



ASSESSMENT AND ECONOMIC VALUATION OF CARBON STOCK OF A GUINEA SAVANNAH ECOSYSTEM IN NORTH-CENTRAL, NIGERIA

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ABSTRACT

Global warming is among the most dreaded challenges of this era where carbon emission is majorly the causal factor. This is as a result of fossil fuel burning and deforestation. Trees functions as carbon sink by absorbing carbondioxide from the atmosphere and also serve as an avenue to generate foreign earnings in the carbon market through carbon trading hence this study aimed at assessing and estimating the economic value of carbon stock of trees in the study area. A systematic sampling technique was used where four (4) transects of 500m were laid at interval of 150m apart from each other. Four (4) rectangular plots of 100m x 50m in size were laid alternatively along each transect at 20m. Data collected were names of the tree species, diameter at breast height (dbh) and tree height. Allometric equations (non-destructive method) were used for calculation of the tree biomass and carbon sequestered. The results revealed that the total average biomass stock in the study area was estimated at 32.7 tons while the total carbon dioxide sequestered by all trees was 302.3 tons/ha. The estimated economic value of the carbon dioxide sequestered was \$72,550.26 or equivalent to ₦56,252,569.29. This showed the economic and ecological significance of the study area where foreign earnings can be generated in addition to contributing towards mitigation of climate change.

Keywords: Economic valuation, climate change, carbon stock

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INTRODUCTION

Global warming is incontrovertibly one of the main issues of this era. This phenomenon is having adverse impact on the global climate through increase temperature of the earth. It is caused principally by the increase in the atmospheric concentration of the greenhouse gases (GHGs) (Intergovernmental Panel for Climate Change [IPCC], 2014). The most common among the gasses is carbondioxide (CO₂). Saha *et al.* (2008) reported that with

the increasing trends of CO₂ there are few fears that its concentration in the atmosphere will be doubled by the closed 21st century. The rates of emissions of CO₂ has continued to surge, with increased in concentrations reaching their fastest rate for 30 years in 2013, regardless of the warning given by the worlds scientists to reduce emission in order to stop increases in global temperatures. According to United Nations Framework Convention on Climate Change (UNFCCC, 2014), in order to reduce the GHGs in the atmosphere, two key activities are relevant, reduce the anthropogenic emission of CO₂ and create or promote carbon sink in the biosphere. Trees can function as carbon sink and absorb CO₂ from atmosphere when agricultural land and pastures are left to fallow and convert to forests or are returned to forest or plantations by enrichment planting forests (Ciccasere *et al.*, 2012). Trees also provide ecosystem services such as climate change mitigation and adaptation, hydrological service, help in agricultural productivity, combat erosion, improve wildlife habitat or wood or availability of other forest resources. Forest, thus play an important role in climate change through global carbon cycle due to the large amount of carbon store in vegetation (Pana *et al.*, 2011). In addition to the ecological functions, forest also have economic and unique role to advance national development. The carbon market allows foresters to transfer the carbon conserved in trees to companies needing an equivalent number of carbon emission credits or allowances, and or that need to purchase credits to offset increased emissions. Therefore, forests must be conserved for the welfare of the people. According to the report of Rochmayanto *et al.* (2010) the value of the carbon economy is one of the values of environmental services that can be used as a criteria for decision making. In Nigeria, however there has been a lot of degradation in the nation forests including Jos wildlife park where deforestation, bush burning, clearing of trees for agriculture among others are ongoing. This has negatively affected the study area and had led to release of more carbondioxide in the atmosphere. When the trees are lost, the economic value of carbon stored in them are also gone hence this research study aim at assessing the carbon stock and obtain their economic value with the view of exploring the carbon market where proceeds from it can be used to improve the standard of living of people around the park and this can be achieve through conservation of tree species in Jos wildlife park.

