following objectives:
-Acquire the Tree parameters, needed for carbon sequestration estimation.
-Calculate and estimate the carbon sequestration potential of Trees within the RSU campus.
-Estimate the number of fallen trees within the campus.
-Determine if there is any correlation between the CO_2 sequestered with the tree height and the tree diameter.
-Determine the spatial distribution of trees species within the campus and determine the campus's suitability as a carbon offset site.

This study addressed the following research questions:

-How much CO_2 can be sequestered by each tree species in the studied area?
-Which tree species sequester the most carbon dioxide on the university campus?
-Can RSU be enlisted/bought as a potential Carbon trading site?
-Where do we have more carbon-sequestering trees?
-Is there any correlation between the CO_2 sequestered and the Diameter at Breast Height (DBH) of the trees on the University Campus?

2. METHODOLOGY

The above- and below-ground biomasses were estimated using the non-destructive (indirect) sampling method. Individual trees on the campus were measured for their height and diameter at breast height (DBH) and estimates of carbon storage were performed using allometric equations. The overall method followed the sequence itemized in Figure 1 below:

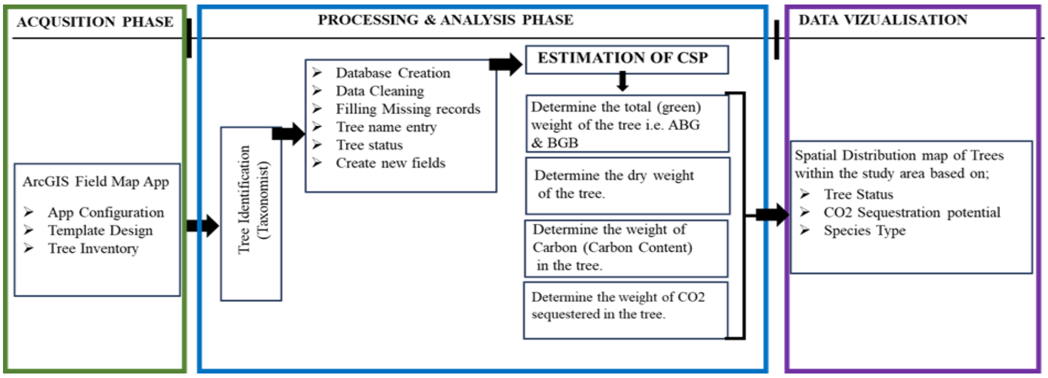


Figure. 1. Workflow diagram of the carbon sequestration methodological approach.

2.1.1 Acquisition Phase

This deals with configuration of the ArcGIS Field app to suit the project parameters specifications which involves, Tree Height (Top and Bottom), Data of Acquisition, Tree Status, Image of Tree, Diameter of Tree, Distance to Tree, and field observation.

2.1.2. Processing and Analysis

This involves identifying and naming trees that weren't identified during the field exercise, by a taxonomist from the department of Forestry and Environment, RSU. Also, data cleaning; field record/missing value update, and database was created. Also, the allometric equation was used The Carbon Sequestration Potential was estimated and calculated for each tree species and categories. The tree species were categorized based on physical examination of the Tree bark, stem, leaves etc., as no record was found on the age and time of planting.

2.1.3. Visualization

Various charts and maps were created showing the spatial distribution of trees, regression analysis, and Hot Spot analysis created.

2.2 Study area

The study area, Figure 2, Rivers State University (RSU) main campus, covers about 199 hectares, out of which almost 50% is covered by green areas, comprising of grasses, trees, plants, etc. dominated by foreign and native tree plant species, and evergreen trees such as *Mangifera Indica*, *Ficus Ovala*, etc. It is one of the few universities with many trees growing, in Rivers State, which plays a very important role in carbon sequestration and eventually local climate sustainability. It is situated in Port Harcourt City Local Government Area and lies between latitudes 4°47'12.85" to 4°48'25.49" North of the equator and longitude 6°58'26.72" to 6°59'15.50" East of Greenwich Meridian. This region has a tropical climate, which is characterized by two distinct seasons; the rainy season, which occurs between April and September, and the dry season, which falls between November and March. The campus has witnessed extensive urbanization over the years, with several hostels, administrative buildings, departments, and faculties being built. It is well connected to the capital of the state and is located about 250 meters away from the Ikwerre Road Expressway, connecting the Port-Harcourt metropolis. The campus is divided into academic and administrative blocks, interspersed with plenty of green spaces. It has 11 faculties, and 65 departments.

