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Tree species diversity and carbon sequestration potentials in Jos wildlife park, Jos, Plateau state, Nigeria

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Abstract
This study evaluated Tree species diversity, Biomass, and Carbon sequestration capacity of tree species in Jos wildlife Park, Plateau State. A systematic sampling technique was used for this study, in which four (4) transects of 0.5 km in length were laid at intervals of 150m apart. In each of the transect, four (4) rectangular plots of 100 X 50m in size were laid alternatively along each transect at an interval of 20m where all trees were identified, counted and the height and diameter at breast height (DBH) of trees were recorded. Non-destructive method was used for data estimation of tree species diversity, biomass and carbon sequestration using their equations. The result revealed 1,035 trees belonging to 17 families and 38 different species in the study area. The most dominant tree species was *Pinus caribaea* 482 (46.57%) individuals, followed by *Jacaranda mimosifolia* 76 (7.34%) individuals while, *Anogeissus leiocarpus*, *Etanda africana*, *Gmelina arborea*, *Milicia excelsa*, and *Tectona grandis* were encountered only once (0.1%) in the sampled areas. Shannon-Weigner Diversity Index showed that the study area has a diversity index of 2.3445. The average biomass stock of the study area was estimated as 32.7 tons. The species with the highest mean biomass stock was *Eucalyptus toreliana* with a value of 10.09 tons, while *Croton macrostachyus* had the lowest mean biomass value of 0.115 ton. *Pinus caribaea* accounted for the highest carbon sequestration of 210.7 tons/ha, while *Gmelina arborea* had the lowest carbon sequestration of 0.05 tons/ha. The result further revealed that tree species with high biomass and carbon sequestration capacities should be given higher priority in reforestation and afforestation projects. Rare trees species that existed in the study area should be properly protected to maintain tree diversity and prevent their complete extinction.

Keywords: Biomass stock, carbon sequestration, tree species diversity, non-destructive

Introduction

The sustainable management and use of these Forest resources is essential for the nation's economic and environmental security (Akinsanmi, 1999) [44]. Nigeria harbors about 7,895 species of plant thereby making it one of the richest biodiversity hotspot in the continent (Adeyimi and Ogundipe, 2012; Nodza *et al*., 2014) [4, 25]. Trees, apart from forming the major structural and functional basis of tropical rainforest also serve the functions of carbon sequestration, watersheds, provide shades and homes to many life forms and above all, act as purifier to the ecosystem Fuwape and Onyekwelu (2011) [13] and (Singh, 2002). A higher number of tree species increases the number of ecologically niches as well as the number of associated species (Agbelade *et al*., 2016a; Adekunle *et al*., 2013; Kanowski *et al*., 2003; Wunderle, 1997) [5, 2, 20, 41]. The continued existence of these forests and their plant species is in jeopardy due to different disturbances that can either be natural or anthropogenic which could range from deforestation, logging, flooding, erosion, fire outbreaks etc., all of which are drastically on the increase in recent times thereby posing an appreciable risk to local extinction of some of these species (Nodza *et al*., 2014) [25]. The evidence of climate change is linked to human-induced increase in greenhouse gas (GHG) concentrations which is well documented and supported by several international studies (Intergovernmental Panel on Climate Change, 2007). Due to rapid economic growth and large population size, energy consumption is projected to increase in developing countries, largely in India. This increase in energy consumption will result in higher greenhouse gas emissions (Takeshita, 2009) [26], associated with fossil fuel use.

Forests play an important role in the global carbon cycle. The Forest serves as a major terrestrial carbon pool and also has the potential to absorb and store carbon dioxide from the atmosphere.

Tropical forests play a very significant role in mitigating global climate change. Forests are estimated to sequestrate about 15% of global carbon emissions, global deforestation and forest degradation accounts for up to 20% of annual greenhouse gas emissions (Achard *et al.* 2007) [1]. Estimation of the accumulated biomass in the forest ecosystem is important for assessing the productivity and sustainability of the forest. It also gives us an idea of the potential amount of carbon that can be emitted in the form of carbon dioxide when forests are being cleared or burned (Lu, 2006) [23].

Bush burning, hunting activities that involve the use of fire, cutting down of trees for fuel wood, furniture, agriculture and infrastructure are ongoing; this has contributed to the negativity affecting Jos Wildlife Park. According to Sahney *et al*. (2010) [31], deforestation causes the decline and extinction of some flora and fauna species, changes in climatic conditions, desertification, and displacement of animal and plant populations. Therefore, this study provides baseline data on tree species diversity and carbon sequestration potential in Jos Wildlife Park with the view of contributing to the amelioration of global climate change, while still conserving the biodiversity of the study area.