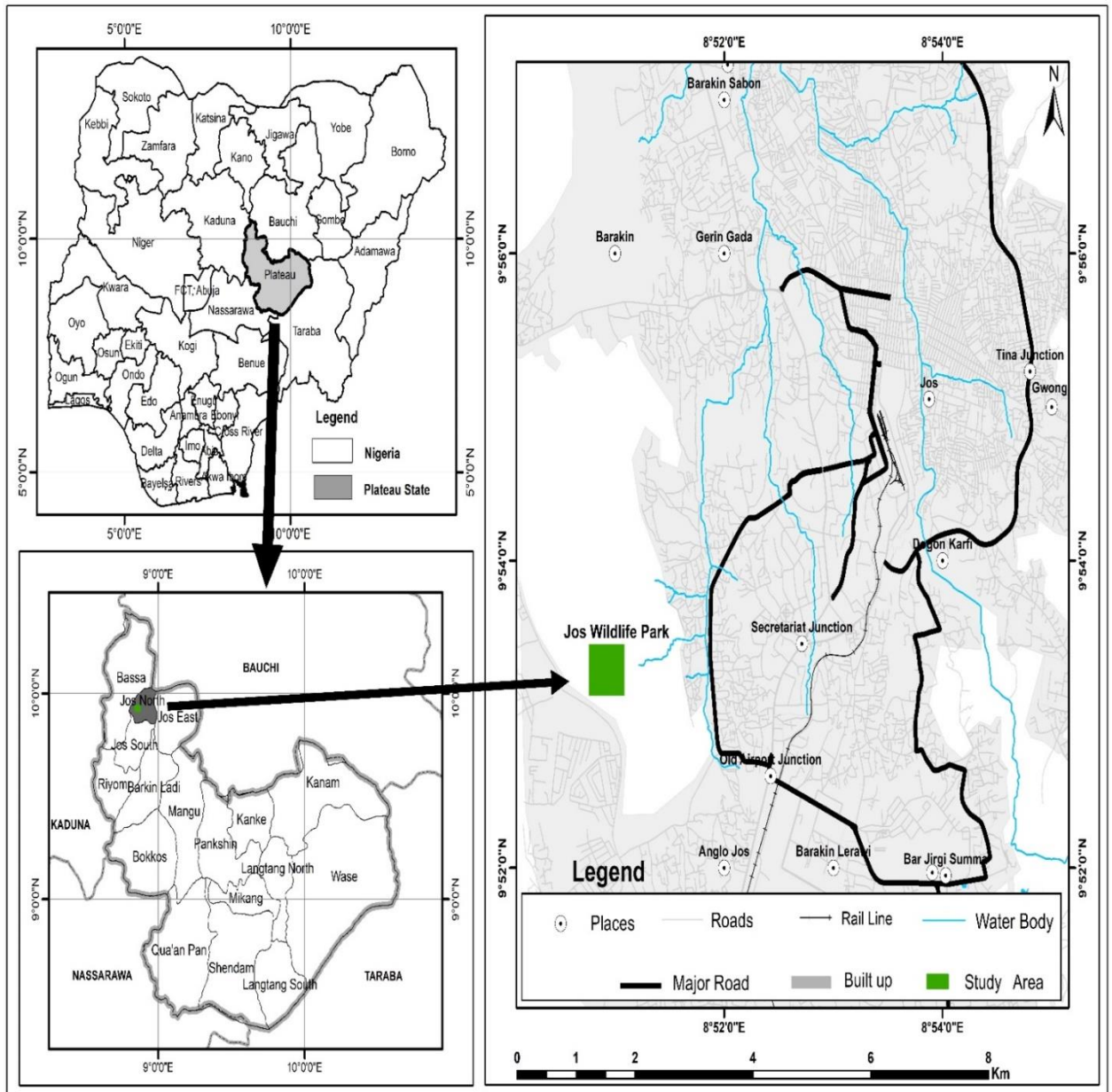
MATERIALS AND METHODS

Study Area

The study was carried out in Jos Wildlife Park which is one of the largest man-made zoological gardens in the country and it is owned and managed by the Government of Plateau State (Kwaga *et al.*, 2017). The park was established in 1972 and it is located in South-west of Jos, on latitude 52° N and longitude 8° 53'E and covers an area of 8km² (Figure 1) (Kwaga *et al.*, 2017). It is characterized by savannah woodlands, gallery forests with seasonal streams, gentle hills and rocky outcrops, and some exotic plants. It covers hills, streams and varied upland vegetation with about 43 kilometers of network of safari tracks (Ijeomah *et al.*, 2011). The average rainfall of the area is 1,411mm per annum.

According to Iloejo (1981) two soil types can readily be identified at the superficial level. These are the sandy loam and grey loam soils. Most soils are stony, fertile, and hard to work on for the agriculturalist. The site hosts a variety of animals ranging from birds, mammals and reptiles. It also holds one of the best remaining areas of natural vegetation of the Jos-Plateau with representatives of plants such as *Daniella oliveri*, *Lophira*

lanceolata, *Khaya snegalensis*, *Vitex doniana*, *Piliostigma thonningii* and different species of *Ficus* (Ezealor, 2002). However, high human population (200-300 people per km²) has resulted in continued, large-scale deforestation and conversion of grassland and scrub to agriculture and the few remaining patches of forest and woodland are fast being depleted by unsustainable fuelwood collection (Molokwu and Chikaze, 2007).



Source: National Population Commission, 2022
 Figure 1: Map of Plateau State Showing the Study Area

Sampling Procedure and Measurement of Tree Variables

A systematic sampling technique was used for this study as adopted by Adeyemi *et al.* (2015). Four (4) transects of 500m were laid at intervals of 150m apart from each other. Four (4) rectangular plots of 100m X 50m in size were laid alternatively along each

transect at an interval of 20m and stands equal or above 10cm diameter at breast height were enumerated within the plots. The data collected include name of the tree species, diameter at breast height (dbh), and tree height. The non-destructive method which involve the use of allometric equations for calculation of tree biomass and carbon sequestration was used. Allometric equations are an alternative to a simpler and cost effective approach than destructive methods (Khan *et al.*, 2020).

Data Analysis

Estimation of volume

The volume of each tree was estimated using Huber's formula as adopted by Avery and Burkhart, (2002).

$$V = h(A_m) = h(\pi d_m^2/4)$$

$$A = \pi r^2 = \pi d^2/4$$

Where;

A = Cross-sectional area (m²)

R = Radius (m)

D_m = Diameter at the middle (cm)

h = Height of tree (m)

π = Constant (22/7)

Estimation of wood density

The wood density values for the tree species in Jos wildlife park where obtained from the web (www.worldagroforestry.org) according to species, genus and family as adopted by Suryawanshi *et al.* (2014).

