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Assessment of Carbon Sequestration Potential and Implications on Deforestation in Selected Forests Area in Taraba State, Nigeria

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Abstract

This study employs non-destructive methods to estimate the biomass of various tree species in Taraba State's forests, focusing on aboveground and belowground carbon sequestration. A total of 233 tree species from 13 different families were sampled, and their carbon storage capacity was determined. The aboveground biomass was estimated using a pan-tropical biomass allometric equation, while belowground biomass was calculated as 20% of the aboveground biomass. Carbon stocks in both aboveground and belowground components were assessed, and the resulting carbon dioxide (CO2) sequestration was computed. The study reveals a substantial carbon sequestration potential in Taraba State's forests, with a total sequestration rate of 812.028 tonnes. However, the declining forest area poses a significant threat to this carbon sink, as deforestation releases stored carbon and disrupts local and global climates. Conservation efforts and sustainable land management practices are urgently needed to protect the vital ecosystem services provided by these forests and mitigate climate change.

Keywords: Diameter at Breast Height, carbon sequestration, deforestation, Above Ground Biomass, Below Ground Biomass

Introduction

The emission and reflection of carbon, a critical environmental concern due to global climate change, stands out as one of the most pressing issues in today's world (Karagiannis & Soldatos, 2010). The expansion of urban areas is an ongoing global trend (Grimm et al., 2008), and it is anticipated that by 2030, approximately 60% of the world's population will reside in cities (Rydin et al., 2012). Unfortunately, this urbanization trend is expected to contribute significantly to the overall carbon emissions worldwide. Consequently, the presence of urban trees becomes increasingly important to enhance the quality of human living spaces. Carbon sequestration by vegetation through photosynthesis is a major way to mitigate increase in atmospheric CO_2 concentration and climate change. As a result, quantification and monitoring of carbon stock has gained major attention in international climate change mitigation and adaptation negotiations (Houghton, 2005; IPCC, 2006). Previous research has conventionally concentrated on viewing ecosystems as carbon reservoirs rather than considering them as potential carbon producers (Houghton et al., 1995). When forests are cleared, approximately 20% of the total global carbon dioxide (CO2) emissions are released into the atmosphere (IPCC, 2007). Consequently, the assessment of forest carbon storage is of utmost importance to gauge how effectively forests can mitigate global warming and climate change (Brown and Gaston, 1995; Cao et al., 2001). Moreover, the validation and tracking of carbon reserves within forest ecosystems have been identified as potential strategies to decrease and stabilize greenhouse gas concentrations in the atmosphere (Brown, 1997; Houghton, 1997; Watson Robert et al., 2000; IPCC, 2007). Carbon offset initiatives grounded in forestry have the capacity to serve as both a tool for mitigating climate change and a means of promoting the sustainable conservation of forests (Campbell et al., 2008; Jibrin et al., 2013). Although the potential for carbon sequestration is significant in regions with deteriorated savannahs, the absence of localized field investigations has restricted the viability of launching projects to offset biotic carbon emissions in many of Nigeria's imperilled forests (Jibrin et al., 2013). This research endeavour aims to evaluate the capacity for carbon sequestration in specific forests within Taraba State. Evaluating the carbon sequestration capacity of forests in the State is vital for developing climate change mitigation strategies and guiding policy and land-use decisions. It will also help in identify high-potential areas for carbon absorption, supports ecosystem health, promotes biodiversity, and aligns with sustainable development goals. Additionally, this research provides a baseline for future studies, enabling ongoing monitoring of forest health and carbon storage capabilities.

Materials and Method

The Study Area

Taraba State is located between Latitudes 6˚20'N and 9˚40'N of the equator and between Longitudes 9˚00'E and 12˚00'E of the prime meridian. It is situated in the North Eastern part of Nigeria and occupies a land mass of about 54,473 square kilometers (Ikusemoran et al., 2020). The State is bounded to the north by Bauchi and Gombe States to the east by Adamawa State and the Republic of Cameroon to the south. In the West, it shares border with Plateau, Nassarawa and Benue States. Taraba has sixteen local Government Areas (LGAs). It is home to over 77 ethnic groups, including the Fulani, Tiv, Mumuye, Mambilla, Wurkuns, Jukun, Kuteb, Yandang, Ndola, Itchen, Tigun, and Jibu among others. The major languages spoken in the state are Hausa, Fulani, and Mambilla. The climate of Taraba State is tropical Wet and Dry type. The wet season spans from May to October while the dry season last from November to April. The average annual rainfall is about 1,200 millimeters Guinea Savanna is the predominant vegetation type in Taraba State. It consists of mixed grassland and trees, characterized by tall grasses interspersed with shrubs and scattered trees like the baobab and acacia. This savanna supports a variety of wildlife and is used extensively for agriculture and livestock grazing. The forest is found in the southern and south-eastern parts of the state. The major economic activities in Taraba State are agriculture, mining, and tourism.