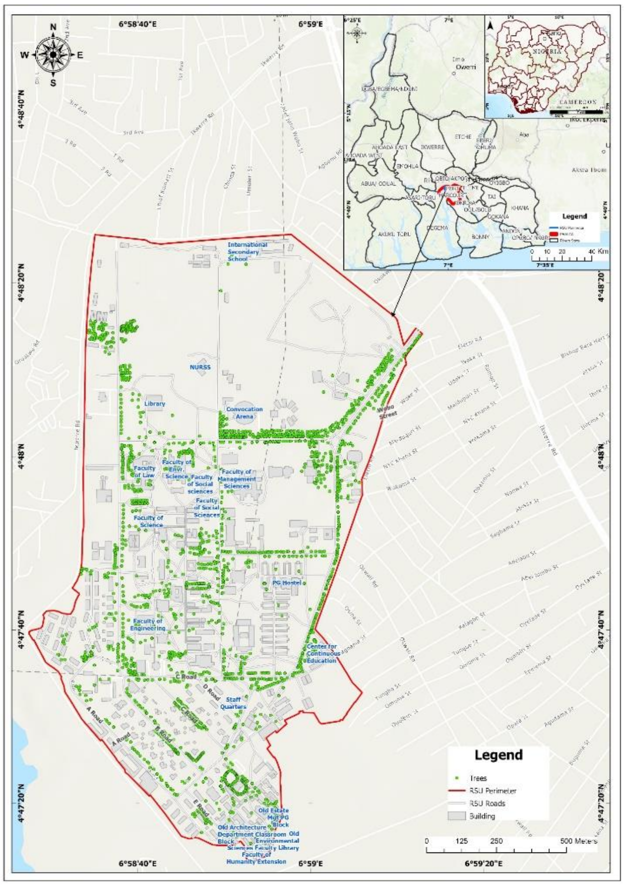


Figure. 2. Map showing the studied area (RSU Main Campus).

2.3 Materials and Methodology for Estimating the CSP of Trees within RSU

2.3.1 Tree Inventory and Tree Cover Mapping

Field data was recorded in real-time using the ArcGIS Field Map App and a backup Field sheet. Species-level identification of trees was obtained through visual observation, and photos of doubtful samples was taken for later identification by taxonomists. Shrubs and herbs weren't recorded. The year these trees were planted could not be ascertained as there wasn't any record from argic department. All recently planted trees, with diameter less than 30cm in girth at breast height (1.37 m) were enumerated for the purpose of populating the schools' tree database, for further studies and monitoring. The above- and below-ground biomasses was estimated using the non-destructive (indirect) sampling method. Individual trees on the campus were measured for their height and diameter at breast height (DBH) and estimates of carbon storage was performed using allometric equations. The project area was be subdivided into non-overlapping blocks, for effective enumeration and data collection.

2.3.2. Locating Trees in the Field

Two options exist for establishing and marking plot locations on the map and in the field- Global Positioning System (GPS), Compass bearing, and distance. (MacDicken et al. 1997). Esri's Field Maps App was used to precisely determine the position of trees within each stratum, collecting the Trees attribute. The Field Map app is an all-in-one app, that uses data-driven maps to help fieldworkers perform mobile data collection and editing, find assets and information, and report their real-time locations. It also allows for Images to be collected which helps in further identification of the trees and supports multiple data entry. Tree attributes such as the Name of the trees, Diameter, Top and Bottom of Tree, distances away from the tree, Date of observation, Tree Class; Recently Planted, Old, Dead without leaves (DWL), and fallen. Images (snapshot) of each tree were also collected. The inbuilt GPS on the mobile phone and Satellite Imagery, made it possible in collecting Precise position of Trees.

2.3.3. Tree Height and Girth at Breast Height (GBH)

Tree height and girth were measured using a clinometer and measuring tape respectively. Field data were recorded in real-time using Esri's Field Maps App and a backup in spreadsheets. Species-level identification of trees was obtained through visual observation, and the doubtful samples were snapped for later identification by taxonomists. Shrubs and herbs were not measured. The calculation (eq 2.1), involving the Top and Bottom readings of the trees using the clinometer, measured on the percent (%) section, and the distance away from the tree, from the observer's standpoint in meters, while the diameter is measured using a 30m tape. Individual trees greater than or equal to 30cm in girth at breast height (1.37 m) were enumerated, recently planted trees below 30cm in girth were also measured. This will help the school management predict and plan and make insightful decisions on the number of trees that will also contribute to atmospheric carbon reduction in the future.

$$\text{Tree Height} = \frac{[(\text{TreeTop} + \text{TreeBottom}) \times \text{DIstance}]}{100} \qquad 2.1$$

Since the surveyor's tape was used to measure the DBH, the measured diameter was converted using equation 2.2.

$$\text{Tree Diameter} = \frac{Distance(Circumference)}{3.142} \qquad 2.2$$

2.4. Estimating the Above-Ground and Below-Ground Biomass (AGB and BGB)

There is a greater choice of available methods for field biomass estimations. (Brown, 1997) stipulates that often these methods apply to closed forests, open forests, woodlands, woody savannahs, woodlots, line tree plantings, home gardens, living fences, and many more cover groupings. Lemmy, (2022), pointed out that estimating total organic carbon, a substantial proportion of biomass, requires a complete enumeration of the entire ecosystem's components which may include saplings, vines, epiphytes, and dead plant matter such as standing woody stems. To account for all these in one method makes the method not only difficult and lengthy but also tedious and expensive.

Therefore, for practical reasons, this study determines both the aboveground woody living component of biomass and BGB from which total carbon stored was determined. Allometric equations was used to estimate the aboveground dry weight biomass.