Estimation of above-ground biomass (AGB)

The allometric equation used in estimating the above ground biomass as adopted by Hangarge *et al.* (2012).

$$AGB = V \times \rho$$

Where;

AGB = Above-ground biomass (kg)

V = Volume (m³)

Wood density = (kg/m³)

Estimation of below-ground biomass (BGB)

Below-ground biomass is an important carbon pool for many vegetation types and land-use systems and accounts for above 20% (Santantonio *et al.*, 1997) to 26% (Cairns *et al.*, 1997) of the total biomass. It includes all living biomass of live roots excluding fine roots of less than 2mm diameter because these often cannot be distinguished empirically from soil organic matter or litter. The BGB calculated as adopted by Hangarge *et al.* (2012) which include multiplying AGB by factor of 0.26.

$$\text{BGB} = \text{AGB} \times 0.26$$

Where;

BGB = Below-ground biomass (ton/tree)

AGB = Above-ground biomass (ton/tree)

Estimation of total biomass (TB) and carbon storage of the trees

The total biomass of trees was calculated using equation as adopted by Sheikh *et al.* (2011) and FAO (2011).

$$\text{TB} = \text{AGB (excluding litter)} + \text{BGB (excluding soil organic matter)}$$

Where;

TB = Total biomass (kg)

AGB = Above-ground biomass (kg)

BGB = Below-ground biomass (kg)

In the case of the carbon storage of trees, 50% of its biomass is considered as carbon. The carbon was calculated using the following equation as adopted by Veilledent *et al.*, (2012)

$$\text{CS} = \text{Biomass} \times 50\%$$

Where;

CS = Carbon Stored (kg)

Estimation of CO₂ sequestered

The estimation of CO₂ sequestered in the trees was calculated by multiplying the carbon stored in the trees by 3.6663 as adopted by (Pascua *et al.*, 2021).

$$\text{CO}_2 \text{ sequestered in trees} = \text{Atomic weight of CO}_2 \times \text{carbon stored}$$

Where;

CO₂ = Carbon dioxide (tons/kg)

Estimation of economic value of CO₂ sequestered per ton

The basic medium used in the United Nations framework to reduce emissions from deforestation and forest degradation (REDD +) is through carbon trading. The economic

valuation of carbon depends on the goals and standards of the world economy (Perez-Verdin *et al.*, 2016). The total stock of carbon was estimated in tons and was converted into an equivalent amount of \$30 per ton of CO₂ sequestered as adopted by Pelemo *et al.* (2018)

$$\text{Price} = \text{Carbon sequestrated/ton} \times \$30$$

Where;

Price = US dollars

Determination of relationship between carbon sequestered and the tree variables

Pearson correlation coefficient was used to test the degree of association between carbon sequestrated and the tree variables (Diameter at breast height and tree height).

RESULTS AND DISCUSSION

One thousand and thirty five (1035) individual tree species were enumerated within the sample plots. The most dominant tree species was *Pinus caribaea* (482) while *Anogeissus leiocarpus*, *Etanda africana*, *Gmelina arborea*, *Miliacia excelsa* and *Tectona grandis* had frequency of one (1). Results from the field related to the tree variables viz., dbh and height varied according to species. The maximum mean diameter at breast height of the tree 58.9cm was recorded for *Eucalyptus torrelliana* while the minimum was *Croton macrostachyus* 15.8cm. The mean maximum height was observed in *Eucalyptus torrelliana* 35.5m while the minimum was recorded for *Lina samphera* 5.3m (Table 1). The average biomass stock in the study area was estimated at 32.7 tons where *Eucalyptus torrelliana* had the highest average biomass of 10.09 tons while *Croton macrostachyus* had the lowest with 0.12 tons (Table 2). It was observed that the reason for the high value for *Eucalyptus torrelliana* could be as a result of the trees having the highest dbh and height. This agrees with the findings of Drupadi *et al.*, (2021) who reported a high value of biomass and carbon stock is presumably due to tree height parameters that affected the biomass of the trees. Bismark *et al.* (2008) stated that the increase in biomass and carbon stock is due to the size of the trees particularly the tree height parameters. The significant stock of biomass obtained (32.7 tons) highlights the ecological relevance of Jos Wildlife Park as well as indicates its potential for carbon sequestration. Table 2 further showed the variation in CO₂ sequestration capacity among the tree species in the study area. The total CO₂ sequestered by all trees was estimated at 302.3 tons/ha. Four hundred and eighty two (482) *Pinus caribaea* tree species in the study area had a carbon sequestration capacity of 210.66 tons/ha while *Gmelina arborea* had the lowest with only a tree sequestering 0.05 ton/ha. The reason why *Pinus caribaea* had the highest CO₂ sequestration capacity might be because the pine stands have the most frequency among other stand. This agree with the findings of Rahmadwiati *et al.*, (2022) who reported in a similar study that the highest carbon was obtained from pine stands and this is because they have the most frequency among other stands.