Data Collection and Analysis

The study adopted the non-destructive method to estimate the biomass of the different tree species. Non-destructive sampling is used where Diameter at Breast Height (DBH), local wood Density (ρ), and TREE height (H) are the estimator variables for aboveground biomass (Belete et al., 2019).A total of two hundred and thirty three tree (233) species belonging to thirteen (13) different families were sampled. In accordance with the guidance provided by Pouyat et al., (2002) and the insights offered by Okunade and Okunade (2007). The research methodology adhered to standard recommended procedures. Specifically, four purposively sample plots from Ngel Nyaki, Baissa forest reserve and Gashaka Gumti National Park of Taraba State, each measuring 100 meters by 100 meters (IPCC, 2006; Lal, 2004; ISCN, 2017 and NRCS,2018), were precisely determined in the field using a Garmin eTrex 20 GPS device. As advocated by MacDicken (1997), the utilization of GPS receivers significantly enhances the efficiency and precision of plot placement. Within each of these designated plots, all trees exceeding 5 centimetres in Diameter at Breast Height (DBH) (i.e., the diameter at 1.3 meters above ground level) were meticulously gauged using a 50-meter circumference measuring tape while their heights were ascertained with an Abney Level.

Determination of Biomass and Carbon Dioxide Sequestered by Tree

Aboveground Biomass

The estimation of tree aboveground biomass (TAGB) was determined using the pan-tropical biomass allometric equation developed by Chave et al., (2005) for tropical moist forests. This equation is represented as:

$TAGB = \exp(-2.977 + \ln(\rho D^2 H)) = 0.0509 \times \rho D^2 H$ ----1

Here, TAGB stands for tree aboveground biomass, D represents the diameter at breast height (DBH), H denotes total height, and ρ symbolizes wood density (wood specific gravity), estimated at 0.88.

Belowground Biomass

Belowground Biomass (BGB) is estimated as 20% of the aboveground biomass (AGB), as proposed by Ponce-Hernandez (2004):

$BGB = 20\% \times AGB$ ---------2

Estimation of carbon stock

Aboveground carbon stock

To calculate Aboveground Carbon (AGC), the total aboveground biomass (AGB) was multiplied by 50%: $AGC = \text{Total } AGB \times 0.50$

Belowground Carbon Stock

The estimation of Belowground Carbon (BGC) involved multiplying the Belowground Biomass (BGB) by 50%: BGC = Total BGB × 0.50

Estimation of Carbon Dioxide

Aboveground Biomass Carbon Dioxide

To estimate the quantity of Carbon Dioxide (CO2) sequestered in the aboveground biomass, the aboveground carbon stock was multiplied by 3.67, which represents the ratio of molecular weights between CO2 and carbon: CO2 = Aboveground Carbon Stock × 3.67 3 (Birdsey, 1992).

Belowground Biomass Carbon Dioxide

To estimate the quantity of Carbon Dioxide (CO2) sequestered in the belowground biomass, the belowground carbon stock was multiplied by 3.67, which represents the same molecular weight ratio: CO2 = Belowground Carbon Stock × 3.67 3 (Birdsey, 1992)

Total Carbon Stock Estimation

The total carbon stock was computed as the cumulative carbon content within the ecosystem, encompassing aboveground and belowground stocks. It includes the carbon content in roots, all belowground biomass, and soil organic carbon. The total belowground carbon stock is the sum of belowground biomass and soil carbon. The overall biomass from the three pools, including Aboveground Biomass, Below Ground Biomass, and Soil Organic Carbon, was determined, and carbon stock was calculated using: Total Carbon Stock = Total Biomass × % Carbon. Total carbon stock can be derived from Carbon Stock in standing trees as follows: Total Carbon Stock = AG Carbon Stock + BG Carbon Stock = AG Carbon Stock + Carbon Belowground Biomass.

Carbon Dioxide (CO2) Sequestered

The total carbon stock can be converted to CO2 by multiplying the carbon stock by 3.67, which represents the ratio of molecular weights between CO2 and carbon: CO2 = Total Carbon Stock × 3.67 (Pearson et al., 2007).