Materials and Methods

Study Area

The study area is in Jos Plateau State, North-central Nigeria. Plateau State lies between Latitudes $8^{0}30'$ and $10^{0}30'$ North and Longitude $7^{0}30'$ and $8^{0}37'$ East of the Equator with a land mass covering 53, 585 square kilometres (Fig. 1). It has a unique vegetation unit, within the Guineo-Congolian / Sudanian Regional Transition Zone. It comprises high plains with scattered rock outcrops ranging from 1120 to 1450 m above sea level and several granite hill ranges that rise to 1,781 m. The average rainfall of the Jos-Plateau is 1,411 mm per year. The average temperature is about 22 °C, though in the months of December, January and February, temperature sometimes drop to 10 °C, and thereafter rises to 30 °C in the months of March and April (Ihemegbulem and Nyong, 2002) [16]. The vegetation cover is the montane type, with gallery forests along river valleys and grass on plains and hillslopes. Much of the vegetation of the Jos Plateau has been devastated by tin-mining activities (Hadejia *et al.* 2000) [14]. A high human population density (200-300 people per km^2) 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 fuel wood collection (Molokwu, 2009) [24]. According to Iloejo (1981) [18], 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. Only a few areas of natural grasslands, savanna-woodlands, and forest remain on the Jos Plateau and one of such areas is the Jos Wildlife Park.

The Jos Wildlife Park is one of the largest man-made zoological gardens in the country and it is owned and managed by the Government of Plateau State. The park was established in 1972 and it is located south west of Jos, on latitude 52°N 2 and longitude 8° 53'E, and covers an area of 8 km^2 (Kwaga *et al*., 2017) [21]. It is essentially characterized by savanna 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) [17]. This 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*, *Parkia biglobosa*, *Lophira lanceolata*, *Khaya senegalensis*, *Vitex doniana*, *Piliostigma thonningii* and different species of Ficus (Ezealor 2002) [11].

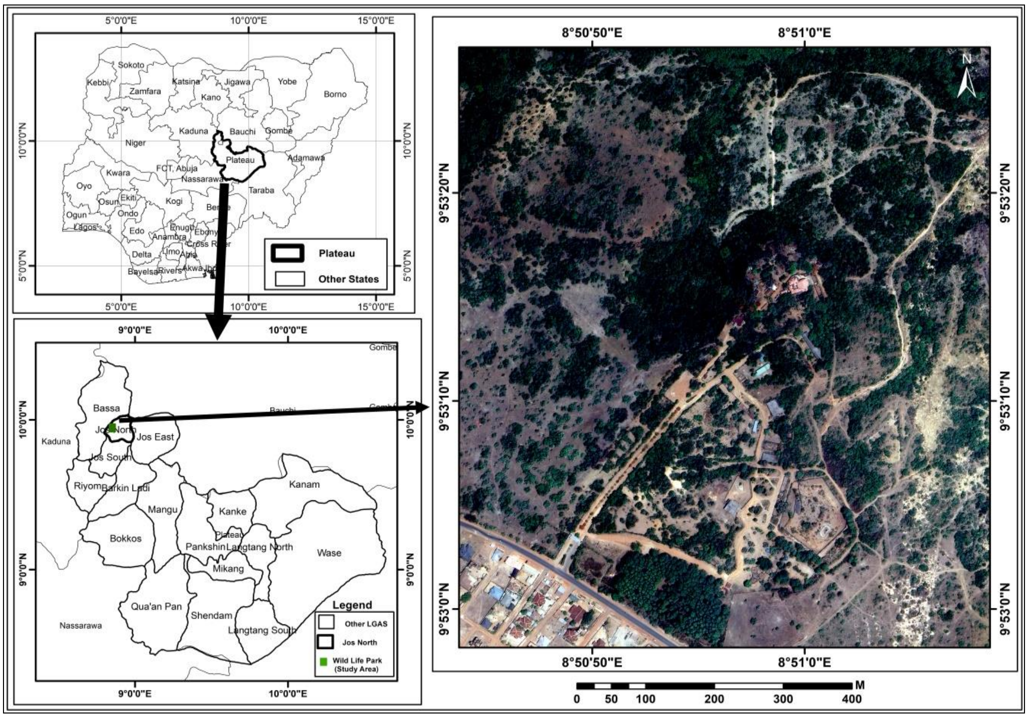

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Fig 1: Map of Plateau State showing the Study Area

Sampling Procedure and Measurement of Tree Variables

A systematic sampling technique was used for this study as adopted by (Adeyemi *et al.* 2015) [1]. Four (4) transects of 0.5 km were laid at intervals of 150m. Four (4) rectangular plots of 100 X 50m in size were laid alternately along each transect at an interval of 20m. Tree species and tree variables such as tree height and tree diameter at breast height (dbh) were all recorded. Non-destructive method which involves the use of equations and formulas were used to estimate tree species diversity, biomass and carbon sequestration.