Table 1: Tree Species Composition in the Study Area

S/no	Family	Trees Species	No. of Trees	Mean Dbh (cm)	Mean Tree height(m)
1	<i>Phyllosiphonaceae</i>	<i>Afzelia Africana</i>	2	19.1	7
2	<i>Fabaceae</i>	<i>Albizia zygia</i>	22	35.8	13.3
3	<i>Combretaceae</i>	<i>Anogeissus leiocarpus</i>	1	25.5	7.5
4	<i>Meliaceae</i>	<i>Barsema abyssinica</i>	21	22.4	8.6
5	<i>Phyllanthaceae</i>	<i>Bridelia farruginea</i>	10	15.9	8
6	<i>Casuarinaceae</i>	<i>Casuarina equisetifolia</i>	21	28.7	10.2
7	<i>Combretaceae</i>	<i>Combretum molle</i>	8	19.5	8.4
8	<i>Euphorbiaceae</i>	<i>Croton macrostachyus</i>	27	15.8	9
9	<i>Fabaceae</i>	<i>Daniella oliveri</i>	2	29	9.3
10	<i>Fabaceae</i>	<i>Delonix regia</i>	4	28	14
11	<i>Fabaceae</i>	<i>Dichrostachys cinerea</i>	5	15.7	7
12	<i>Maliaceae</i>	<i>Ekebergia senegalensis</i>	7	26.6	9.5
13	<i>Rubiaceae</i>	<i>Etanda Africana</i>	1	22.6	11.5
14	<i>Myrtaceae</i>	<i>Eucalyptus camaldulensis</i>	20	56.2	24.6
15	<i>Myrtaceae</i>	<i>Eucalyptus torelliana</i>	2	58.9	35.5
16	<i>Moraceae</i>	<i>Ficus thonningii</i>	7	23.1	6
17	<i>Lamiaceae</i>	<i>Gmelina arborea</i>	1	26.4	8
18	<i>Bignoniaceae</i>	<i>Jacaranda mimosifolia</i>	76	33.9	9
19	<i>Maliaceae</i>	<i>Khaya senegalensis</i>	10	30.1	7.2
20	<i>Anacardiaceae</i>	<i>Lannea acida</i>	29	21.4	6.4
21	<i>Asteraceae</i>	<i>Lina samphera</i>	7	23.7	5.3
22	<i>Ochnaceae</i>	<i>Lophira lanceolata</i>	15	23.4	9.6
23	<i>Anacardiaceae</i>	<i>Mangifera indica</i>	15	21.3	5.8
24	<i>Moraceae</i>	<i>Milicia excels</i>	1	22.3	11
25	<i>Ochnaceae</i>	<i>Ochna schweinfurthii</i>	35	24.3	24.3
26	<i>Polypodiaceae</i>	<i>Parkia biglobosa</i>	24	33.4	9.1
27	<i>Lauraceae</i>	<i>Persea americana</i>	3.0	19.7	8.5
28	<i>Pinaceae</i>	<i>Pinus caribaea</i>	482.0	40.8	21

29	<i>Rubiaceae</i>	<i>Polysphaeria arbuscula</i>	38.0	30.3	10.7
30	<i>Fabaceae</i>	<i>Pterocarpus erinaceus</i>	4.0	33	8.8
31	<i>Anacardiaceae</i>	<i>Rhus natalensis</i>	2.0	16.7	7.3
32	<i>Fabaceae</i>	<i>Senna siamea</i>	30.0	33.5	22.2
33	<i>Myrtaceae</i>	<i>Syzygium guineense</i>	65.0	22.1	7
34	<i>Myrtaceae</i>	<i>Syzygium macrocarpum</i>	5.0	19.6	8.3
35	<i>Lamiaceae</i>	<i>Tectona grandis</i>	1.0	38.2	13.5
36	<i>Combretaceae</i>	<i>Terminalia glauscescens</i>	9.0	18.7	6.7
37	<i>Sapotaceae</i>	<i>Vitellaria paradoxa</i>	10.0	21	5.8
38	<i>Lamiaceae</i>	<i>Vitex doniana</i>	13.0	26.7	11
1035					