The Above-ground and below-ground biomasses was estimated based on field measurements of diameter at breast height (DBH) of the tree using allometric equations Eneji et al. (2014). The equations; 2.1 - 2.12 is applicable to dry climates with annual rainfall < 1500 mm; hence, it was adopted in this research, where the average annual rainfall ranges between 700 and 800 mm. (Adeyemi and Adeleke, 2020).

The rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood. It is greatest in the younger stages of tree growth, between 20 to 50 years. (Clark et al., 1986).

The allometric equation used by Eneji, et al. (2014), used in Carbon sequestration by different tree species in tropical dry deciduous forests, was adopted for this research. The processes are:

-Determine the total (green) weight of the tree.
-Determine the dry weight of the tree.
-Determine the weight of carbon in the tree.
-Determine the weight of carbon dioxide sequestered in the tree.
-Determine the weight of CO_2 sequestered in the tree per year.

2.4.1 Determine the total (green) weight of the tree.

The algorithm proposed by Eneji, et al. (2014), was used to calculate the total weight of a tree.

Where:

W = Above-ground weight of the tree in kilograms(kg)

D = Diameter of the trunk in inches

H = Height of the tree in meters.

For trees with D =≤ 10 (0.254m), $W = 0.25D^2H$ (2.3)

For trees with D ≥ 11, $W = 0.15D^2H$ (2.4)

The root system weighs about 20% as much as the above-ground weight of the tree. (Adeyemi and Adeleke 2020). Therefore, to determine the total green weight of the tree, multiply the above-ground weight of the tree by 120%.

Below-ground biomass was estimated from the AGB, as developed by Ponce-Hernandez et al., (2004) for a non-destructive approach, which depends on below-ground biomass (BGB) values for vegetation as 20% of the above-ground biomass, where 0.2 (or 20 %) is the assumed proportion of the aboveground biomass commonly used by most literature especially MacDicken (1997)

$$\text{BGB} = 0.2 \times \text{AGB} \quad (2.5)$$

The total biomass of individual trees is the sum of their above- and below-ground biomasses, respectively, given by the following equation:

$$\text{Total Biomass} = \text{TGW} = \text{AGB} + \text{BGB} \quad (2.6)$$

$$\text{Or Total Green Weight of Tree} = \text{W x 1.2} \quad (2.7)$$

2.4.2 Determine the dry weight of the tree.

Based on an extension publication from the University of Nebraska (Chavan and Rasal, 2010). The dry weight of the tree was calculated by multiplying the weight of the tree by 72.5%.

$$W_{(Dry\ Weight)} = \text{W x } 72.5\% \quad (2.8)$$

2.4.3 Determine the weight of carbon (Carbon Content) in the tree.

The average carbon content is generally 50% of the tree's total volume (biomass), (DeWald et al., 2005). Therefore, to determine the weight of carbon in the tree, multiply the dry weight of the tree by 50%.

$$\text{Carbon Content} = 0.5 \times \text{Total Biomass} \quad (2.9)$$

2.4.4 Determine the weight of carbon dioxide sequestered in the tree.

Since CO_2 is composed of One (1) molecule of Carbon and Two (2) molecules of Oxygen, and the atomic weight of Carbon is 12.001115 and the atomic weight of Oxygen is 15.9994.

$$Weight\ of\ CO_2 = \mathrm{C} + (2 \times \mathrm{O}) \quad (2.10)$$

$$= [12.001115 + (2 \times 15.9994)] = 43.999915$$

$$The\ Ratio\ of\ CO_2\ to\ C = \frac{43.999915}{12.001115} = 3.6663 \quad (2.11)$$

Where C is carbon, O is Oxygen, and CO_2 is Carbon dioxide.
Therefore, to determine the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree (Carbon Content) by the ratio of CO_2 to C (3.6663.6) (Birdsey, 1992).

$$Weight\ of\ CO_{2(Seq)} = \text{Carbon Content} \times 3.6663 \quad (2.12)$$

3. Results and discussion

3.1 Field observation result

1,865 trees were measured, covering a total of 41 Tree species, categorized as Recently Planted, Old, Fallen, and Dead without Leaves (DWL), Table 1. About 24.2 % of the entire tree population were recently planted, 5.2 % of the trees are Fallen, 1.0 % were dead without leaves. A total of 41 Tree species was found within the studied area. This revealed that since the last enumeration that was done by Nnadi et al (2021).

Table 1 Tree count based on tree status.

S/N	Tree Status	Number of Trees	%
1	Old	1297	69.5
2	Recently Planted	452	24.2
3	Fallen	97	5.2
4	Dead without leaves	19	1.0

Palm Tree (*Elaeis guineensis*) has the highest population with a total population of 268 trees, followed by Foxtail Palm (*Wodyetia bifurcate*) with a population of 263 trees, and Masquerade Tree (*Polyalthia longifolia*) having a population of 240 tree species Table 2. Foxtail Palm (*Wodyetia bifurcate*) has the highest tree population with trees that are dead without leaves; 13 trees, followed by Caribbean pine (*Pinus caribaea*) with 3 trees. Also, the Palm Tree (*Elaeis guineensis)* has the highest population of fallen trees; 5, within the studied area. It is worthy to note that a total of 77 fallen trees were also found within the studied area, the tree species were difficult to identify using the physical properties or characteristics (tree trunk, leaves etc.) of the trees.