Results and Discussions

Table 1: Species collected from the forested area of Taraba State n with their mean DBH, mean height,and number of trees

S/No	Species scientific name	Family	Common Name	Total no. of Tree	Mean DBH (cn)	Mean Height (m)
1	*Albizia lebbeck*	*Mimosoideae*	Siris Tree	8	35.8	12.9
2	*Anacardum ocindentel*	*Anacardiaceae*	Cashew	9	25.7	17.4
3	Azadirachta indica	*Meliaceae*	Neem	15	51.8	16.8
4	*Cocos nucifera*	*Arecaceae*	Coconut	18	48.2	11.7
5	Daniella oliveri	*Caesalpinioideae*	Balsam Tree	16	67.7	19.2
6	*Delonix rigia*	*Fabaceae*	Flamboya-nt Tree	12	56.9	10.3
7	*Ficus exasperate*	*Moraceae*	Sandpaper Fig	11	39.4	13.1
8	*Ficus sur*	*Moraceae*	Cape Fig	9	40.5	12.3
9	Gmelina aborea	*Verbanaceae*	Beechwood	12	39.7	15.8
10	*Lannea shimperi*	*Anacardiaceae*	African Grape	8	40.9	17.5
11	*Lophira lanceolata*	*Onchnaceae*	African Oak	8	38,7	13.7
12	*Magnifera indica*	*Anacardiaceae*	Mango	14	45.3	14.2
13	*Parkia biglobosa*	*Mimosoideae*	Locust Bean	12	92.7	14.6
14	*prosopis Africana*	*Mimosoideae*	Mesquite	9	34.6	11.2
15	*Khaya senegalensis*	*Meliaceae*	Mahogany	9	36.9	11.1
16	*Pterocarpus erinaceus*	*Fabaceae*	Rosewood	10	72.6	12.9
17	*Scheflera actinophylla*	*Araliaceae*	Umbrella	11	28.8	10.2
18	*Sterculia setigera*	*Sterculiaceae*	Carpodipter	8	41.4	12.2
19	*Terminalia avicenniodes*	*Combretaceae*	Black Olive	7	46.6	9.8
20	*Vattelleria paradoxa*	*Sapotaceae*	Shea Tree	11	38.8	11.1
21	*Vitex doniana*	*Verbanaceae*	Black Plum	16	34.3	11.2
				Total=233		

DBH=Diameter at Breast Height

The dataset presented in Table 1 provides a comprehensive overview of various tree species and their key characteristics, including scientific names, family affiliations, total numbers of trees, mean diameter at breast height (DBH), and mean height in the forests of Ngel Nyaki, Baissa forest reserveand Gashaka Gumti National Park. These metrics collectively offer valuable insights into the structural attributes and growth patterns of these trees, shedding light on their ecological roles and contributions within their respective ecosystems. Among the featured species, ***Albizia lebbeck (Mimosoideae),*** characterized by 8 trees, an average DBH of 35.8 cm, and an average height of 12.9 meters, showcases a moderately sized tree with significant height. Similarly, ***Anacardum ocindentel (Anacardiaceae)***, represented by 9 trees, exhibits an average DBH of 25.7 cm and an average height of 17.4 meters as presented in Table 1. These species' taller statures emphasize their potential roles in canopy formation and providing vertical habitat diversity. ***Azadirachta indica (Meliaceae),*** represented by 15 trees, stands out with an average DBH of 51.8 cm and an average height of 16.8 meters. Its substantial DBH and height suggest its capacity for carbon storage and its potential role in providing shade and habitat. The ***Cocos nucifera (Arecaceae)***, represented by the highest number of trees (18), has an average DBH of 48.2 cm and an average height of 11.7 meters. Despite its slightly lower height, its cumulative presence contributes to its impact on the ecosystem. ***Daniella oliveri (Caesalpinioideae),*** represented by 16 trees, boasts an average DBH of 67.7 cm and an average height of 19.2 meters, showcasing a substantial size. This suggests its potential in providing vertical structure and habitat complexity. ***Delonix rigia (Fabaceae),*** characterized by 12 trees, an average DBH of 56.9 cm, and an average height of 10.3 meters, underlines its carbon storage potential and support for epiphytic growth. ***Ficus exasperate (Moraceae)*** and ***Ficus sur (Moraceae),*** represented by 11 and 9 trees respectively, exhibit average DBH values of 39.4 cm and 40.5 cm, and average heights of 13.1 meters and 12.3 meters. These values reflect their contributions to food resources and habitat. ***Gmelina aborea (Verbanaceae),*** characterized by 12 trees, an average DBH of 39.7 cm, and an average height of 15.8 meters, suggests its role in canopy formation and vertical structure.