Source: Field Survey, 2023

Table 2: Biomass and Accumulated (CO₂) of Some Trees Species in the Study Area

Trees Species	No. of Trees	Mean ABG Biom as (kg)	Mean BG Biom as (kg)	Total Mean Biom as (ton/tree)	Carbon Stored (Kg)	C02 Sequest ered (kg)	C02 Sequestered (ton/ha)
<i>Afzelia africana</i>	2.0	144	37.4	0.18	181.40	665.74	0.083217
<i>Albizia zygia</i>	22.0	689	179	0.87	9548	35057.31	4.382164
<i>Anogeissus leiocarpa</i>	1.0	336	87.4	0.42	211.75	777.12	0.09714
<i>Barsema abyssinica</i>	21.0	226	58.9	0.29	2995.65	10994.04	1.374254
<i>Bridelia farruginea</i>	10.0	93.4	24.3	0.12	588.50	2159.8	0.269974
<i>Casuarina equisetifolia</i>	21.0	553	144	0.7	7312.20	26835.77	3.354472
<i>Combretum molle</i>	8.0	212	55	0.27	1066.80	3915.16	0.489395
<i>Croton macrostachyus</i>	27.0	91.5	23.8	0.12	1556.55	5712.54	0.714067
<i>Daniella oliveri</i>	2.0	313	81.4	0.39	394.30	1447.08	0.180885
<i>Delonix regia</i>	4.0	635	165	0.8	1599.60	5870.53	0.733817
<i>Dichrostachys cinerea</i>	5.0	128	33.2	0.16	402.50	1477.18	0.184647
<i>Ekebergia senegalensis</i>	7.0	293	76.1	0.37	1290.45	4735.95	0.591994
<i>Etanda africana</i>	1.0	339	88.2	0.43	213.80	784.65	0.098081
<i>Eucalyptus camaldulensis</i>	20.0	4637	1206	5.84	58425	214419.8	26.80247
<i>Eucalyptus torelliana</i>	2.0	8006	2081	10.1	10086.9	37018.92	4.627365
<i>Ficus thonningii</i>	7.0	111	28.9	0.14	490.70	1800.87	0.225109
<i>Gmelina arborea</i>	1.0	193	50	0.24	121.25	444.99	0.055623
<i>Jacaranda mimosifolia</i>	76.0	400	104	0.5	19129.20	70204.16	8.775521
<i>Khaya senegalensis</i>	10.0	337	87.6	0.42	2121.50	7785.91	0.973238
<i>Lannea acida</i>	29.0	119	30.8	0.15	2164.85	7945	0.993125
<i>Lina samphera</i>	7.0	121	31.4	0.15	532.70	1955.01	0.244376
<i>Lophira lanceolata</i>	15.0	326	84.7	0.41	3076.50	11290.76	1.411344
<i>Mangifera indica</i>	15.0	123	31.9	0.15	1158.75	4252.61	0.531577

<i>Milicia excelsa</i>	1.0	255	66.2	0.32	160.35	588.48	0.073561
<i>Ochna schweinfurthii</i>	35.0	700	182	0.88	15428	56620.76	7.077595
<i>Parkia biglobosa</i>	24.0	424	110	0.53	6406.80	23512.96	2.93912
<i>Persea americana</i>	3.0	146	37.9	0.18	275.85	1012.37	0.126546
<i>Pinus caribaea</i>	482.0	1512	393	1.91	459201.40	1685269	210.6586
<i>Polysphaeria arbuscula</i>	38.0	514	134	0.65	12308.20	45171.09	5.646387
<i>Pterocarpus erinaceus</i>	4.0	476	124	0.6	1198.80	4399.60	0.54995
<i>Rhus natalensis</i>	2.0	99.3	25.8	0.13	125.10	459.12	0.05739
<i>Senna siamea</i>	30.0	1332	346	1.68	25165.50	92357.39	11.54467
<i>Syzygium guineense</i>	65.0	183	47.6	0.23	7497.75	27516.74	3.439593
<i>Syzygium macrocarpum</i>	5.0	177	46	0.22	556.75	2043.27	0.255409
<i>Tectona grandis</i>	1.0	948	246	1.19	597.05	2191.17	0.273897
<i>Terminalia glauscescens</i>	9.0	134	34.8	0.17	758.25	2782.78	0.347847
<i>Vitellaria paradoxa</i>	10	254	66	0.32	1599	5868.33	0.733541
<i>Vitex doniana</i>	13	366	95.1	0.46	2996.50	10997.16	1.374644
				32.7			302.2926

Source: Field survey, 2023

ABG = Above Ground BG = Below Ground

Perez-Cordero and Kanninen (2003), Tschakert *et al.* (2006) and Terakunpisut *et al.* (2007) stated that variations in carbon stock can be as a result of many factors viz: forest type, plant age, size class of trees, tree density, wood density, tree volume, forest disturbances including illegal logging and forest fire. The results further revealed that the total carbon (both AGB and BGB) sequestered by trees in the study area 302.3 tons/ha is higher than the value 4.89 tons/ha reported by Ibrahim *et al.*, (2018) for Majiya fuelwood reserve. It was also higher than the value 167.51 tons/ha reported by Oke *et al.* (2020) for a lowland rainforest in Nigeria. The variation observed in the biomass and carbon sequestered by trees in Jos Wildlife Park could be as a result of the density of trees and size. It could also be due to environmental differences as suggested by Rajput *et al.* (2017) and Daba and Soromessa (2018). Ibrahim *et al.* (2018) and Aghimien (2019) reported that above and below carbon are very important in carbon pool study as they provide insight to carbon sequestration potential of the forest. Total carbon sequestered (AGB and BGB excluding other pools) by trees for Jos Wildlife Park which was estimated at 302.3 tons/ha falls within the class of high density area (158 – 408 tons/ha) as classified by Ravilious *et al.* (2010). The estimated economic value of CO₂ sequestered in the study area was \$72,550.26 or equivalent to ₦56,252,569.59. *Pinus caribaea* had the highest cost of carbon sequestration at \$50,558.07 or equivalent to ₦39,200,705.16 while *Gmelina arborea* had the lowest cost at \$13.35 or equivalent to ₦10,351.06 (Table 3). The results further showed that *Eucalyptus camaldulensis* tree species despite having a frequency of 20, the economic value of its carbon sequestration was estimated at \$6,432.60 or equivalent to ₦4,987,580.74. Zhang *et al.* (2018) investigated the cost effectiveness of utilizing various tree species for CO₂ sequestration. They found that the choice of tree species significantly influenced the economic performance of carbon sequestration projects. In this era of carbon trading, Nigeria has made slight effort in exploring the carbon market. This could be as a result of poor forest management and government attitude towards conservation issues. If the carbon market is properly harness, this could provide economic incentives for forest conservation and afforestation projects in the study area which will have significant implications for climate change mitigation.