Data Analysis

Tree species diversity, Biomass and carbon sequestration was analyzed using Microsoft Excel 2016 software. Descriptive statistics such as frequencies, percentage, and tables were used to show the number of trees per species, above-ground biomass, below-ground biomass, and carbon stock of trees per species.

Tree species diversity Estimation

Tree species diversity was calculated using the Shannon-Weiner (H') Diversity Index as adopted by Asifat *et. al* (2019) [7].

$$H' = -\sum pi \ln pi$$

H′ = The Shannon-Wiener diversity index
Pi = the proportion of the plant species relative to the total number of species
ln = natural logarithm

Volume Estimation

Huber's formula was used to obtain volume as adopted by Avery and Burkhart, (2002) [8]:

$$V = h\,(Am) = h\,(\pi dm^2/4)$$
$$A = \pi r^2 = \pi d^2/4$$

Where;
A = Cross-sectional area (m²),
r = Radius (m),
Dm = Diameter at the middle (cm)
h = Height of tree
π = Constant (22/7).

Wood Density Estimation

The wood density values (Appendix I) for the tree species in the study area were obtained from the web (www.worldagroforestry.org) according to species, genus, and family as adopted by Suryawanshi *et al*., 2014 [35].

Estimation of Above-Ground Biomass (AGB)

The above-ground biomass (AGB) was estimated using the non-destructive method as adopted by Hangarge *et al*., 2012 [15].

AGB (Kg) = Volume of tree (V) x Wood density (Kg/m³)

Estimation of below-ground biomass (BGB)

The Below Ground Biomass (BGB) includes all biomass of roots excluding fine roots having < 2 mm diameter. The BGB was calculated by multiplying AGB by 0.26 factor as the expressing root: shoot ratio. BGB was calculated by using the following formula as adopted by (Hangarge *et al*., 2012) [15].

BGB (ton/tree) = AGB (ton/tree) x 0.26.

Estimation of Total Biomass (TB)

The total biomass of trees was calculated by summation of the AGB and BGB of trees. The total Biomass of trees was calculated using the following equation as adopted by (Sheikh *et al*., 2011) [33] and (FAO 2011) [12]. In this research, the equation for total biomass was:

TB = Aboveground biomass (excluding litter) + Belowground biomass (Excluding Soil Organic Matter).

Estimation of Carbon Storage

Generally, for any plant species, 50% of its biomass is considered as carbon. The carbon of trees was calculated using the following equation (Vieilledent *et al*., 2012) [39].

Carbon store = Biomass×50% or Carbon store = Biomass /2

Estimation of Carbon dioxide sequestered

The weight of carbon dioxide sequestered (CO_2 is composed of one molecule of Carbon and 2 molecules of Oxygen and the atomic weight of Carbon is 12.001115; The atomic weight of Oxygen is 15.9994). Hence, the weight of carbon dioxide is C + (2 X O) = 43.999915, while the ratio of carbon dioxide to carbon is 43.999915/12.001115 = 3.6663. Therefore, to estimate the carbon dioxide sequestered in the tree, the carbon stored in the tree was multiplied by 3.6663 (Pascua *et al*., 2021) [26].

Results and Discussions

Tree Species Diversity in the Study Area

Results from Table 1 showed the tree species diversity of the study area. A total of 1,035 individuals comprising 38 species belonging to 17 families were encountered in the study area. The most dominant tree species was *Pinus caribaea* 482 (46.57%) individuals, followed by *Jacaranda mimosifolia* 76 (7.34%) and *Syzygium guineense* 65 (6.28%) individuals while, *Anogeissus leiocarpus*, *Etanda africana*, *Gmelina arborea*, *Milicia excelsa*, and *Tectona grandis* were encountered only once (0.1%) in the sampled areas. Shannon-Weiner Diversity Index showed that the study area has a diversity index of 2.3445.This score shows that the Jos Wildlife Park harbors a moderately diverse community of species and signifies a healthy mix of different species, each contributing to the ecological balance and richness of the environment.

The findings of this research revealed that *Pinus cariba* and *Jacaranda mimosifolia* had the highest species diversity, with a frequency of 482 (46.57%) and 76 (7.34%) respectively in the study area. This result of this finding conforms to that of Emtage (2020) [10] who reported, that the established supply chain and the rapid growth rates of this exotic species have led to their choice for plantation establishment in Nigeria.

