SPECIAL ISSUE
Bima Journal of Science and Technology, Vol. 7 (2.1) August, 2023 ISSN: 2536-6041

CARBON SEQUESTRATION IN RELATION TO TREE COMPOSITION IN WAWA ZANGE FOREST RESERVES, GOMBE STATE, NIGERIA

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ABSTRACT

The study examined carbon dioxide (CO_2) sequestration in relation to trees composition in Wawa-Zange Forest Reserve Gombe State. Twenty (20) sample plots of (50X50m) were systematically laid at 100m interval in order to carry out tree survey. Simpson's Diversity Index and non-destructive biomass estimation technique were employed (allometric equation) to determine the volume of carbon in Above-Ground Biomass. A total of 192 individual trees encountered in the forest with *Parkia biglobosa* and *Gmelina arborea* as the most widely distributed and the least distributed trees respectively. The result also indicated that *Gmelina arborea* has the highest CO_2 sequestration potential (2,860,00kg) while *Ximenia Americana* (339,36kg) has the lowest CO_2 sequestration potential. The study further revealed that the sampled plots in Wawa-zange forest reserve has the potential of storing 362.57tC/ha and total of 20,340,177 tonnes of carbon throughout its existence. Regression analyses indicated that both girth and Diameter at Breath Height (DBH) of trees have a positive relation (r=0.9) with carbon sequestration rate of tree species. The study recommended that government should put more efforts towards forest protection through effective monitoring within and outside the forest reserve. The study recommended that government should establish a guide on the type of tree species that should be planted for carbon capture for effective sequestration purpose.

Keywords: Carbon Sequestration, Wawa Zange, Forest reserve, Atmosphere

INTRODUCTION

A carbon sink is a natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period. The process by which carbon sinks remove carbon dioxide (CO_2) from the atmosphere is known as carbon sequestration. Public awareness of the significance of CO_2 sinks has grown since passage of the Kyoto Protocol, which promotes their use as a form of carbon offset (IPCC, 2013).

A forest is considered to be a carbon sink if it absorbs more carbon from the atmosphere than it releases. Carbon is absorbed from the atmosphere through photosynthesis. It then becomes deposited in forest biomass (that is, trunks, branches, roots and leaves), in dead organic matter (litter and dead wood) and in soils (Ofoegbu & Eneji, 2014). This process of carbon absorption and deposition is known as carbon sequestration. Forests can be carbon stores, and they are carbon dioxide sinks when they are increasing in density or area.

Globally, forests store large amounts of carbon sequestered from the atmosphere and retained in living and dead biomass and soil (IPCC, 2022). The estimated amount of carbon dioxide (CO_2) in the atmosphere is equivalent to 810 Pg C, but 500 and 1500 Pg C are stored in terrestrial biomass and soil, respectively, of which 60% is stored in forest systems (McKinley, Ryan & Birdsey., 2011). However, the imbalance between sources of

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carbon released to the atmosphere from anthropogenic burning of fossil fuels and deforestation, with uptake by sinks in oceanic and terrestrial systems, has led to an increase in CO_2 partial pressure in the atmosphere from 28 Pa at the start of the industrial revolution in the nineteenth century to just less than 32 Pa in 1960 and the present-day value of close to 39 Pa (Doblas-Miranda, Rovira & Brotons., 2013, IPCC 2007, McKinley *et al.* 2011). Establishment and management of forests to enhance the removal and storage of CO_2 from the atmosphere are recognized as major opportunities to offset the increase in anthropogenic emissions of greenhouse gases and reduce the rate of global warming.

The Carbon sequestration potential of regenerating Savanna parkland is substantial, because they rapidly accumulate Carbon in above-ground biomass during regrowth (Abby, Lindsay, Daisy, Ute & Emma, 2022). For example in a multi-site Chrono sequence study in the Neotropics, naturally regenerating tropical savanna recovered 90% of old-growth biomass values after 66 years (Poorter et al., 2016). However, as much as 60% of the total tropical forest C stock is stored below-ground in soils (Don et al., 2011) and, in contrast to above-ground biomass, soil C stocks do not necessarily follow a predictable pattern of accumulation over time during secondary succession (Marín-Spiotta & Sharma, 2013; Powers & Marín-Spiotta, 2017). Important knowledge gaps in our understanding of soil C cycling and storage during secondary forest regrowth limit our ability to accurately predict and manage soil C sequestration in secondary tropical forests, such as the influence of past disturbance versus current land cover (Marín-Spiotta & Sharma, 2013.