However, recently announcement was made by the Federal Government of Nigeria (FGN) on creation of Intergovernmental Committee on carbon markets at the COP28 which held in December, 2023. The FGN aim to implement a co-created blueprint targeted at positioning the country with requisite frameworks and policies to drive an efficient and sustainable carbon market ecosystem with an estimated value of \$2.5 billion (<https://businessday.ng/news/article/shettima-inaugrates-committee-as-fg-eyes-2-5bn-green-economy-oppourtunity/?amp=1>).

Table 3: Price Estimation of Carbon dioxide (CO₂) Sequestered in the Study Area

S/no	Trees Species	CO ₂ Sequestered (ton)	Price of CO ₂ Sequestered (\$30)	Price of CO ₂ Sequestered (₦)
1	<i>Azelia Africana</i>	0.666	19.98	15,491.69
2	<i>Albizia zygia</i>	35.057	1,051.71	815,453.87
3	<i>Anogeissus leiocarpa</i>	0.777	23.31	18,073.64
4	<i>Barsema abyssinica</i>	10.994	329.82	255,729.24
5	<i>Bridelia farruginea</i>	2.16	64.80	50,243.33
6	<i>Casuarina equisetifolia</i>	26.836	805.08	624,226.83
7	<i>Combretum molle</i>	3.915	117.45	91,066.03
8	<i>Croton macrostachyus</i>	5.713	171.39	132,888.95
9	<i>Daniella oliveri</i>	1.447	43.41	33,658.38
10	<i>Delonix regia</i>	5.871	176.13	136,564.16
11	<i>Dichrostachys cinerea</i>	1.477	44.31	34,356.20
12	<i>Ekebergia senegalensis</i>	4.736	142.08	110,163.15
13	<i>Etanda Africana</i>	0.785	23.55	18,259.73
14	<i>Eucalyptus camaldulensis</i>	214.42	6,432.60	4,987,580.74
15	<i>Eucalyptus torelliana</i>	37.019	1,110.57	861,091.56
16	<i>Ficus thonningii</i>	1.801	54.03	41,892.70
17	<i>Gmelina arborea</i>	0.445	13.35	10,351.06
18	<i>Jacaranda mimosifolia</i>	70.204	2,106.12	1,633,001.20
19	<i>Khaya senegalensis</i>	7.786	233.58	181,108.59
20	<i>Lannea acida</i>	7.945	238.35	184,807.06
21	<i>Lina samphera</i>	1.955	58.65	45,474.86
22	<i>Lophira lanceolate</i>	11.291	338.73	262,637.69
23	<i>Mangifera indica</i>	4.253	127.59	98,928.18
24	<i>Milicia excels</i>	0.588	17.64	13,677.35
25	<i>Ochna schweinfurthii</i>	56.621	1,698.63	1,317,049.76
26	<i>Parkia biglobosa</i>	23.513	705.39	546,931.19
27	<i>Persea Americana</i>	1.012	30.36	23,539.93
28	<i>Pinus caribaea</i>	1685.269	50,558.07	39,200,705.16
29	<i>Polysphaeria arbuscula</i>	45.171	1,355.13	1,050,713.60

30	<i>Pterocarpus erinaceus</i>	4.4	132	102,347.52
31	<i>Rhus natalensis</i>	0.459	13.77	10,676.71
32	<i>Senna siamea</i>	92.357	2,770.71	2,148,297.71
33	<i>Syzygium guineense</i>	27.517	825.51	640,067.43
34	<i>Syzygium macrocarpum</i>	2.043	61.29	47,521.81
35	<i>Tectona grandis</i>	2.191	65.73	50,964.41
36	<i>Terminalia glauscescens</i>	2.783	83.49	64,734.81
37	<i>Vitellaria paradoxa</i>	5.868	176.04	136,494.37
38	<i>Vitex doniana</i>	10.997	329.91	255,799.02
			72,550.26	56,252,569.59

*Note: The Central Bank of Nigeria Exchange Rate as of 1/08/2023 is 1\$ = ₦ 775.36

Source: Field Survey, 2023

Pearson correlation coefficient was also used in this study to determine the relationship between carbon sequestered and the tree variables, dbh and height. The result found that the carbon sequestered is positively correlated with both diameter at breast height (Dbh) and tree height (TH) (Table 4) but the correlation with TH is stronger. This means that most tall trees with larger Dbh stores more carbon than others. This results is in consistent with previous studies that have shown that carbon storage in trees is positively correlated with both Dbh and TH e.g., Chen *et al.* 2019; Li *et al.* 2020; Saka *et al.* 2020; Wu *et al.* 2022.