In addition, the rare existence of some tree species such as *Anogeissus leiocarpus*, *Etanda africana*, *Gmelina arborea*, *Milicia excelsa*, and *Tectona grandis* in the study area may be attributed to the anthropogenic activities which have created a negatively impact on some of the important tree species in the study area. This findings is in accordance with

Wardle *et al.* (2004) [40] who also reported that the effect of anthropogenic activities on certain trees species caused a great risk of extinction if not properly conserved.

Table 1: Tree Species Diversity

S/No.	Family	Tree Species	Frequency (n)	Frequency (%)	Pi	LnPi	-(Pi*LnPi)
1	*Phyllosiphonaceae*	*Afzelia africana*	2	0.19	0.0019	-6.249	0.0121
2	*Fabaceae*	*Albizia zygia*	22	2.13	0.0213	-3.8511	0.0819
3	*Combretaceae*	*Anogeissus leiocarpa*	1	0.1	0.001	-6.9422	0.0067
4	*Meliaceae*	*Barsema abyssinica*	21	2.03	0.0203	-3.8976	0.0791
5	*Phyllanthaceae*	*Bridelia farruginea*	10	0.97	0.0097	-4.6396	0.0448
6	*Casuarinaceae*	*Casuarina equisetifolia*	21	2.03	0.0203	-3.8976	0.0791
7	*Combretaceae*	*Combretum mole*	8	0.77	0.0077	-4.8627	0.0376
8	*Euphorbiaceae*	*Croton macrostachyus*	27	2.61	0.0261	-3.6463	0.0951
9	*Fabaceae*	*Daniella oliveri*	2	0.19	0.0019	-6.249	0.0121
10	*Fabaceae*	*Delonix regia*	4	0.39	0.0039	-5.5559	0.0215
11	*Fabaceae*	*Dichrostachys cinerea*	5	0.48	0.0048	-5.3327	0.0258
12	*Maliaceae*	*Ekebergia senegalensis*	7	0.68	0.0068	-4.9962	0.0338
13	*Rubiaceae*	*Etanda africana*	1	0.1	0.001	-6.9422	0.0067
14	*Myrtaceae*	*Eucalyptus camaldulensis*	20	1.93	0.0193	-3.9464	0.0763
15	*Myrtaceae*	*Eucalyptus torelliana*	2	0.19	0.0019	-6.249	0.0121
16	*Moraceae*	*Ficus thonningii*	7	0.68	0.0068	-4.9962	0.0338
17	*Lamiaceae*	*Gmelina arborea*	1	0.1	0.001	-6.9422	0.0067
18	*Bignoniaceae*	*Jacaranda mimosifolia*	76	7.34	0.0734	-2.6114	0.1918
19	*Maliaceae*	*Khaya senegalensis*	10	0.97	0.0097	-4.6396	0.0448
20	*Anacardiaceae*	*Lannea acida*	29	2.8	0.028	-3.5749	0.1002
21	*Asteraceae*	*Lina samphera*	7	0.68	0.0068	-4.9962	0.0338
22	*Ochnaceae*	*Lophira lanceolata*	15	1.45	0.0145	-4.2341	0.0614
23	*Anacardiaceae*	*Mangifera indica*	15	1.45	0.0145	-4.2341	0.0614
24	*Moraceae*	*Milicia excels*	1	0.1	0.001	-6.9422	0.0067
25	*Ochnaceae*	*Ochna schweinfurthii*	35	3.38	0.0338	-3.3868	0.1145
26	*Polypodiaceae*	*Parkia biglobosa*	24	2.32	0.0232	-3.7641	0.0873
27	*Lauraceae*	*Persea americana*	3	0.29	0.0029	-5.8435	0.0169
28	*Pinaceae*	*Pinus caribaea*	482	46.57	0.4657	-0.7642	0.3559
29	*Rubiaceae*	*Polysphaeria arbuscula*	38	3.67	0.0367	-3.3046	0.1213
30	*Fabaceae*	*Pterocarpus erinaceus*	4	0.39	0.0039	-5.5559	0.0215
31	*Anacardiaceae*	*Rhus natalensis*	2	0.19	0.0019	-6.249	0.0121
32	*Fabaceae*	*Senna siamea*	30	2.9	0.029	-3.541	0.1026
33	*Myrtaceae*	*Syzygium guineense*	65	6.28	0.0628	-2.7678	0.1738
34	*Myrtaceae*	*Syzygium macrocarpum*	5	0.48	0.0048	-5.3327	0.0258
35	*Lamiaceae*	*Tectona grandis*	1	0.1	0.001	-6.9422	0.0067
36	*Combretaceae*	*Terminalia glauscescens*	9	0.87	0.0087	-4.7449	0.0413
37	*Sapotaceae*	*Vitellaria paradoxa*	10	0.97	0.0097	-4.6396	0.0448
38	*Lamiaceae*	*Vitex doniana*	13	1.26	0.0126	-4.3772	0.055
			1035				2.3445