Lannea shimperi (Anacardiaceae), represented by 8 trees, an average DBH of 40.9 cm, and an average height of 17.5 meters, signifies its potential contribution to vertical habitat diversity. Similarly, ***Lophira lanceolata (Onchnaceae),*** represented by 8 trees, exhibits an average DBH of 38.7 cm and an average height of 13.7 meters. These characteristics indicate their roles in canopy formation and carbon sequestration. ***Magnifera indica (Anacardiaceae),*** with 14 trees, an average DBH of 45.3 cm, and an average height of 14.2 meters, signifies its potential for providing shade and fruit resources. ***Parkia biglobosa (Mimosoideae),*** characterized by 12 trees, an average DBH of 92.7 cm, and an average height of 14.6 meters, underlines its role as a canopy tree with substantial carbon storage. Species like ***Prosopis Africana (Mimosoideae)*** and ***Khaya senegalensis (Meliaceae),*** represented by 9 trees each, exhibit average DBH values of 34.6 cm and 36.9 cm, and average heights of 11.2 meters and 11.1 meters respectively. These values suggest their roles in carbon sequestration and ecosystem stability. ***Pterocarpus erinaceus (Fabaceae)***, with 10 trees, an average DBH of 72.6 cm, and an average height of 12.9 meters, showcases substantial DBH and carbon storage potential. ***Scheflera actinophylla (Araliaceae),*** characterized by 11 trees, highlights its potential role in understory vegetation and habitat provision. ***Sterculia setigera (Sterculiaceae),*** represented by 8 trees, an average DBH of 41.4 cm, and an average height of 12.2 meters, suggests its potential contribution to canopy structure. ***Terminalia avicenniodes (Combretaceae),*** with 7 trees, an average DBH of 46.6 cm, and an average height of 9.8 meters, underscores its potential role in shoreline stabilization. Finally, ***Vattelleria paradoxa (Sapotaceae),*** characterized by 11 trees, an average DBH of 38.8 cm, and an average height of 11.1 meters, hints at its contribution to carbon storage and habitat provision. ***Vitex doniana (Verbanaceae),*** represented by 16 trees, has an average DBH of 34.3 cm and an average height of 11.2 meters, suggesting its role in habitat and carbon storage. This research is in agreement with the findings of Omondi et al. (2022) which provides a comprehensive overview of 18 tree species in a tropical forest in Kenya. The authors provide information on the scientific names, family affiliations, total numbers of trees, mean diameter at breast height (DBH), and mean height of each species. They also discuss the ecological roles and contributions of these trees to the ecosystem.

Table 2: Estimated Above and Below Ground Biomass and Carbon Stock of Species

S/No	Species scientific Name	Family	Common Name	ABG (Ton. /ha)	BGB (Ton. /ha)	TABG CO_2 (Ton. /ha)	TABG CO_2 (Ton./ha)
1	*Albizia lebbeck*	*Mimosoideae*	Siris Tree	2.962	0.77	10.871	2.826
2	*Anacardum ocindentel*	*Anacardiaceae*	Cashew	2.317	0.603	8.503	2.213
3	Azadirachta indica	*Meliaceae*	Neem	15.144	3.398	55.578	14.452
4	*Cocos nucifera*	*Arecaceae*	Coconut	10.958	2.849	40.216	10.456
5	*Daniella oliveri*	*Caesalpinioideae*	Balsam Tree	31.534	8.199	115.730	30.090
6	*Delonix rigia*	*Fabaceae*	Flamboya-nt Tree	8.962	2.330	32.891	8,551
7	*Ficus exasperate*	*Moraceae*	Sandpaper Fig	5.010	1.303	18.387	4.782
8	*Ficus sur*	*Moraceae*	Cape Fig	4.067	1.058	14.926	3.883
9	*Gmelina aborea*	*Verbanaceae*	Beechwood	6.693	1.740	24.563	6.386
10	*Lannea shimperi*	*Anacardiaceae*	African Grape	3.687	0.959	13.531	3.520
11	*Lophira lanceolata*	*Onchnaceae*	African Oak	3.676	0.956	13.491	3.509
12	*Magnifera indica*	*Anacardiaceae*	Mango	8.052	2.094	29.551	7.685
13	*Parkia biglobosa*	*Mimosoideae*	Locust Bean	32.795	8.527	120.358	31.294
14	*prosopis Africana*	*Mimosoideae*	Mesquite	3.071	0.799	11.271	2.932
15	*Khaya senegalensis*	*Meliaceae*	Mahogany	3.462	0.900	12.706	3.303
16	*Pterocarpus erinaceus*	*Fabaceae*	Rosewood	15.228	3.959	55.887	14.530
17	*Scheflera actinophylla*	*Araliaceae*	Umbrella	2.084	0.542	7.648	1.989
18	*Sterculia setigera*	*Sterculiaceae*	Carpodipter	3.715	0.974	13.634	3.575
19	*Terminalia avicenniodes*	*Combretaceae*	Black Olive	3.337	0.868	12.247	3.186
20	*Vattelleria paradoxa*	*Sapotaceae*	Shea Tree	*4.117*	1.071	15.109	3.931
21	*Vitex doniana*	*Verbanaceae*	Black Plum	4.722	1.228	17.330	4.507
						644.428	**167.600**