Table 4: Pearson's Correlation of Carbon with Tree Variables

		Carbon sequestered	DBH	TH
Carbon sequestered	Pearson Correlation	1	.315*	.440**
	Sig. (1-tailed)		.029	.003
	N	38	37	38
DBH	Pearson Correlation	.315*	1	.886**
	Sig. (1-tailed)	.029		.000
	N	37	37	37
TH	Pearson Correlation	.440**	.886**	1
	Sig. (1-tailed)	.003	.000	
	N	38	37	38

* Correlation is significant at the 0.05 level (1-tailed), ** Correlation is significant at the 0.01 level (1-tailed)

Key: DBH = Diameter at Breast Height; TH = Tree Height

CONCLUSION AND RECOMMENDATIONS

The results from this study showed that the estimated total carbon dioxide sequestered in Jos Wildlife Park was 302.3 tons/ha. The economic value of the carbon was \$72,550.26

or equivalent to ₦56,252,569.59. Based on this result, the park has a potential carbon economic value, so proper forest management should be carried out to increase the economic value of the forest through carbon sequestration services. The findings from this study also emphasize the importance of incorporating tree species with high biomass and carbon sequestration capacities such as *Eucalyptus torreliana*, *Eucalyptus camaldulensis*, *Pinus caribaea* etc. into reforestation and afforestation projects. This could increase the mitigation of climate change while boosting the country's foreign exchange earnings.

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REFERENCES

- Adeyemi, A. A., Ibe, A. E. and Okedinwa, F. C. (2015). Tree Structural and Species Diversities in Okwangwo Forest. Cross River State, Nigeria. *Journal of Research in Forestry Wildlife and Environment*, 7: 36-53
- Aghimien, E. V. (2019). Above-ground carbon stock estimation using Pleiades satellite imagery of the secondary forest ecosystem in Ibadan, Nigeria. *Forestry Research and Engineering: International Journal*, 3(2), 46-54
- Avery, T. E. and Burkhardt, H. E. (2002). *Forest Measurement*. 5th edition, McGraw Hill, New York. Pp. 144-167
- Bismark, M., Heriyanto, N. and Iskandar, S. (2008). Biomassa dan Kandungan Karbon Pada Hutan Produksi di Cagar Biosfer Pulau Siberut, Sumatera Barat. *Jurnal Penelitian Hutan dan Konservasi Alam*, 5(5): 357-407.
- Cairns, M. A., Brown, S., Helmer, E. H. and Baumgardner, G. A. (1997). Root biomass allocation in the world's upland forests. *Oecologia*, 111(1): 1-11
- Chen, Y., Li, X. and Luo, G. (2019). Allometric equations for estimating biomass and carbon stock of dominant tree species in a subtropical forest, China. *Forests*, 10(2), 163
- Daba, D. E. and Soromessa, T. (2018). The accuracy of species-specific allometric equations for estimating above-ground biomass in tropical moist montane forest: case study of *Albiza grandibracteata* and *Trichilia dregeana*. *Carbon Balance and Management*, 14(18):1-13. Retrieved May 26, 2020, from <https://doi.org/10.1186/s13021-019-0134-8>
- Drupadi, T. A., Ariyanto, D. P., and Sudadi, S. (2021). Pendugaan Kadar Biomassa dan Karbon Tersimpan pada Berbagai Kemiringan dan Tutupan Lahan di KHDTK Gunung Bromo UNS. *Jurnal Agrikultura*, 32(2): 112-119.
- Ezealor, A. U. ed. (2002). Critical sites for biodiversity conservation in Nigeria. Nigeria Conservation Foundation: Lagos, Nigeria. pp110

- Food and Agriculture Organization of the United Nations (2011). State of the World's Forest 2011.
- Hangarge, R. M. and Patil, G. B. (2012). Carbon Sequestration Potential of Tree Species in Somjaichi Rai (Sacred Grove) at Nandghur Village, in Bhor Region of Pune District Maharashtra State, India. *Asian journal of Plant Sciences and Research*, 2(4): 256-264
- Ibrahim, M., Isah, A., Shamaki, S. and Audu, M. (2018). Carbon Stock Assessment in Majiya Firewood Research Sokoto State, Nigeria. *Journal of Scientific Research and Reports* 18(2): 1-12
- Ijeomah, H. M., Alarape, A. A. and Ogogo, A. U. (2011). Ecotourism potentials of Plateau State, Nigeria: A monitoring survey. *Asian Pacific Journal of Tourism Research* 16(2): 153-166
- Illojo, N. P. (1981). *A new geography of Nigeria*. New revised edition, Longman Nigeria Plc. Pp.21-31
- Intergovernmental Panel on Climate Change (IPCC). (2014). Pichs-madroga, O.R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlomer, S., Vonstchow, C., Zwickel, T., Minx, J.C (Eds.), climate change 2014: mitigation of climate change. Contribution of working group III to the fifth assessment report of the IPCC Cambridge university press, cambridge UK and New York.
- Jos Wildlife Park, Plateau State, Nigeria, 2014
- Khan, M. N. J., Islam, M. R., Rahman, A., Azad, M. S., Mollick, A. S., Kamfuzzaman, M., Sadath, M. N., Feroz, S. M., Rakkibu, M. G. and Knohl, A. (2020). Allometric relationships of stand level Carbon Stocks to Basal Area, Tree Height and Wood Density of Nine Tree Species in Bangladashe. *Global Ecology and Conservation* 22:e01025. DOI: 10.1016/J.gecco.2020.e01025
- Kwaga, B. T., Iliya, D., Ali, A. and Khobe, D. (2017). Avifauna abundance and diversity in Jos Wildlife Park, Nigeria. *Agricultural Science and Technology*. 9(3): 234-239
- Li, X., Chen, Y., Luo, G. and Wang, C. (2020). Correlation between carbon and biometric variables of forest trees: A review. *Forests*, 11(5): 492
- Molokwu, M. N. and Chikaze, D. N. (2007). Biomass and Carbon sequestration potential of *Tectona grandis*
- Oke, O. S., Akindele, S. O. and Onyekwelu, J. C. (2020). Biomass and Carbon Stock Assessment of a Tropical Rainforest Ecosystem in Nigeria. *Journal of Forestry Research and Management*, 17(2): 83-92
- Palemo, O., Ibode, R., Agbenu, D., Okanlawon, J. and Agbe, F. J. (2018). Sequestration and Storage Capacity of Trees and Its Impacts on Climate Change in Old Oyo National Park Nigeria. Proceedings of 6th NSCB Biodiversity Conference; Uniuyo 2018