***Source*:** Field Survey, 2023

Biomass of Tree Species in the Study Area

Table 2, revealed the biomass of trees species in the study area. The average biomass stock in Jos Wildlife Park was estimated to 32.7 tons in the sampled plots. The tree species with the highest average biomass was *Eucalyptus toreliana* (10.09 tons) followed by *Eucalyptus camaldulensis* (5.84 tons), *Pinus caribaea* (1.91 tons), *Senna siamea* (1.68 tons), and *Tectona grandis* (1.19 tons) and *Croton macrostachyus* showed the lowest biomass value of 0.12 tons.

According to Ravindranath *et al*. (2008) [30], biomass density (expressed as dry matter per unit area) indicates the potential amount of CO_2 that can be released into the atmosphere when vegetation is burned or cleared. The findings of this research reveal that average of (32.7) tons of CO_2 can be released into the atmosphere when the trees in the study area are burned or cleared. The obtained results from this study represents a significant stock of biomass, which highlights the ecological importance of the study area as well as signifies its potential for carbon sequestration and the provision of various ecosystem services such as habitat provision and nutrient cycling.

Appendix II shows observations related to plant growth *viz*., diameter at breast height, and height varied with tree species. The maximum mean diameter at breast height of the tree (58.9 cm) was recorded for *Eucalyptus torelliana* followed by *Eucalyptus camaldulensis* (56.2 cm). The minimum mean diameter at breast height was found in *Croton macrostachyus* (15.8 cm). The mean maximum height was encountered in *Eucalyptus torelliana* (35.5 m), followed by *Delonix regia* (28 m) and *Eucalyptus camaldulensis* (26.8 m). A minimum mean height of 4.6m was obtained in *Lina samphera*. The maximum mean diameter at breast height of (58.9cm) was recorded for *Eucalyptus torelliana* followed by *Eucalyptus camaldulensis* (56.7 cm), and 35.5 m, 24.6 m respectively for mean trees height stores the highest carbon per trees. This means that most trees with larger DBHs and tree height tend to stores more biomass in them. This conforms to the findings of Saka *et al*. (2020) [32] who reported in a similar study, that the bole component of the studied species (Neem) had the highest mean biomass content and stores more carbon. Additionally, this finding agrees with Pokhrel and Sherpa (2020) [29] who reported that trees having larger DBH and bigger height contributes more biomass as well as provides greater ecosystem resilience. Taller trees have larger crowns, which allow them to photosynthesize more carbon.

Table 2: Biomass per Tree Species in the Study Area

S/no	Trees Species	Frequency (n)	Mean ABG Biomas (kg)	Mean BG Biomas (kg)	Total Mean Biomass (Tones/tree)
1	*Afzelia africana*	2	144	37.4	0.18
2	*Albizia zygia*	22	689	179	0.87
3	*Anogeissus leiocarpa*	1	336	87.4	0.42
4	*Barsema abyssinica*	21	226	58.9	0.29
5	*Bridelia farruginea*	10	93.4	24.3	0.12
6	*Casuarina equisetifolia*	21	553	144	0.7
7	*Combretum molle*	8	212	55	0.27
8	*Croton macrostachyus*	27	91.5	23.8	0.12
9	*Daniella oliveri*	2	313	81.4	0.39
10	*Delonix regia*	4	635	165	0.8
11	*Dichrostachys cinerea*	5	128	33.2	0.16
12	*Ekebergia senegalensis*	7	293	76.1	0.37
13	*Etanda africana*	1	339	88.2	0.43
14	*Eucalyptus camaldulensis*	20	4637	1206	5.84
15	*Eucalyptus torelliana*	2	8006	2081	10.1
16	*Ficus thonningii*	7	111	28.9	0.14
17	*Gmelina arborea*	1	193	50	0.24
18	*Jacaranda mimosifolia*	76	400	104	0.5
19	*Khaya senegalensis*	10	337	87.6	0.42
20	*Lannea acida*	29	119	30.8	0.15
21	*Lina samphera*	7	121	31.4	0.15
22	*Lophira lanceolata*	15	326	84.7	0.41
23	*Mangifera indica*	15	123	31.9	0.15
24	*Milicia excels*	1	255	66.2	0.32
25	*Ochna schweinfurthii*	35	700	182	0.88
26	*Parkia biglobosa*	24	424	110	0.53
27	*Persea americana*	3	146	37.9	0.18
28	*Pinus caribaea*	482	1512	393	1.91
29	*Polysphaeria arbuscula*	38	514	134	0.65
30	*Pterocarpus erinaceus*	4	476	124	0.6
31	*Rhus natalensis*	2	99.3	25.8	0.13
32	*Senna siamea*	30	1332	346	1.68
33	*Syzygium guineense*	65	183	47.6	0.23
34	*Syzygium macrocarpum*	5	177	46	0.22
35	*Tectona grandis*	1	948	246	1.19
36	*Terminalia glauscescens*	9	134	34.8	0.17
37	*Vitellaria paradoxa*	10	254	66	0.32
38	*Vitex doniana*	13	366	95.1	0.46
		1035			32.7