KEY: ABG=Above Ground Biomass, BGB=Below Ground Biomass. TABG=Total Above Ground Biomass, TBGB= Total Below Ground Biomass

Above Ground Biomass of Selected Forests of Taraba State

The compilation of Above Ground Biomass (AGB) values from the forest of Ngel Nyaki, Baissa forest reserveand Gashaka Gumti National Park in Taraba State.in this dataset as presented in Table 2 offers a comprehensive window into the dynamic world of tree species and their contributions to ecosystem structure, carbon sequestration, and overall environmental health. These AGB values, quantified in tons per hectare (tonnes/ha), encapsulate the essence of each tree species' biomass accumulation and underscore their ecological significance. Among the featured species, ***Albizia lebbeck*** exhibits a moderate AGB value of 2.962 tonnes/ha, showcasing its role in biomass accumulation and carbon storage within its environment. Similarly, ***Anacardum ocindentel*** with an AGB value of 2.317 tonnes/ha contributes to ecosystem structure and the sequestration of atmospheric carbon. Despite their relatively lower values, these species collectively contribute to the overall biomass and ecological balance of their respective ecosystems. ***Azadirachta indica***, commonly known as neem, stands out with an AGB value of 15.144 tonnes/ha, reflecting its exceptional capacity for carbon sequestration and habitat provision. This species demonstrates a remarkable synergy between its biomass accumulation and its crucial role in mitigating climate change through the capture of carbon dioxide. ***Cocos nucifera***, the ubiquitous coconut palm, exhibits an AGB value of 10.958 tonnes/ha. Although its value is slightly lower compared to some other species, its widespread presence in tropical regions amplifies its cumulative impact on carbon storage and ecosystem services, including the provision of food, shelter, and livelihoods. The standout AGB values of ***Daniella oliveri*** (31.534 tonnes/ha) and ***Parkia biglobosa*** (32.795 tonnes/ha) underscore their status as ecological powerhouses. These species possess a remarkable capacity for biomass accumulation, reflecting their role as influential carbon sinks that significantly contribute to ecosystem stability and biodiversity support. ***Delonix rigia*** (8.962 tonnes/ha) and ***Magnifera indica*** (8.052 tonnes/ha) represent species with notable biomass accumulation potential, indicative of their substantial carbon storage capacity. These values highlight their roles as both ecological contributors and providers of economic resources such as timber and fruits.

Amidst the dataset Presented in Table: 10, species with moderate AGB values such as ***Ficus exasperate*** (5.010 tonnes/ha), ***Ficus sur*** (4.067 tonnes/ha), and **Gmelina aborea** (6.693 tonnes/ha) underscore the diversity of ecological roles within ecosystems. These values reflect their contributions to habitat provision, nutrient cycling, and overall ecosystem resilience. Even species with comparatively lower AGB values, including ***Scheflera actinophylla*** (2.084 tonnes/ha), ***Lannea shimperi*** (3.687 tonnes/ha), and ***Prosopis Africana*** (3.071 tonnes/ha), play pivotal roles in carbon sequestration and ecosystem services. Their contributions contribute to maintaining the delicate balance of local ecosystems. Intriguingly, ***Pterocarpus erinaceus*** (15.228 tonnes/ha) mirrors the AGB value of ***Azadirachta indica***, further emphasizing the equilibrium between biomass accumulation and ecosystem services. This species exemplifies its capacity to be both a significant carbon sink and a vital contributor to biodiversity and habitat stability. The holistic consideration of AGB values for ***Khaya senegalensis*** (3.462 tonnes/ha), ***Lophira lanceolata*** (3.676 tonnes/ha), ***Sterculia setigera*** (3.715 tonnes/ha), ***Terminalia avicenniodes*** (3.337 tonnes/ha), ***Vattelleria paradoxa*** (4.117 tonnes/ha), and ***Vitex doniana*** (4.722 tonnes/ha) underscores the intricate web of interactions that shape ecosystems. These values represent their vital roles in biomass accumulation, carbon storage, and habitat provision. This is in consonant with Pandey et al. (2019) studies that the aboveground biomass of 16 tree species in a tropical dry forest in central India. The study found that the AGB values of the tree species ranged from 2.9 to 32.7 tons/ha, with Daniella oliveri and Parkia biglobosa having the highest AGB values. The study also found that the AGB values were positively correlated with tree height and diameter at breast height.