Study Area

Wawa Zange Forest Reserve is located in Gombe State. This Forest Reserve lies between latitude 10 49 ' 22.7"N and longitudes10 46' 23"E. It occupied a total land area of 561.03sq (Mbaya and Hashidu 2017). The forest reserve is named after two notable villages located at the forest area i.e. Zange village in Dukku Local Government and Wawa Village of Funakaye LGA (Figure 1) .

Wawa Zange forest reserves has an altitude of 411 m above sea level. Topography is mainly mountainous, undulating and hilly to the Southeast and open plains in the central Northeast, west and northwest (Abbas, 2012). The reserve is within Sudan Savannah ecological zone with concentration of wood lands in the south east and south western parts. The vegetation is typically a light closed canopy, with shrubs and a sparse growth of grass. The soils are shallow to deep loamy, sandy clay, loam and vertisols with cracking clays that have weathered from shales (Hayatu and Abba, 2021). The climate of the area is characterized by two distinct seasons: a humid and wet season from April through October and a dry season which runs from November through March (Hayatu and Abba, 2021).

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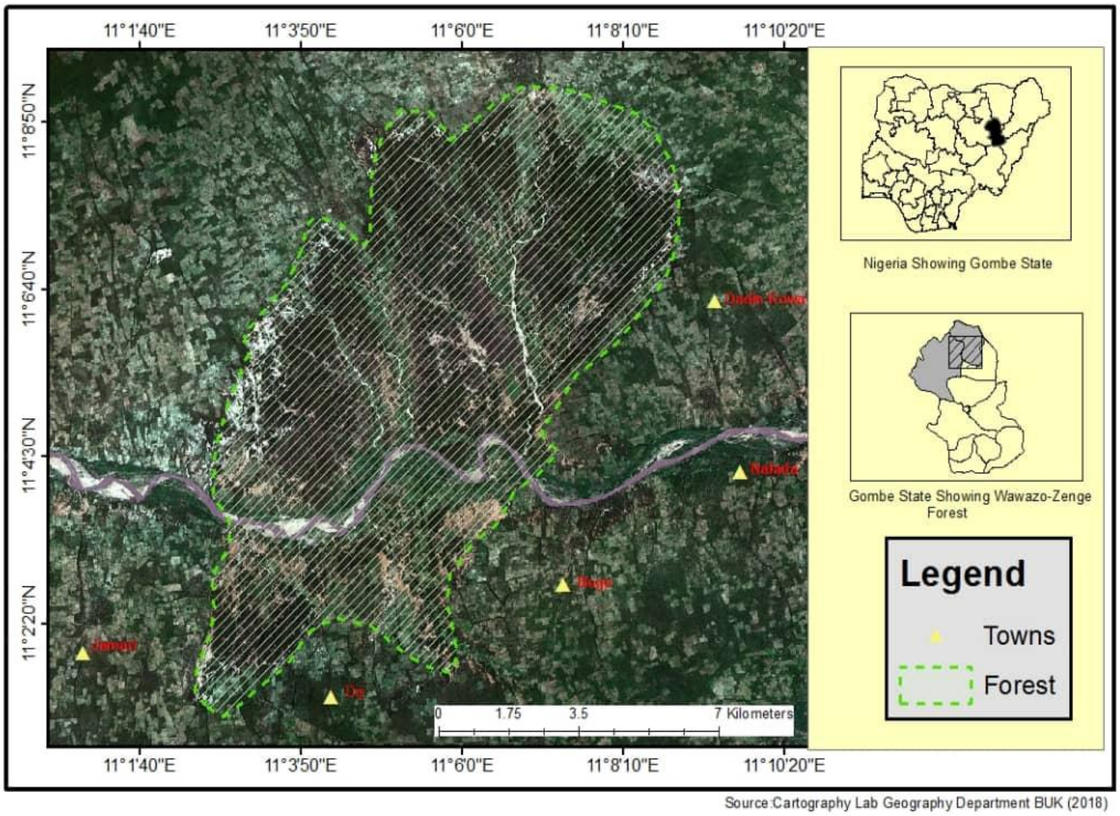

Figure 1: Wawa Zange Forest Reserve Gombe State, Nigeria
Source: Gombe State University GIS Lab

MATERIALS AND METHODS

Quantitative techniques of data collection were used to establish the relationships between different tree variables in order to determine the diversity as well as the rate at which they capture and store carbon dioxide in their tissues. The sampling procedure was systematic sampling as it is usually more efficient and tends to provide better representation of the distribution of forest and forest types. Measurements and observations in the field were made on individual trees and the common tree measurements and observations are: diameter, height, stem form, girth and basal area. Plot size was determined according to the expected number of measurements of the tree parameters in the study area, as plots for measuring small trees can sometimes be smaller than plots for measuring larger trees.