***Source*:** Field Survey, 2023
AG- Above-Ground BG- Below-Ground

The Carbon Dioxide Sequestration of some Tree Species in the Study Area

The finding from this study indicates significant variation in the carbon sequestration capacity among the 38 tree species studied. The total CO_2 sequestered by all tree species in the study area was estimated to be 302.3 t/ha (Table 3). Four hundred and eighty-two (482) *Pinus caribaea* trees were counted, with a carbon sequestration capacity of 210.66 tons/ha. Additionally, there were 20 *Eucalyptus camaldulenses* trees, which sequestered 26.80 tons/ha of carbon. *Senna siamea* consisting of 30 trees, stored 11.54 tons/ha of carbon. *Jacaranda mimosifolia* accounted for 76 trees, with a carbon sequestration capacity of 8.77 tons/ha while, *Gmelina arborea* had the lowest carbon sequestration, with only a tree sequestering 0.05 tons/ha.

The high carbon sequestration capacity of *Pinus Caribbean* aligns with previous studies by Adeyemi *et al.* (2020) [3], showing *Pinus caribaea* plantation having more net total biomass and carbon stock when compared to other tree species like *Gmelina arborea,and Tectona grandis*. This makes *Pinus Caribbean* an ideal choice for large-scale afforestation programs. For *Eucalyptus camaldulenses*, despite having only 20 individual trees, it still exhibited a considerable carbon sequestration capacity of 26.8 tons/ha. This result aligns with previous research highlighting the high carbon sequestration potential of eucalyptus species (Behera *et al.* 2020) [9] and this suggest, that *Eucalyptus camaldulenses* could be a viable option for afforestation or reforestation projects in suitable regions.

This finding also agrees with Pelemo *et. al.* (2018) [27] who stated that trees stored high carbon content per tree, due to tree sizes, higher wood density and tree maturity. These findings also agree with the studies carried out by by Perez-Cordero and Kanninen (2003) [28], Tschakert *et al.* (2006) [38], and Terakunpisut *et al*. (2007) [37] which stated that variations in carbon stock can be the 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.