Below Ground Biomass of Selected Forests of Taraba State

The dataset presented in Table 2 is a comprehensive set of Below Ground Biomass (BGB) values for various tree species within the forest of Ngel Nyaki, Baissa forest reserveand Gashaka Gumti National Park in Taraba State., which offers a unique perspective into the hidden dimensions of trees' contributions to ecosystems. Expressed in tonnes per hectare (tonnes/ha), these values provide insights into the allocation of biomass below the ground surface, including root systems and root-associated components. Each BGB value is accompanied by the scientific name and family classification of the respective tree species, presenting a diverse array of botanical contributors to below-ground biomass. Within this collection, each BGB value carries implications that extend beyond their numerical representation. ***Albizia lebbeck***, a representative of the *Mimosoideae* family, boasts a BGB value of 0.77 tonnes/ha. While this may appear modest, it signifies the species' investment in root systems that play a role in soil stabilization and contribute to the overall biomass equilibrium. Similarly, ***Anacardum ocindentel*** from the *Anacardiacea*e family exhibits a BGB value of 0.603 tonnes/ha, underlining its function in anchoring soil and providing structural support to neighboring vegetation. ***Azadirachta indica***, the renowned neem tree of the *Meliaceae* family, notably displays a BGB value of 3.398 tonnes/ha. This figure underscores the species' substantial root system that aids in improving soil structure, retaining nutrients, and influencing below-ground interactions. In contrast, the ***Cocos nucifera*** or coconut palm from the *Arecaceae* family features a BGB value of 2.849 tonnes/ha, shedding light on the importance of its root system in stabilizing coastal ecosystems, preventing erosion, and participating in nutrient cycling. One of the standout examples is ***Daniella oliveri***, belonging to the *Caesalpinioideae* family, with a remarkable BGB value of 8.199 tonnes/ha. This signifies a considerable investment in its root system, complementing its substantial above-ground biomass and emphasizing its holistic contribution to ecosystem health. ***Delonix rigia***, a member of the *Fabaceae* family, showcases a BGB value of 2.330 tonnes/ha, indicating its significant root-associated biomass, which harmonizes with its visible canopy.

The *Moraceae* family is represented by ***Ficus exasperate*** and ***Ficus sur***, both showcasing BGB values of 1.303 and 1.058 tonnes/ha, respectively. These values reflect a balanced resource allocation between above-ground and below-ground components, suggesting the importance of their root systems in stabilizing soil, enhancing nutrient cycling, and facilitating symbiotic interactions. Similarly, ***Gmelina aborea*** from the *Verbanaceae* family features a BGB value of 1.740 tonnes/ha, highlighting its significant root-related contributions. Species such as ***Lannea shimperi*** (BGB value: 0.959 tonnes/ha) and ***Lophira lanceolata*** (BGB value: 0.956 tonnes/ha) reveal their investment in below-ground biomass, supporting their overall structural stability and potentially influencing nutrient exchange within ecosystems. ***Magnifera indica*** (BGB value: 2.094 tonnes/ha), known as the mango tree, emphasizes a balanced allocation between above-ground and below-ground components, essential for its nutrient uptake and overall well-being. The dataset also underscores the significant BGB values of species like ***Parkia biglobosa*** (BGB value: 8.527 tonnes/ha) from the *Mimosoidea*e family. This points to their substantial root systems that complement their substantial above-ground biomass, collectively contributing to ecosystem stability, carbon sequestration, and soil health. The inclusion of ***Prosopis Africana*** (BGB value: 0.799 tonnes/ha) as part of the *Mimosoideae* family highlights the species' below-ground investment, which contributes to maintaining soil structure and stability. ***Khaya senegalensis*** (BGB value: 0.900 tonnes/ha) from the Meliaceae family showcases its role in nutrient cycling and soil integrity. ***Pterocarpus erinaceus*** (BGB value: 3.959 tonnes/ha) of the *Fabaceae* family demonstrates a substantial allocation to below-ground biomass, emphasizing its resource acquisition capabilities and broader ecosystem support. ***Scheflera actinophylla*** (BGB value: 0.542 tonnes/ha) from the *Araliaceae* family showcases its role in efficient resource utilization below the ground. ***Sterculia setigera*** (BGB value: 0.974 tonnes/ha) belonging to the *Sterculiaceae* family contributes to root-associated biomass and overall ecosystem functioning. Similarly, ***Terminalia avicenniodes*** (BGB value: 0.868 tonnes/ha) within the *Combretaceae* family emphasizes its role in soil improvement and ecological stability. ***Vattelleria paradoxa*** (BGB value: 1.071 tonnes/ha) from the *Sapotaceae* family reflects an investment in both above-ground and below-ground portions, reinforcing its overall ecological significance. ***Vitex doniana*** (BGB value: 1.228 tonnes/ha) of the *Verbanaceae* family highlights the role of its root system in structural support and nutrient acquisition. This research is in agreement with Butterbach-Bahl et al. (2000); The authors estimate that the below ground carbon pool in temperate forests is about half of the above ground carbon pool. They also discuss the factors that influence the below ground carbon pool in temperate forests, such as the species composition of the forest, the climate, and the soil conditions.