Materials used includes SUUNTO Clinometer, measuring tape, handheld GPS, ranging poles and DBH tape. A sample of Twenty (20) plots of regular shape of dimensions (50 x 50 m) were established for measuring the diversity of trees and determining their carbon sequestration capacity at 100m interval.

The field data was analysed using simple percentage to present the amount Carbon dioxide Sequestration Per Specie, DBH, Height and weight of trees in the forest. SPSS and Excel worksheets (2016) were used for the statistical analysis.

RESULTS AND DISCUSSION

Tree Carbon Sequestration Capacity

The result discovered that, in terms of carbon sequestration, all trees are not created equal. Different plant species have different capacity to sequestrate carbon during photosynthesis. Generally, slow growing species have slow sequestration rate than others. Species like *Shorea robusta, Terminalia tomentosa*, and *Adina cordifolia* are some examples of slow growing plant species as they sequestrate carbon slowly. The amount of carbon a tree sequesters varies based on the growth rate, age, and species of the particular tree. Young, rapidly growing trees uptake far more carbon than mature trees with slower growth rates. Warm and wet climates with long growing seasons also contribute to rapid plant growth and indirectly promote higher rates of carbon sequestration (Pramod & Ishwar,2016).All trees are not created equal, different plant species have different capacity to sequestrate carbon dioxide during photosynthesis. Generally, slow growing species have slow sequestration rate than others. (Pramod *et al*, 2016)

Table 1, revealed that the trees with highest carbon sequestration capacity were found to be *Gmelina arborea, Khaya senegalensis, Parkia biglobosa,* and *Tamarindus indica* with 2,860.57, 2,631.79, 2,200.99, and 2,118.33, kilogram respectively. While the trees in terms of least carbon assimilation and storage were *Ximenia Americana*, *Ceiba petandra, Acacia siberiana* and *Cambrtum spp* with 339.36, 512.82, 822.65 and 818.39 kilogram respectively.

A forest is considered to be a carbon sink if it absorbs more carbon from the atmosphere than it releases. Carbon is absorbed from the atmosphere through photosynthesis. It then becomes deposited in forest biomass (that is, trunks, branches, roots and leaves), in dead organic matter (litter and dead wood) and in soils.

Table 1: Carbon dioxide Sequestration Per Specie

Specie	HEIGHT (M)	DBH (CM)	Weight from tree (kg)			
			Green	Dry	Carbon	CO_2
Acacia sayel	18.86	16.45	918.64	555.01	277.51	1,017.42
Acacia siberiana	16.72	15.71	742.78	448.76	224.38	822.65
Anogeisus leocarpus	18.2	16.66	909.27	549.35	274.68	1,007.04
Azadirachta indica	22.16	16.48	1,083.32	654.51	327.25	1,199.81
Cassia siemea	23.4	15.27	982.12	593.37	296.68	1,087.73
Cambretum spp	19.77	14.41	738.94	446.44	223.22	818.39
Detarium microcarpum	23.1	14.26	845.52	510.83	255.42	936.44
Entada Africana	21.83	15.16	903.08	545.61	272.80	1,000.18
Gmelina arborea	28.7	22.36	2,582.84	1,560.47	780.23	2,860.57
Khaya senegalensis	24.74	23.1	2,376.27	1,435.66	717.83	2,631.79
Parkia biglobosa	21.58	22.19	1,912.66	1,155.57	577.78	2,118.33
Prosopsis Africana	23.45	18.36	1,422.86	859.64	429.82	1,575.85
Vitalleria paradoxum	15.76	19.69	1,099.82	664.47	332.24	1,218.08
Ximenia Americana	13.45	11.25	306.41	185.12	92.56	339.36
Termarindus indica	20.53	23.19	1,987.30	1,200.66	600.33	2,200.99
Sterculia setigera	22.65	15.44	971.93	587.21	293.60	1,076.44
Ceiba pentandra	16.73	12.4	463.03	279.75	139.87	512.82
Total	**351.63**	**292.38**	**20,246.79**	**12,232.44**	**6,116.22**	**22,423.89**

It was observed that the amount of carbon dioxide sequestered increased with increase in the girth and DBH. The finding was validated by Ofoegbu and Eneji (2014) whose result showed that *Gmelina arborea* tend to sequester more carbon than the other tree species in a tropical forest reserve. Also, Kura, (2003) estimated the amount of forest degradation and carbon sequestration and suggested the use of *Gmelina arborea* tree species in reforestation programme to help mitigate global warming.