Table 3: Accumulated (CO_2) of Some Tree Species in the Study Area

S/no	Tree Species	Frequency	Carbon Stored (Kg)	Carbon Stored (%)	$C0_2$ Sequestered (kg)	$C0_2$ Sequestered (ton/ha)
1	*Afzelia Africana*	2.0	181.40	0.03	665.74	0.083217
2	*Albizia zygia*	22.0	9552.40	1.45	35057.31	4.382164
3	*Anogeissus leiocarpa*	1.0	211.75	0.03	777.12	0.09714
4	*Barsema abyssinica*	21.0	2995.65	0.45	10994.04	1.374254
5	*Bridelia farruginea*	10.0	588.50	0.09	2159.8	0.269974
6	*Casuarina equisetifolia*	21.0	7312.20	1.11	26835.77	3.354472
7	*Combretum molle*	8.0	1066.80	0.16	3915.16	0.489395
8	*Croton macrostachyus*	27.0	1556.55	0.24	5712.54	0.714067
9	*Daniella oliveri*	2.0	394.30	0.06	1447.08	0.180885
10	*Delonix regia*	4.0	1599.60	0.24	5870.53	0.733817
11	*Dichrostachys cinerea*	5.0	402.50	0.06	1477.18	0.184647
12	*Ekebergia senegalensis*	7.0	1290.45	0.20	4735.95	0.591994
13	*Etanda Africana*	1.0	213.80	0.03	784.65	0.098081
14	*Eucalyptus camaldulensis*	20.0	58425	8.87	214419.8	26.80247
15	*Eucalyptus torelliana*	2.0	10086.9	1.53	37018.92	4.627365
16	*Ficus thonningii*	7.0	490.70	0.07	1800.87	0.225109
17	*Gmelina arborea*	1.0	121.25	0.02	444.99	0.055623
18	*Jacaranda mimosifolia*	76.0	19129.20	2.90	70204.16	8.775521
19	*Khaya senegalensis*	10.0	2121.50	0.32	7785.91	0.973238
20	*Lannea acida*	29.0	2164.85	0.33	7945	0.993125
21	*Lina samphera*	7.0	532.70	0.08	1955.01	0.244376
22	*Lophira lanceolata*	15.0	3076.50	0.47	11290.76	1.411344
23	*Mangifera indica*	15.0	1158.75	0.18	4252.61	0.531577
24	*Milicia excels*	1.0	160.35	0.02	588.48	0.073561
25	*Ochna schweinfurthii*	35.0	15428	2.34	56620.76	7.077595
26	*Parkia biglobosa*	24.0	6406.80	0.97	23512.96	2.93912
27	*Persea Americana*	3.0	275.85	0.04	1012.37	0.126546
28	*Pinus caribaea*	482.0	459201.40	69.69	1685269	210.6586
29	*Polysphaeria arbuscula*	38.0	12308.20	1.87	45171.09	5.646387
30	*Pterocarpus erinaceus*	4.0	1198.80	0.18	4399.60	0.54995
31	*Rhus natalensis*	2.0	125.10	0.02	459.12	0.05739
32	*Senna siamea*	30.0	25165.50	3.82	92357.39	11.54467
33	*Syzygium guineense*	65.0	7497.75	1.14	27516.74	3.439593
34	*Syzygium macrocarpum*	5.0	556.75	0.08	2043.27	0.255409
35	*Tectona grandis*	1.0	597.05	0.09	2191.17	0.273897
36	*Terminalia glauscescens*	9.0	758.25	0.12	2782.78	0.347847
37	*Vitellaria paradoxa*	10.0	1599	0.24	5868.33	0.733541
38	*Vitex doniana*	13.0	2996.50	0.45	10997.16	1.374644
					2,418,341	302.2926

Source: Field survey, 2023

Conclusion

Tree species diversity provides numerous benefits and services to humans, wildlife and the environment. However, special attention must be paid to trees species that are rare such as *Anogeissus leiocarpus*, *Etanda africana*, *Gmelina arborea*, *Milicia excelsa*, and *Tectona grandis* to prevent their extinction. The average of 302.3 tons/ha of carbon dioxide sequestrated by trees in the study area indicates the ecological importance of the area as a carbon sink and an essential component of the local ecosystem. Furthermore, this study has revealed significant variations in the carbon sequestration capacity among different trees species, with *Pinus Caribbea (482)* emerging as the most efficient species in the study area with 210.66 tons per hectare. E*ucalyptus camaldulenses* also exhibited a notable carbon sequestration capacity with 20 trees storing 214.4 tons of carbon.

This suggests that *Eucalyptus camaldulenses* could be another valuable tree species to consider in carbon sequestration initiatives. Hence emphasizes on the importance of incorporating tree species such as *Eucalyptus toreliana*, *Eucalyptus camaldulenses*, *Pinus caribeae*, *Senna siamea*, and *Tectona grandis* with high biomass and carbon sequestration capacities into reforestation and afforestation efforts to ameliorate the effects of global climate change and promote sustainable forestry practices should be given higher priority. Weaker trees species that existed in the study area should be properly protected to maintain tree diversity and prevent their complete removal as a result of developmental projects. Additionally, frequent survey and inventory of trees on Jos Wildlife Park should be conducted by relevant stakeholders to assess their abundance, distribution and density as well as structural and physical changes appropriate for management practices.

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Appendix I: Standard Wood Density of Some Tree Species in Jos Wildlife Park