Table 2. Carbon Sequestration Potential of each tree species

SN	Common Names	Scientific Names	Tree Count	DWL	Fallen Trees	Old Trees	Recently Planted	Carbon Sequestered (kg)				
								AGB (W)	**Total Green Weight**	**Dry Weight**	**Carbon Content**	**CO_2 Seq**
1	Africa star apple	*Chrysophyllum albidum*	11	0	0	10	1	40.85	49.02	35.53	17.77	65.15
2	African breadfruit	*Treculia africana*	72	0	0	70	2	416.23	499.47	362.12	181.06	663.82
3	Almond Tree	*Terminalia catappa*	13	0	0	11	2	44.83	53.8	39.01	19.5	71.5
4	Avocado Tree	*Perscea americana*	25	0	0	22	3	101.3	121.56	88.13	44.06	161.55
5	Bitter Kola	*Garcinia kola*	1	0	0	1	0	1.49	1.79	1.3	0.65	2.38
6	Black afara	*Terminalia ivorensis*	145	0	0	78	67	396.41	475.69	344.88	172.44	632.21
7	Brazilian Fern Tree	*Schizolobium parahyba*	4	0	0	4	0	20.41	24.49	17.76	8.88	32.55
8	Breadnut	*Artocarpus camansi*	2	0	0	2	0	24.82	29.78	21.59	10.8	39.58
9	Caapi	*Banisteriopsis caapi*	1	0	0	1	0	2.62	3.14	2.28	1.14	4.17
10	Caribbean pine	*Pinus caribaea*	56	3	2	50	1	11.16	13.39	9.71	4.85	17.79
11	Coconut Tree	*Cocos nucifera*	58	0	0	44	14	424.27	509.12	369.11	184.56	676.64
12	Dwarf Oriental Arborvitae	*Thuja orientalis*	9	0	0	0	9	214.26	257.12	186.41	93.21	341.72
13	Early black wattle	*Mimosa decurrens*	3	0	0	3	0	4.82	5.78	4.19	2.1	7.68
14	Eucalyptus Torelliana	*Eucalyptus torelliana*	1	0	0	1	0	14.03	16.84	12.21	6.1	22.38
15	Foxtail Palm	*Wodyetia bifurcata*	263	13	2	55	193	442.68	531.22	385.13	192.57	706.01
16	Garden Croton	*Codiaeum variegatum*	1	0	0	1	0	0.26	0.31	0.23	0.11	0.42
17	Grape Tree	*Vitis vinifera*	1	0	0	1	0	1.54	1.85	1.34	0.67	2.46
18	Guava Tree	*Psidium guajava*	10	0	0	9	1	22.79	27.35	19.83	9.91	36.34
19	Gum Tree	*Eucalyptus spp*	21	1	0	20	0	196.66	235.99	171.09	85.55	313.63
20	Jacaranda	*Jacaranda mimosifolia*	79	1	0	76	2	329.88	395.85	286.99	143.5	526.1
21	Kashmir tree	*Gmelina arborea*	123	0	0	116	7	1401.63	1681.95	1219.41	609.71	2235.37

22	Mango Tree	*Mangifera indica*	15	0	0	13	2	82.49	98.98	71.76	35.88	131.55
23	Masquerade Tree	*Polyalthia longifolia*	240	0	1	157	82	639.71	767.65	556.55	278.27	1020.24
24	Monkey Kola	*Cola lepidota*	2	0	0	2	0	2.37	2.85	2.07	1.03	3.79
25	Moringa	*Moringa olifera*	3	0	1	2	0	11.9	14.28	10.35	5.18	18.98
26	Native Pear Tree	*Dacryodes edulis*	4	0	0	4	0	11.66	14	10.14	5.08	18.59
27	Neem (Dogoyaro)	*Azadirachta indica*	5	0	0	5	0	26.01	31.21	22.63	11.31	41.48
28	Orange Tree	*Citrus sinensis*	44	1	0	39	4	60	72	52.2	26.1	95.69
39	Palm Tree	*Elaeis guineensis*	268	0	5	237	26	1194.84	1433.8	1039.51	519.75	1905.57
30	Pawpaw Tree	*Carica papaya*	16	1	1	5	9	25.26	30.31	21.98	10.99	40.29
31	Red Lucky Seed	*Adenanthera pavonina*	1	0	0	1	0	11.16	13.39	9.71	4.85	17.8
32	Rose Apple	*Syzygium Jambos*	2	0	0	2	0	7.46	8.95	6.49	3.24	11.89
33	Sandbox Tree	*Hura crepitans*	5	0	0	4	1	1.87	2.24	1.63	0.81	2.98
34	Sapele Mahogany	*Entandrophragma cylindricum*	1	0	0	1	0	24.77	29.73	21.55	10.78	39.51
35	She-oak	*Casuarina equisetifolia*	111	0	2	109	0	1337.12	1604.55	1163.3	581.65	2132.5
36	Soursop	*Annona muricata*	1	0	0	1	0	2.31	2.77	2.01	1	3.68
37	Tallow tree	*Allanblackia floribunda*	1	0	0	1	0	5.03	6.04	4.38	2.19	8.03
38	Teak	*Tectona grandis*	10	0	0	10	0	269.92	323.9	234.83	117.41	430.47
39	Unknown (DWL)	*Unknown (DWL)*		4	0	0	0					
40	Unknown (Fallen)	*Unknown (Fallen)*		0	77	0	0					
41	Variegated Mahoe Tree	*Hibiscus tiliaceus*	1	0	0	0	1	0.64	0.76	0.55	0.28	1.01
42	Wattle	*Acacia genus*	16	0	0	14	2	42.09	50.51	36.62	18.31	67.13
43	White afara	*Eucalyptus nimosifolia*	*138*	0	1	115	22	665.4	798.48	578.9	289.45	1061.21

