An Integrated Review of Potentials and Significance of Carbon Sequestration by Different Trees in Northern Nigeria

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Abstract

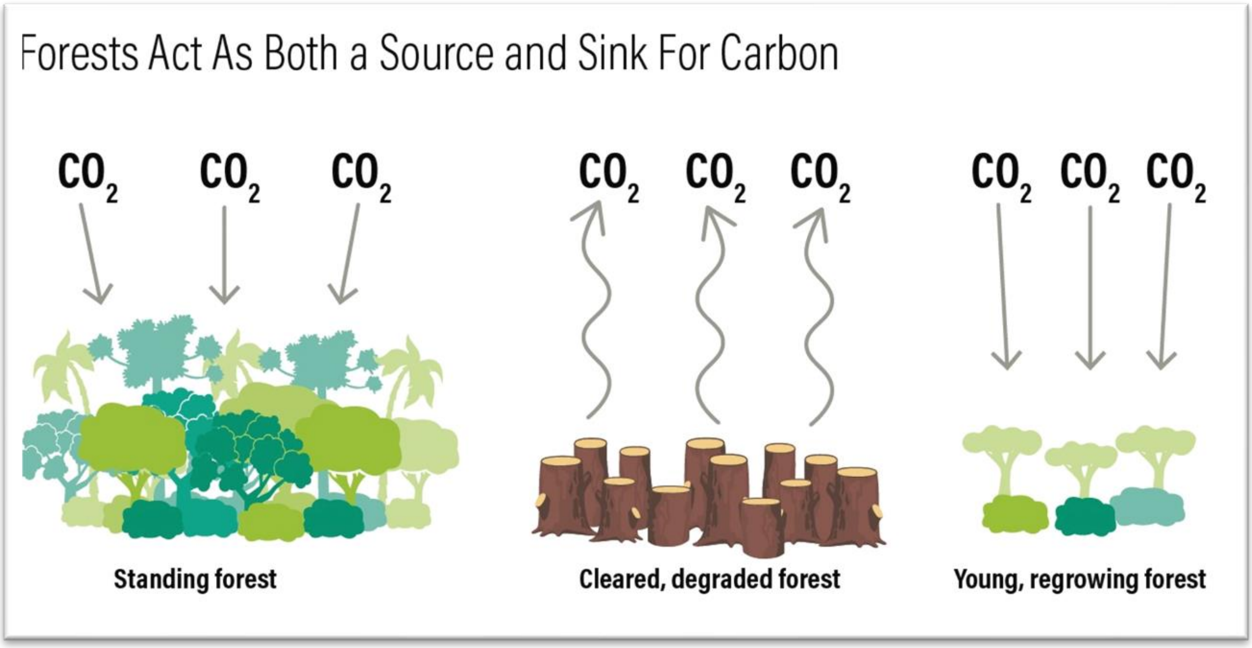
Forests are significant terrestrial carbon sinks that play a crucial role in mitigating climate change by sequestering atmospheric carbon dioxide (CO_2). Trees as the primary components of forests, have been extensively studied for their carbon sequestration potential. This review comprehensively explored the factors influencing tree carbon sequestration, the methodologies employed to measure and estimate carbon sequestration and the potential of trees in addressing climate change. The carbon sequestration potential of trees is influenced by various factors, including species-specific characteristics, stand age and structure, site conditions and management practices. Tree species possess inherent differences in their growth rates, photosynthetic efficiency and biomass allocation patterns, which directly impact their carbon sequestration capacity. Older, mature forests generally exhibit higher potential due to their larger biomass and slower growth rates. Site factors such as soil fertility, climate and topography also influence tree growth and carbon storage. Proper forest management practices, including silvicultural treatments and harvesting strategies, can optimize carbon sequestration by promoting tree health and growth. A variety of methodologies have been developed to measure and estimate tree carbon sequestration. Direct measurements involve destructive sampling to quantify aboveground and belowground biomass, while indirect methods utilize allometric equations, the mean ratio method (MRM), the biomass expansion factor (BEF) and remote sensing techniques. Trees have immense potential to sequester carbon and mitigate global climate change. Afforestation and reforestation initiatives can create new forest ecosystems, expanding the global carbon sink. Sustainable forest management practices can enhance carbon sequestration in existing forests while ensuring their long-term health and productivity. Tree-based carbon offset programs offer opportunities for individuals and organizations to reduce their carbon footprint by supporting tree planting and conservation projects.