S/no	Family	Tree Species	Wood Density (g/cm^3)
1	*Phyllosiphonaceae*	*Afzelia africana*	0.72
2	*Fabaceae*	*Albizia zygia*	0.51
3	*Combretaceae*	*Anogeissus leiocarpa*	0.88
4	*Meliaceae*	*Barsema abyssinica*	0.67
5	*Phyllanthaceae*	*Bridelia farruginea*	0.59
6	*Casuarinaceae*	*Casuarina equisetifolia*	0.84
7	*Combretaceae*	*Combretum molle*	0.84
8	*Euphorbiaceae*	*Croton macrostachyus*	0.52
9	*Fabaceae*	*Daniella oliveri*	0.51
10	*Fabaceae*	*Delonix regia*	0.74
1	*Fabaceae*	*Dichrostachys cinerea*	0.94
12	*Maliaceae*	*Ekebergia senegalensis*	0.56
13	*Rubiaceae*	*Etanda africana*	0.74
14	*Myrtaceae*	*Eucalyptus camaldulensis*	0.76
15	*Myrtaceae*	*Eucalyptus torelliana*	0.83
16	*Moraceae*	*Ficus thonningii*	0.44
17	*Lamiaceae*	*Gmelina arborea*	0.44
18	*Bignoniaceae*	*Jacaranda mimosifolia*	0.49
19	*Maliaceae*	*Khaya senegalensis*	0.66
20	*Anacardiaceae*	*Lannea acida*	0.52
21	*Asteraceae*	*Lannea schimperi*	0.52
22	*Ochnaceae*	*Lophira lanceolata*	0.79
23	*Anacardiaceae*	*Mangifera indica*	0.6
24	*Moraceae*	*Milicia excels*	0.59
25	*Ochnaceae*	*Ochna schweinfurthii*	0.62
26	*Polypodiaceae*	*Parkia biglobosa*	0.53
27	*Lauraceae*	*Persea americana*	0.56
28	*Pinaceae*	*Pinus caribaea*	0.55
29	*Rubiaceae*	*Polysphaeria arbuscula*	0.67
30	*Fabaceae*	*Pterocarpus erinaceus*	0.63
31	*Anacardiaceae*	*Rhus natalensis*	0.62
32	*Fabaceae*	*Senna siamea*	0.68
33	*Myrtaceae*	*Syzygium guineense*	0.68
34	*Myrtaceae*	*Syzygium macrocarpum*	0.71
35	*Lamiaceae*	*Tectona grandis*	0.61
36	*Combretaceae*	*Terminalia glauscescens*	0.73
37	*Sapotaceae*	*Vitellaria paradoxa*	1.28
38	*Lamiaceae*	*Vitex doniana*	0.59

***Source*:** www.worldagroforestry.org
Date Retrieved: 1/07/2023

Appendix II: Tree Species Composition in the Study Area

S/no	Tree Species	Frequency (n)	Mean Tree height(m)	Mean Dbh (Cm)
1	*Afzelia africana*	2	7	19.1
2	*Albizia zygia*	22	13.3	35.8
3	*Anogeissus leiocarpa*	1	7.5	25.5
4	*Barsema abyssinica*	21	8.6	22.4
5	*Bridelia farruginea*	10	8	15.9
6	*Casuarina equisetifolia*	21	10.2	28.7
7	*Combretum mole*	8	8.4	19.5
8	*Croton macrostachyus*	27	9	15.8
9	*Daniella oliveri*	2	9.3	29
10	*Delonix regia*	4	14	28
11	*Dichrostachys cinerea*	5	7	15.7
12	*Ekebergia senegalensis*	7	9.5	26.6
13	*Etanda africana*	1	11.5	22.6
14	*Eucalyptus camaldulensis*	20	24.6	56.2
15	*Eucalyptus torelliana*	2	35.5	58.9
16	*Ficus thonningii*	7	6	23.1
17	*Gmelina arborea*	1	8	26.4
18	*Jacaranda mimosifolia*	76	9	33.9
19	*Khaya senegalensis*	10	7.2	30.1
20	*Lannea acida*	29	6.4	21.4
21	*Lina samphera*	7	5.3	23.7
22	*Lophira lanceolata*	15	9.6	23.4
23	*Mangifera indica*	15	5.8	21.3
24	*Milicia excels*	1	11	22.3
25	*Ochna schweinfurthii*	35	24.3	24.3
26	*Parkia biglobosa*	24	9.1	33.4
27	*Persea americana*	3	8.5	19.7
28	*Pinus caribaea*	482	21	40.8
29	*Polysphaeria arbuscula*	38	10.7	30.3
30	*Pterocarpus erinaceus*	4	8.8	33
31	*Rhus natalensis*	2	7.3	16.7
32	*Senna siamea*	30	22.2	33.5
33	*Syzygium guineense*	65	7	22.1
34	*Syzygium macrocarpum*	5	8.3	19.6
35	*Tectona grandis*	1	13.5	38.2
36	*Terminalia glauscescens*	9	6.7	18.7
37	*Vitellaria paradoxa*	10	5.8	21
38	*Vitex doniana*	13	11	26.7
		1035		

***Source*:** Field survey, 2023