Overall, the 1,865 trees sequestered about 13,034.92kg (13.03 metric ton) of carbon. On an individual tree basis, the tree that sequestered the most carbon was the Teak tree (Tectona grandis), sequestering 73.78kg. This tree is found along Road B, opposite NetXpress Cybercafe, with coordinates longitude 6.979243 E, and Latitude 4.792843 N. This is followed by Kashmir tree (*Gmelina arborea*), sequestered about 52.77kg of carbon. This tree is found within the Faculty of Sciences. It has coordinates of Longitude 6.977611 E, and Latitude 4.79825 N. Thirdly, the African breadfruit (*Treculia africana*), with CSP rate of 41.56kg, found in faculty of engineering with coordinates Longitude 6.979002 E, and latitude 4.794529 N.

Table 3. Top 3 most carbon sequestering trees.

S/N	Common Names	Scientific Names	CO_2 Seq (kg)
1	Teak	*Tectona grandis*	73.78
2	Kashmir Tree	*Gmelina arborea*	52.77
3	African Breadfruit	*Treculia africana.*	43.19

On a tree species basis, the Kashmir trees (*Gmelina arborea*), sequestered the most carbon, having a tree population of 123, (this is an increase, when compared to 80 tree population by Nnadi et al (2021)) comprising of 116 that are Old, and 7 that are recently planted, having a CSP rate of 2,235.37kg. This is followed by She-oak tree (*Casuarina equisetifolia*), having a tree population of 111, comprising of 109 Old trees, and 2 fallen trees, having a CSP rate of 2,132.50kg. Thirdly the Palm Tree (*Elaeis guineensis*) with a population of 268 (this is an increase, when compared to 226 tree population by Nnadi et al (2021)), of which 237 were Old Trees, 26 are recently planted and 5 were felled. They have a CSP rate of 6,273.44kg, and account for 46% of the entire CSP of the trees, within the studied area.

Table 4. Top 3 tree species with high CSP

S/N	Common Names	Scientific Names	Trees Count	CO_2 Seq (kg)	% CO_2 Seq
1	Kashmir tree	*Gmelina arborea*	123	2,235.37	16.43
2	She-oak	*Casuarina equisetifolia*	111	2,132.50	15.68
3	Palm Tree	*Elaeis guineensis*	268	1,905.57	14.01

3.2. Distribution of Trees within the study area

Based on the distribution of trees in the studied area (Figure 3), it could be seen that the tree heights are not evenly distributed. From Figure 3 you can see that the tree height is highly positively skewed, seeing we have a skewness above 1. The mean height is 6.79m. Trees height with large population fall between 0.003m to 3.11m respectively. Also, Figure 4, shows that CO_2 is slightly evenly distributed among various tree species within the study area, seeing that the median is close to the mean.

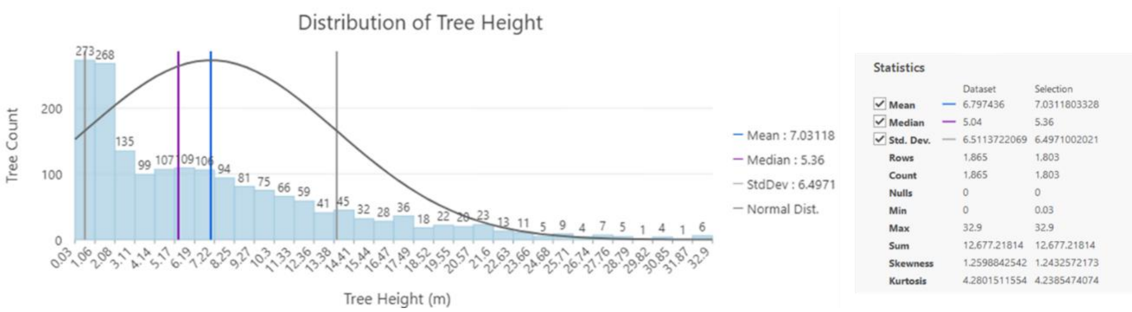


Figure 3: Tree Distribution Within the Study Area.