- Pana, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E. and Kurz, W. A (2011). A large and persistent carbon sink in the World's forests. *Science*, 333: 988-993
- Pascua, J. G., Alfonso, G. P. and Calicia, R. S. (2021). Carbon Sequestration Potential of Tree Species at Isabel State University Wildlife Sanctuary (ISUWS), Cabagan, Isabela, Philippines. *Open Journal of Ecology*, 11(5): 462-473
- Perez-Verdin, G., Sanjurjo-Rivera, E., Galicia, L., Hernandez-Diaz, J. C., Hernandez-Trejo, V. and Marquez-Linares, M. A. (2016). Economic Valuation of Ecosystem Services in Mexico: Current Status and Trends. *Ecosystem Services* 21: 6-19. DOI:10.1016/j.ecoser.2016.07.003
- Perez-Cordero, L. D. and Kenninen, M. (2023). Aboveground Biomass of *Tectona grandis* Plantation in Costa Rica. *Journal of Tropical Forest Science*, 15(1):199-213
- Rahmadwiati, R., Wicaksono, R. L. and Apriyanto, D. (2022). Estimation and Economic Valuation of Above-Ground Carbon in Forest Area with the Special Purpose of Gunung Bromo, *Journal Sylva Lestari* ,10(1): 116-126
- Rajput, B., Bhardwaj, D. and Pala, N. (2017). Factors influencing biomass and carbon storage potential of different land use systems along an elevational gradient in temperate northwestern Himalaya. *Agroforestry System*, 91, 479-486
- Ravilious, C., Kapos, V., Osti, M., Bertzky, M., Bayliss, J., Dahiru, S. and Dickson, B. (2010). *Carbon, biodiversity and ecosystem services: Exploring co-benefits. Nigeria: Preliminary Results*. Cambridge, UK: UNEP-WCMC.
- Rochmayanto, Y., Durusman, D. and Rusolono, T. (2010). Change of the Carbon Stock and its Economic Value on the Conservation of Peat Swamp Forest to Pulpwood Industrial Plantation Forest. *Jurnal Penelitian Hutan Tanaman* 7(2): 93-106.
- Saka, M. G., Osho, J. S. A. and Isa, H. D. (2020). Assessment of Biomass contents and Carbon Stock of Plantation-Grown Neem Species (*Azadiractha indica*) in Yola Nigeria. *Journal of Research in Forestry, Wildlife and Environment*, 12(1): 178-186
- Sheikh, M. A., Kumar, M., Bussman, R. W. and Todaria, N. P. (2011). Forest carbon stocks and fluxes in physiographic zones of India. *Carbon Balance and Management*, 6(1):1-10
- Suryavanshi, M. N., Patel, A. R., Kale, T. S. and Patil, P. R., (2014). Carbon Sequestration Potential of Tree Species in the Environment of North Maharashtra University Campus, Jalgaon (MS) India. *Biosci. Discov.* 5: 175-179
- Terakunpisut, J., Gajaseni, N. and Ruankawe, N. (2007). *Applied Ecology and Environmental Research*, 5(2): 93-102
- Tschakert, P., Coomes, O. T. and Potvin, C. (2006). Indigenous livelihoods, slash-and-burn agriculture, and carbon stocks in Eastern Panama. *Ecol. Econ.*, 60:807-820

- UNFCCC. (2009). National Economic Environment and Development Study (NEEDS) for Climate Change Indonesia Country Study: National Council on Climate Change Republic of Indonesia. United Nations Framework Convention in Climate Change (UNFCCC). Jakarta
- Vieilledent, G., Vaudry, R., Andriamanohisoa, S. F., Rakotonativo, O. S., Randrianasola, H. Z., Razafindrabe, H. N., Rakotoarivony, C. B., Ebeling, J. and Rasemolia, M. (2012). A universal approach to estimate biomass and carbon stock in tropical forest using genetic
- Wu, H., Chen, Y., Luo, G. and Wang, C. (2022). Correlation between carbon storage and biometric variables in a temperate forest in China. *Forests*, 13(3): 625
- Zhang, H., Goll, D. S., Manzoni, S., Ciais, P., Guenet, B. and Hueng, Y. (2018). Modeling the effects of litter stoichiometry and soil mineral N availability on soil organic matter formation using CENTUARY-CUE (v1.0). *Geosci Model Dev*, 11(12): 4779-4796.