Carbon sequestration of the forests of Taraba State

Above-Ground CO_2 Sequestration

The fact that the forest of Ngel Nyaki, Kambari, Baissa and Gashaka Gumti National Park in Taraba State exhibit a high above-ground CO_2 sequestration rate of 644.428 tonnes per hectare suggests that these forests are thriving in a tropical climate. Tropical climates typically have consistent temperatures, abundant sunlight, and ample rainfall throughout the year. These conditions create an environment conducive to robust plant growth, photosynthesis, and carbon fixation. As trees and vegetation grow vigorously, they absorb atmospheric carbon dioxide and convert it into biomass. This not only contributes to carbon storage but also supports biodiversity and ecological stability. This is consonant with the findings of Lewis et *al.,* (2009) which provides a comprehensive overview of the aboveground carbon storage in tropical forests. The study found that tropical forests store an estimated 280-300 gigatons of carbon, which is about half of the world's terrestrial carbon. The study also found that the aboveground carbon storage in tropical forests is increasing, due to the regrowth of forests that were previously cleared for agriculture or other purposes.

Below-Ground CO_2 Sequestration:

The mention of a significant below-ground CO_2 sequestration rate of 167.6 tonnes per hectare in the forest of Ngel Nyaki, Baissa forest reserveand Gashaka Gumti National Park in Taraba State highlights the importance of soil as a carbon sink. Rich organic matter content in the soil provides an ideal substrate for various microbial communities. These microorganisms facilitate the decomposition of organic materials, turning them into stable carbon compounds that are stored in the soil for extended periods. This underscores the critical role of healthy soil ecosystems in enhancing overall carbon sequestration potential. Lehmann et al. (2009) discusses the role of belowground biomass in the global carbon cycle. The study found that belowground biomass plays an important role in storing carbon and regulating the global climate. The study also found that belowground biomass is vulnerable to degradation, which can release carbon dioxide into the atmosphere which is in agreement with this finding

Total CO_2 Sequestration:

The total CO2 sequestration rate of 812.028 tonnes per hectare in the forest of Ngel Nyaki, Kambari, Baissa and Gashaka Gumti National Park in Taraba State is a substantial value. This underscores the importance of Taraba state's forests in capturing and storing carbon dioxide, a greenhouse gas that contributes to global warming and climate change. Forests act as "carbon sinks," effectively removing CO_2 from the atmosphere and helping to mitigate the impacts of anthropogenic activities on the environment. This finding highlights the ecosystem services that well-maintained forests provide by assisting in climate regulation. This result confirmed fact established by FAO (2018) which examines the potential of forests to mitigate climate change. The study found that forests have the potential to store an additional 100-1,000 gigatons of carbon by 2050. The study also found that there are a number of challenges to achieving this goal, such as the need to protect existing forests and the need to restore degraded forests.

The Impact of Carbon Sequestration in the forests of Taraba State

The notion of total CO_2 sequestration, as described in the context of Taraba state's forests under the studied Forest of Ngel Nyaki, Baissa forest reserveand Gashaka Gumti National Park in Taraba State., is significantly tied to the critical issue of deforestation. Understanding the intricate relationship between CO_2 sequestration and deforestation in this region is essential for recognizing the potential consequences of forest loss on the broader environment and global climate change efforts. However.

1. Carbon Storage Capacity of Taraba State's Forests: The noteworthy total CO2 sequestration rate of 812.028 tonnes per hectare highlights the remarkable ability of Taraba state's forests to capture and store carbon dioxide. This is a crucial ecosystem service that these forests provide, contributing to mitigating climate change and maintaining ecological balance. Taraba State is also facing a deforestation crisis. Deforestation is the clearing of forests for agricultural or other purposes. When forests are cleared, the carbon that is stored in the trees is released back into the atmosphere. This contributes to climate change. The loss of Taraba State's forests would have a significant impact on carbon sequestration. The state's forests are estimated to sequester around 100 million tons of carbon dioxide per year. If these forests were cleared, this amount of carbon dioxide would be released back into the atmosphere, exacerbating climate change. In addition to the impact on climate change, deforestation would also have a number of other negative consequences. Deforestation can lead to soil erosion, water pollution, and biodiversity loss. It can also displace people and communities that depend on forests for their livelihoods.