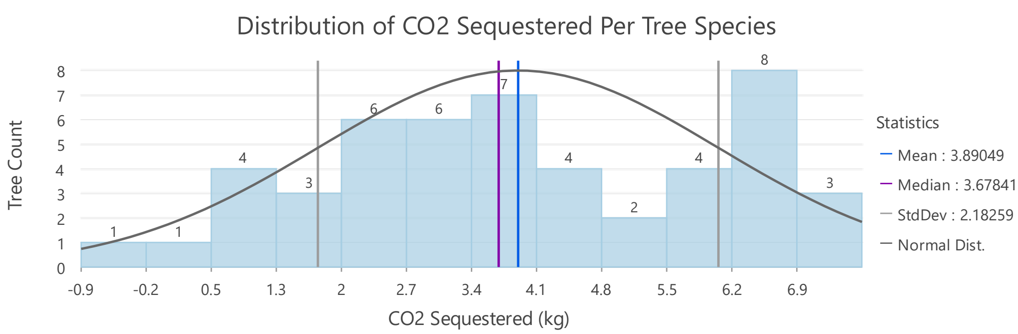
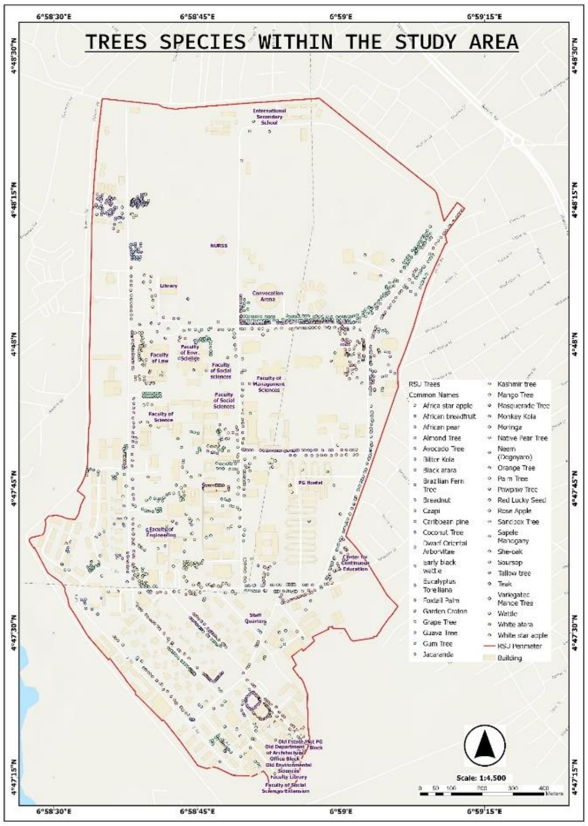


Figure 4. CO_2 Distribution Per Tree Species Within the Study Area

3.3 Spatial distribution

The distribution of trees could be seen in Figure 5. The Spatial distribution shows the spread of individual trees in the studied area. Figure 6 highlighted the spread of the top 3 trees species; Kashmir Tree (*Gmelina arborea*), She-oak (*Casuarina equisetifolia*) and Palm tree (*Elaeis guineensis*) that sequestered more carbon. The hotspot analysis, figure 7 was done to understand the carbon pool dynamics within the study area. The areas with dark red are regions where trees with more carbon are situated, and dark blue are regions where less carbon is been sequestered.



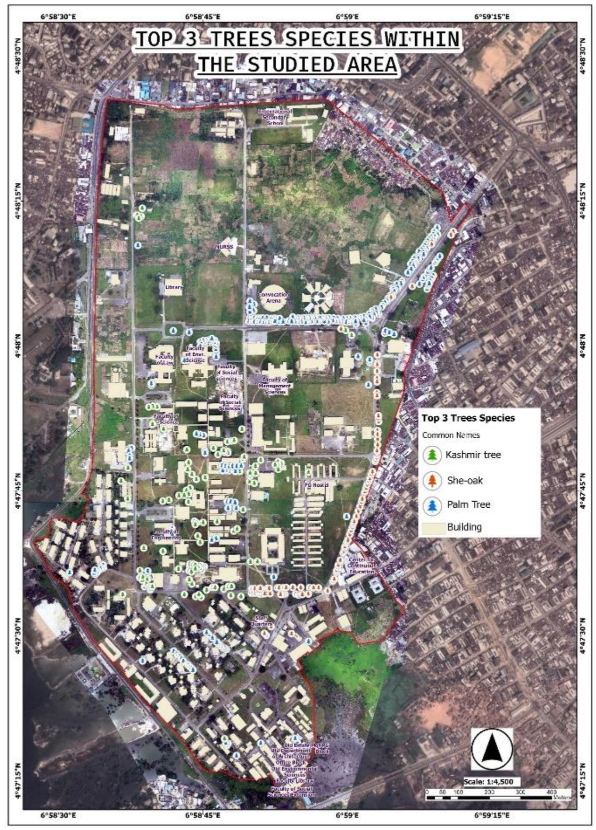


Figure 5. Spatial distribution of tress species.   Figure 6. Spatial distribution of top 3 tress species