Key Words: *Carbon dioxide (CO_2), Carbon Sequestration, Climate Change, Mitigation, Potentials.*

Introduction

The escalating concentration of carbon dioxide (CO_2) in the atmosphere, primarily driven by human activities, poses a significant threat to global climate stability (IPCC, 2021). Trees, as integral components of terrestrial ecosystems, offer a promising solution to mitigate climate change through their remarkable ability to sequester carbon (Pan *et al.,* 2011). Trees, through the process of photosynthesis, absorb CO_2 from the atmosphere and convert it into organic matter, storing carbon in their biomass, including trunks, branches, leaves and roots (IPCC, 2021). This carbon sequestration contributes to reducing atmospheric CO_2 levels, mitigating climate change and improving air quality (Chabot & Goldstein, 2018).

The carbon sequestration potential of trees varies significantly depending on several factors, including tree species, age, size, growth rate and environmental conditions (Sánchez-Bluemel *et al.*, 2016). Certain tree species, such as oaks, pines and maples, have been identified as high carbon sequesters due to their rapid growth rates and large biomass (Bada *et al.,* 2018). Older, larger trees tend to sequester more carbon than younger, smaller trees (Phillips *et al.,* 2008). Environmental factors such as climate, soil quality and water availability also influence tree carbon sequestration potential (IPCC, 2021). Trees growing in favourable conditions with ample sunlight, water and nutrients tend to sequester more carbon than those in more challenging environments (Sánchez-Bluemel *et al.,* 2016).



Source: World Resources Institute

Forests composed primarily of trees, play a crucial role in global carbon sequestration (IPCC, 2021). Tropical rainforests, in particular, are renowned for their immense carbon storage capacity (Pan *et al.,* 2011). However, deforestation and land-use change have led to significant losses of forest carbon stocks, contributing to the increase in atmospheric CO_2 levels (IPCC, 2021). In addition to their role in carbon sequestration, trees provide numerous other ecosystem services, including biodiversity conservation, soil erosion control and water filtration (FAO, 2020). By protecting and restoring forests, we can harness the full potential of trees to mitigate climate change while also benefiting from their many other ecological and societal benefits.

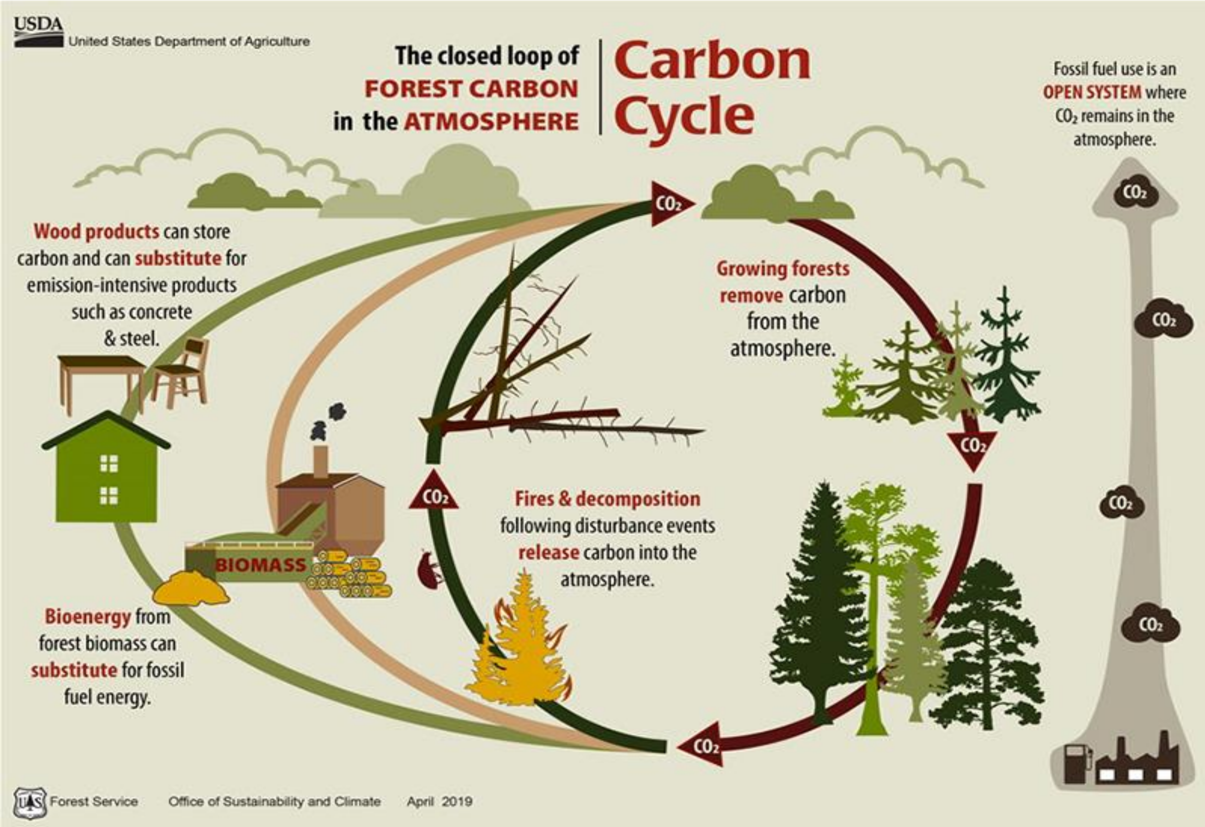
This review aimed to explore the role of trees in mitigating climate change the concept of carbon, carbon sequestration as well as the factors influencing tree carbon sequestration potential in Nigeria and Katsina State.