Carbon Dioxide Sequestration Volume and Potentials

Table 2 revealed that *Gmelina arborea (*2,860.57kg), *Khaya senegalensis (*2,631.79kg), *Termarindus indica (*2,200.99kg) and *Termarindus indica (*2,118.33kg) have high carbon sequestration potential.

Table 2: Carbon Dioxide Sequestration Volume in Wawa-zange Forest Reserve

Species	DBH(CM)	HEIGHT (M)	Carbon Seq (KG)
Acacia sahel	16.45	18.86	1,017.42
Acacia siberiana	15.71	16.72	822.65
Anogeisus leocarpus	16.66	18.2	1,007.04
Azadirachta indica	16.48	22.16	1,199.81
Cassia siemea	15.27	23.4	1,087.73
Cambretum spp	14.41	19.77	818.39
Detarium microcarpum	14.26	23.1	936.44
Entada Africana	15.16	21.83	1,000.18
Gmelina arborea	22.36	28.7	2,860.57
Khaya senegalensis	23.10	24.74	2,631.79
Parkia biglobosa	22.19	21.58	2,118.33
Prosopsis Africana	18.36	23.45	1,575.85
Vitalleria paradoxum	19.69	15.76	1,218.08
Ximenia Americana	11.25	13.45	339.36
Termarindus indica	23.19	20.53	2,200.99
Sterculia setigera	15.44	22.65	1,076.44
Ceiba pentandra	12.40	16.73	512.82
Total	**351.63**	**292.38**	**22,423.89**

The result concur with the findings Ofoegbu and Eneji (2014). It has been discovered that observed that *Gmelina arborea* tree species is the highest in terms of importance value and abundance in storing more carbon than any other tree species in Wawa-zange Forest Reserve. It was also noted that Wawa-zange forest in general could capture and store nearly 362.57 Tc/ha Table 2. It was further revealed that height and Diameter at Breast Height (DBH) determined the rate at which tree species stored carbon dioxide in their tissues. The tree species that follows in terms of carbon store includes; *Khaya senegalensis* (23.10), *Gmelina arborea* (22.36), *Termarindus indica* (23.19) and *Termarindus indica* (22.19). They had higher carbon sequestration rate because of the possession of higher DBH. *Ximenia Americana* (11.25), *Ceiba pentandra* (12.40), *Acacia siberiana* (15.71) had lower DBH, hence, had lower carbon sequestration rates. These tree species tend to have lower Girth which determine the size of the DBH. DBH also determine the biomass of tree species as the tree with higher biomass content tend to sequester carbon more in their tissues than those with lower biomass content (Abby, 2022). Based on the 362.57 Tc/ha carbon dioxide sequestered by the trees in the sampled plots within Wawa-zange Forest Reserve, it was estimated that the forest in general assimilated and sequestered 20,340177 tonnes of carbon throughout its existence. The result is in line with (Ofoegbu and Eneji, 2014) that investigated carbon sequestration potentials of tropical forest reserve and tree species with slice different in carbon content of tree species which is attributed to geographical location and specie type.

CONCLUSION

Wawa-zange forest showed diversity in tree species and significant CO_2 sequestration capacity. In spite of the diversity of trees in Wawa-zange forest, the most important and most widely abundant tree species are not the ones with high sequestration capacity as *Gmelina arborea,* the most least distributed with least Importance Value Index tend to have higher carbon sequestration capacity. Most of the fuelwood and medicinal plants were collected from the forest reserve, exposing it to the dangers of deforestation. Cultivation of medicinal plants on farmlands and gardens therefore is the obvious management option as it might help lessen the pressure on the forest reserve and can greatly increase the amount of CO_2 sequestered by trees from the atmosphere.

Recommendations

1. Efforts should be geared towards protecting the forest from encroachments. Government should employ forest guards that could protect the forest through effective monitoring. Awareness creation against excessive fuelwood exploitation by general public and to ensure strict compliance to appropriate forest regulations.
2. Different tree species have different capacity to sequester carbon. Therefore, trees with higher sequestration potential should be prioritized and incorporated into afforestation /reforestation programs. Namely; G*melina arborea Khaya senegalensis, Termarindus indica* and *Parkia biglobosa.*

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