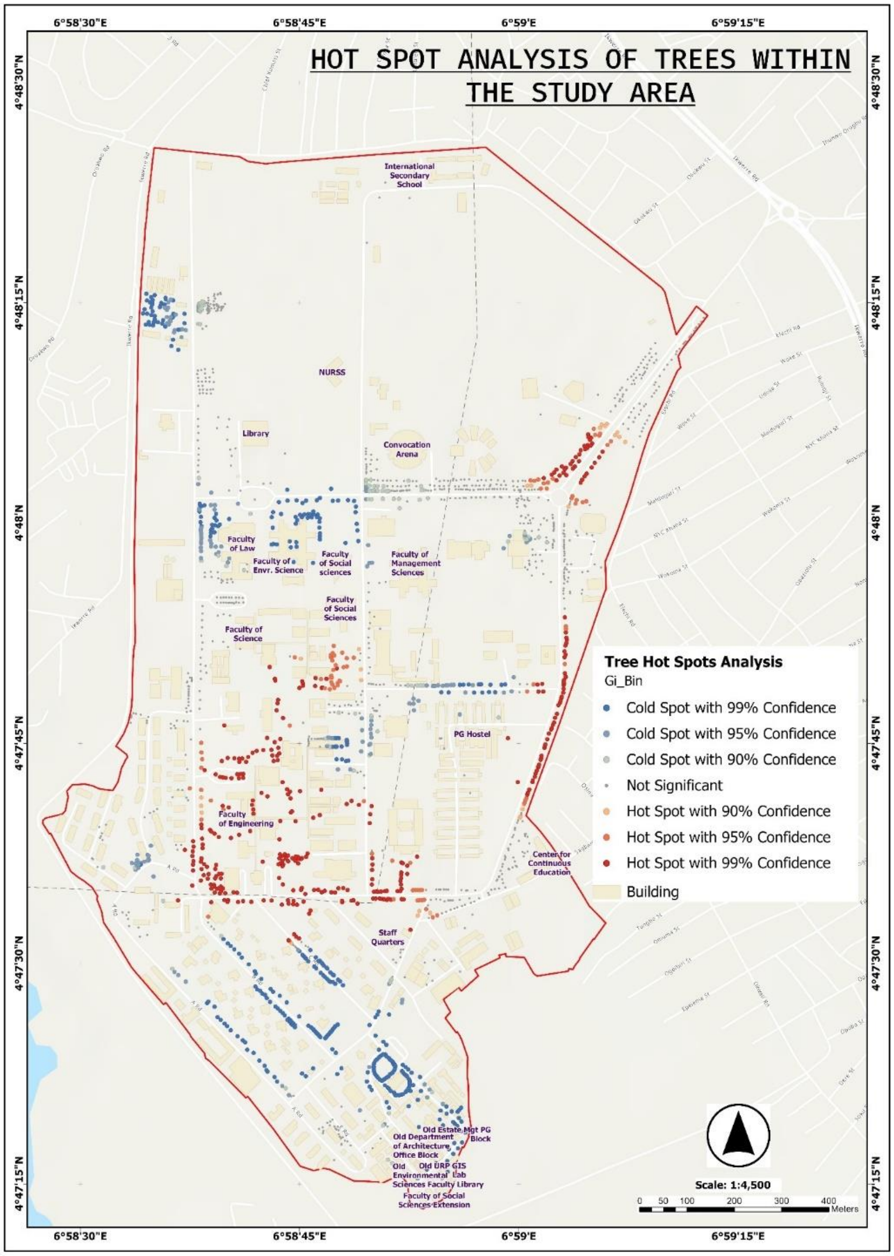


Figure 7. Hot Spot Analysis Showing region with trees with high CSP.

3.4. Relationship between CO_2 Sequestered, the tree height, and tree diameter.

The relationship between CO_2 Sequestered, the tree height, and tree diameter via the multiple linear regression (MLR) carried using R-Studio, to ascertain if there was any correlation between the CO_2 sequestered, the Tree height and Tree Diameter, the coefficient of residual, R-squared revealed that 95% of the dependent variable was explained or accounted for by the explanatory variables (Figure 8), and the explanatory variable were statistically significant. The scatter plots also show how far away each data point measured is away from the line of best fit.

```
##
## Call:
## lm(formula = CO2_Seq ~ Tree_Height + Tree_Diameter, data = df)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.0758  -1.2918  -0.0025   1.0958  25.4696
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  -2.239782   0.070053  -31.97   <2e-16 ***
## Tree_Height   1.070987   0.009047  118.38   <2e-16 ***
## Tree_Diameter 0.175246   0.005186   33.80   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.927 on 1862 degrees of freedom
## Multiple R-squared:  0.9501, Adjusted R-squared:  0.9501
## F-statistic: 1.774e+04 on 2 and 1862 DF,  p-value: < 2.2e-16
```

Figure 8. Summary Statistics of the MLR model between the dependent variables and the independent variables.