Tree and Earth's Ecosystems

A tree is a large, perennial plant that is essential to all of Earth's ecosystems (Raven *et al.*, 2020). Trees are vital for the provision of oxygen, the regulation of climate and the sustenance of a wide variety of life forms. They are distinguished by their woody stems, vast root systems and the capacity to produce leaves (Chabot & Goldstein, 2018). Trees are classified into various groups based on their characteristics. Angiosperms, or flowering plants, are the most diverse group of trees, producing seeds enclosed in fruits (Cronquist, 1981). Gymnosperms, on the other hand, are non-flowering plants that produce seeds directly on the scales of cones (Taylor, 2017). The structure of a tree is essential for its survival and function. The roots anchor the tree to the ground, absorb water and nutrients from the soil and store energy reserves (Taiz & Zeiger, 2017). The trunk, composed of wood, provides structural support and transports water and nutrients throughout the tree (Zimmermann & Milburn, 1975). The leaves are the primary organs of photosynthesis, capture sunlight and convert it into energy (Raven *et al.,* 2020). Trees play a crucial role in the carbon cycle by absorbing carbon dioxide from the atmosphere and storing it in their wood and leaves (IPCC, 2021). This process helps to mitigate climate change by reducing greenhouse gas emissions (Pan *et al.,* 2011). Trees also provide oxygen, a vital gas for human and animal life (Raven *et al.,* 2020). Forests, composed primarily of trees, are essential for biodiversity and ecosystem health. They provide habitat for a wide range of plant and animal species, regulate water cycles and protect against soil erosion (FAO, 2020). Trees also play a vital role in cultural and economic systems, providing timber, fuelwood and other resources (Thomas *et al.,* 2017). Unfortunately, deforestation and climate change pose significant threats to trees and forests worldwide (FAO, 2020).

Carbon Dioxide and Carbon Cycle

Carbon dioxide (CO_2) is a naturally occurring gas that plays a vital role in Earth's atmosphere (IPCC, 2021). It is essential for plant photosynthesis, a process that converts sunlight into energy (Raven *et al.,* 2020). However, excessive levels of CO_2 in the atmosphere can have significant negative impacts on our planet's climate and ecosystems. CO_2 is a part of the Earth's natural carbon cycle, a sequence of activities that entail the exchange of carbon between the atmosphere, seas, land and living beings (IPCC, 2021). Through photosynthesis, plants absorb CO_2 from the atmosphere and release oxygen. Respiration, both in plants and animals, releases CO_2 back into the atmosphere.