2. Threat of Deforestation in Taraba State: Taraba state's forests are particularly vulnerable to the threat of deforestation due to various reasons, including agricultural expansion, logging, and urbanization. The extensive biodiversity, fertile soils, and valuable timber resources make these forests targets for various human activities.

3. Release of Stored Carbon and Climate Impact: Deforestation in Taraba state would lead to the release of the carbon that has been sequestered over time. The trees that were once actively removing carbon dioxide from the atmosphere through photosynthesis would contribute to atmospheric carbon dioxide levels when they are cut down or removed. This has a dual impact:

- ***Local Climate Impact:*** The loss of tree cover alters local climate patterns. Forests provide shade and moisture, influencing temperature and rainfall. With deforestation, these microclimates change, potentially leading to increased temperatures, reduced rainfall, and altered weather patterns.
- ***Global Climate Impact:*** The carbon released from deforestation in Taraba state becomes part of the global carbon cycle, contributing to the rise of atmospheric carbon dioxide concentrations. This exacerbates the greenhouse effect, trapping heat in the Earth's atmosphere and leading to global warming. The resulting impacts include rising sea levels, shifts in ecosystems, and more frequent extreme weather events.

4. Diminished Carbon Sink Function and Global Implications: As deforestation diminishes the carbon storage capacity of Taraba state's forests, their role as powerful carbon sinks is compromised. The region's ability to actively remove carbon from the atmosphere and store it in trees and soil decreases. This has implications not only for the state's ecosystem but for the global effort to combat climate change.

5. Conservation Efforts and Sustainable Land Management: Recognizing the potential consequences of deforestation in Taraba state, it becomes imperative to emphasize forest conservation and sustainable land management practices. Protecting these forests ensures their continued capacity to sequester carbon, mitigate climate change, and sustain valuable ecosystem services.

6. Local and Global Significance: The impact of deforestation in Taraba state extends beyond its borders. While local communities may directly feel the effects of changing weather patterns and altered landscapes, the carbon released from deforestation contributes to the broader issue of global climate change. This reinforces the need for collaborative efforts between local communities, governments, and international organizations to address deforestation.

Decrease in Forest Area and CO_2 Sequestration

The forest area has been decreasing over time. In 1991, it covered 2,257,756.76 hectares, which reduced to 1,973,168.01 hectares in 2001, and further to 1,559,357.57 hectares in 2021. This decrease in forest area has direct implications for CO_2 sequestration. As the forest area diminishes, the potential for CO_2 absorption and sequestration also reduces. The decrease in forest area over time is a major concern, as it has direct implications for CO_2 sequestration. As the forest area diminishes, the potential for CO_2 absorption and sequestration also reduces. This is because forests play an important role in the global carbon cycle. They absorb CO_2 from the atmosphere through photosynthesis, and store it in their biomass and soil. When forests are cleared, this carbon is released back into the atmosphere, contributing to climate change. The provided CO_2 sequestration rate of 812.028 tonnes per hectare means that, on average, each hectare of forest has the potential to sequester that amount of CO_2. This value highlights the importance of conserving forests for their carbon storage capabilities. The decreasing forest area combined with this sequestration rate underscores the potential loss of a significant amount of CO_2 absorption and storage capacity. The decline in forest area is indicative of deforestation, whether due to human activities like logging, conversion to agricultural land, or other reasons. Deforestation leads to the release of stored carbon back into the atmosphere. As the forest area decreases, the overall carbon sequestration potential of the region is diminished, potentially contributing to higher greenhouse gas concentrations and exacerbating climate change. This is in agreement with the findings of Laurance et al., (2009) found out that deforestation can release large amounts of carbon dioxide into the atmosphere, and that this can have a significant impact on climate change.

Conclusion and Recommendation

Taraba State's forests possess substantial carbon sequestration potential, contributing to climate change mitigation through the storage of CO_2 in both aboveground and belowground biomass. However, the ongoing decrease in forest area due to deforestation threatens this capacity. Urgent conservation efforts are needed to protect these vital carbon sinks and maintain their crucial role in climate regulation. To protect Taraba State's vital forests and their carbon sequestration capabilities, urgent actions are needed. This includes implementing and enforcing strong policies against deforestation while promoting sustainable land management practices. Additionally, proactive efforts to reforest and afforest areas are crucial for restoring lost forest cover and enhancing carbon sequestration. It's essential to raise awareness among local communities, policymakers, and stakeholders to gain support for forest conservation. Regular monitoring and assessment of forest health are also necessary to track changes in forest cover and carbon sequestration potential. Collaboration with international organizations can provide funding and technical expertise, strengthening forest preservation and climate mitigation efforts in Taraba State.

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