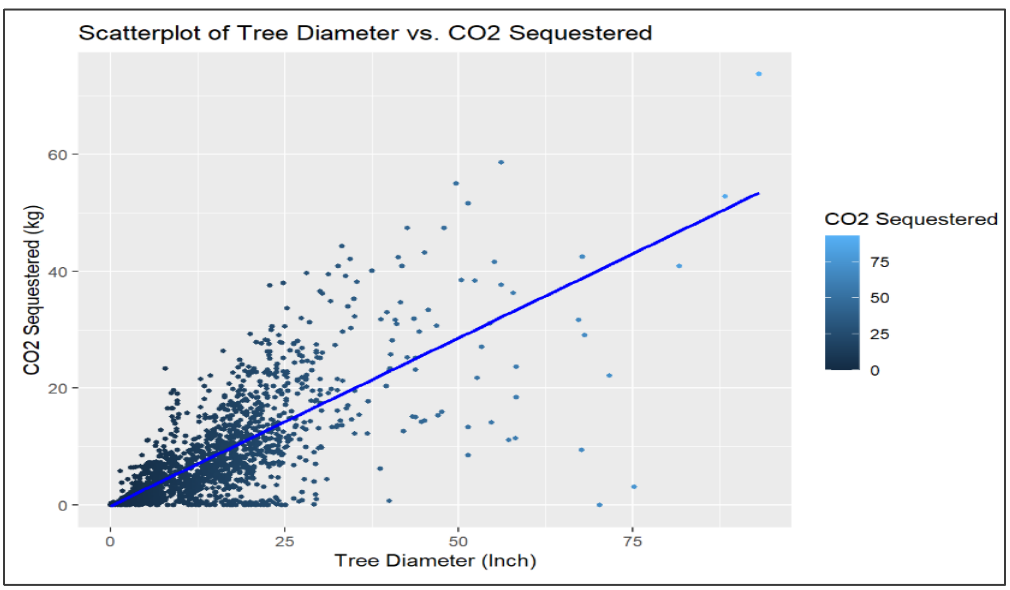


Figure 8a: Scatter plot between the CO_2 sequestered and tree diameter.

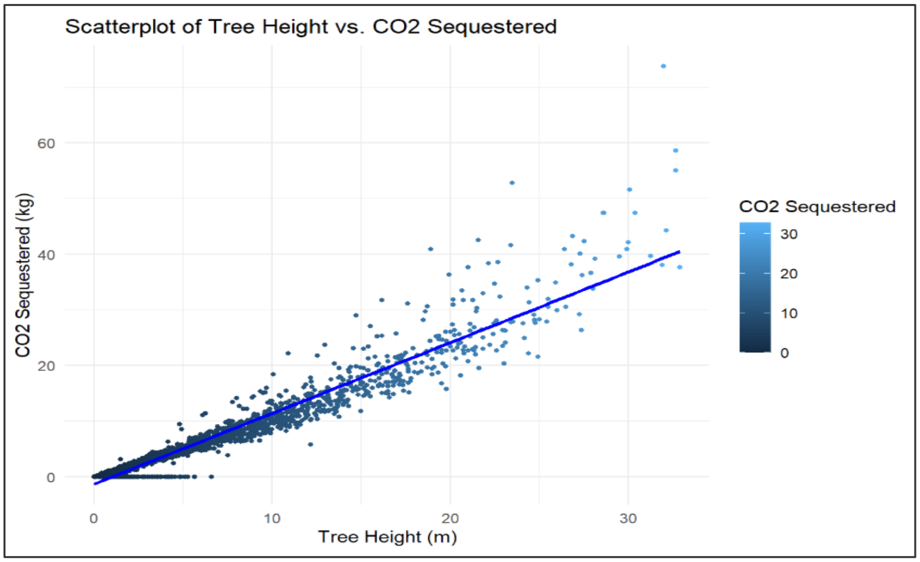


Figure 8b. Scatter Plot between the CO_2 Sequestered and tree height.

4. Conclusion and recommendations

The campus could be adopted as a trading site since it shows great potential for carbon sequestration, sequestering about 3 metric tons of carbon. Although there has been an increase in recently planted trees, they have a low CSP rate, contributing about 3.5% of the entire carbon mix within the study area. Tree planting activities should focus on trees species like *Gmelia Arborea*, *Casuarina equisetifolia*, and *Elaeis guincensis* since they have more Carbon Sequestration Potential. From the research, the carbon sequestered by trees within the studied area is very small. However, this could be increased by intentional tree planting activities geared towards increasing the carbon pool within the study area, to be considered as a potential carbon trading site. While this study focused on the trees' height and diameter, there is a need to extend the parameters observed like the leaves, green areas etc. to have a wholistic estimate of the Carbon sequestration potential within the study area. While there has been an increase in recently planted trees,

Since measurement has been done, there is need for accurate valuation, periodic verifications by a third-party assessment firm to confirm that the project continues to meet the requirements of the international standard before the school can be enlisted as a possible carbon trading or offset project. These carbon offsets could be sold in the voluntary carbon markets or to companies, and carbon credit buyers, who are purchasing carbon credits as an investment or as businesses trying to meet the internal standards for carbon footprint reduction. The amount absorbed depends on location, soil type and the tree canopy.

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