Source: Carbon and Forests (ct.gov)

The carbon cycle is a fundamental Earth system process that governs the transfer of carbon between the atmosphere, oceans, land and living creatures. It is essential for controlling the earth's temperature, the acidity of the ocean and the availability of nutrients for life. The atmosphere is a primary reservoir for carbon, primarily in the form of carbon dioxide (CO_2) and methane (CH4). These greenhouse gases play a vital role in trapping heat from the sun, maintaining Earth's temperature within a habitable range. However, global warming and climate change are the result of human activity's excessive buildup of greenhouse gases (IPCC, 2021). Human activities such as deforestation and land-use change are reducing the Earth's capacity to absorb CO_2 through photosynthesis. Deforestation releases stored carbon into the atmosphere through the decomposition of forest biomass and reduces the planet's overall carbon sink capacity (IPCC, 2021).

Tree and Carbon Sequestration

Tree carbon sequestration involves a complex interplay of physiological processes that allow trees to capture and store carbon dioxide (CO_2). Photosynthesis is the primary process through which trees capture CO_2 from the atmosphere. During photosynthesis, plants use sunlight, water and CO_2 to produce glucose, a simple sugar that serves as the primary energy source for the tree. The glucose produced is then converted into cellulose, hemicellulose and lignin, which form the structural components of the tree's biomass (Taiz & Zeiger, 2010). The rate of photosynthesis is influenced by various environmental factors, including light intensity, temperature, water availability and nutrient availability. Optimal conditions for photosynthesis vary among different tree species and can be influenced by their evolutionary adaptations to specific environments (IPCC, 2021). While respiration releases CO_2, it is also necessary for the breakdown of organic matter, which can ultimately lead to the formation of new tissues and the storage of carbon in the tree's biomass (Taiz & Zeiger, 2010). The balance between photosynthesis and respiration determines the net carbon uptake by a tree. When photosynthesis exceeds respiration, the tree is sequestering carbon. Conversely, when respiration exceeds photosynthesis, the tree is releasing carbon. Factors such as tree age, species and environmental conditions can influence this balance (IPCC, 2021). In addition to photosynthesis and respiration, several other factors influence tree carbon sequestration. Different tree species have varying capacities for carbon sequestration. Some species are more efficient at capturing and storing carbon than others (Piao *et al.,* 2008). The structure of a forest, including tree density, age distribution and species diversity, can affect carbon sequestration. Forests with a diverse mix of species and age classes tend to be more resilient and can sequester more carbon (IPCC, 2021)**.** Climate factors, such as temperature, precipitation and wind patterns, can affect tree growth and carbon sequestration. For example, warmer temperatures can increase the rate of photosynthesis but also increase the risk of forest fires, which can release stored carbon (IPCC, 2021).

Studies by Ballantyne *et al.* (2017), Ciais *et al.* (2019) and Friedlingstein *et al.* (2020) indicate that the global net land CO_2 sink has expanded over the past six decades. The global net land CO_2 sink, calculated as the residual between fossil fuel CO_2 emissions and atmospheric CO_2 growth, has risen from 0.3 ± 0.6 PgC yr–1 in the 1960s to 1.8 ± 0.8 PgC yr–1 in the 2010s (Friedlingstein *et al.,* 2020). Atmospheric inversions conducted by Peylin *et al.* (2013) consistently support this trend of an increasing global net land CO_2 sink since the 1980s. The Northern Hemisphere has contributed more to this increase than the Southern Hemisphere (Ciais *et al.,* 2019), with boreal and temperate forests likely playing a significant role (Tagesson *et al.,* 2020).

The net terrestrial CO_2 sink is mostly regulated by photosynthesis in vegetation. Various studies, including those by (Anav *et al.* 2015; Mao *et al.* 2016; Badgley *et al.* 2017; Campbell *et al.* 2017; Cheng *et al.* 2017 and Zhang *et al.* 2018) provide evidence of enhanced vegetation photosynthesis in recent decades. The rising atmospheric CO_2 concentration, acting as a fertilization effect, is a major contributor to this trend (Sitch *et al.,* 2015; Fernández-Martínez *et al.,* 2019; O'Sullivan *et al.,* 2019; Tagesson *et al.,* 2020 and Walker *et al.,* 2021).

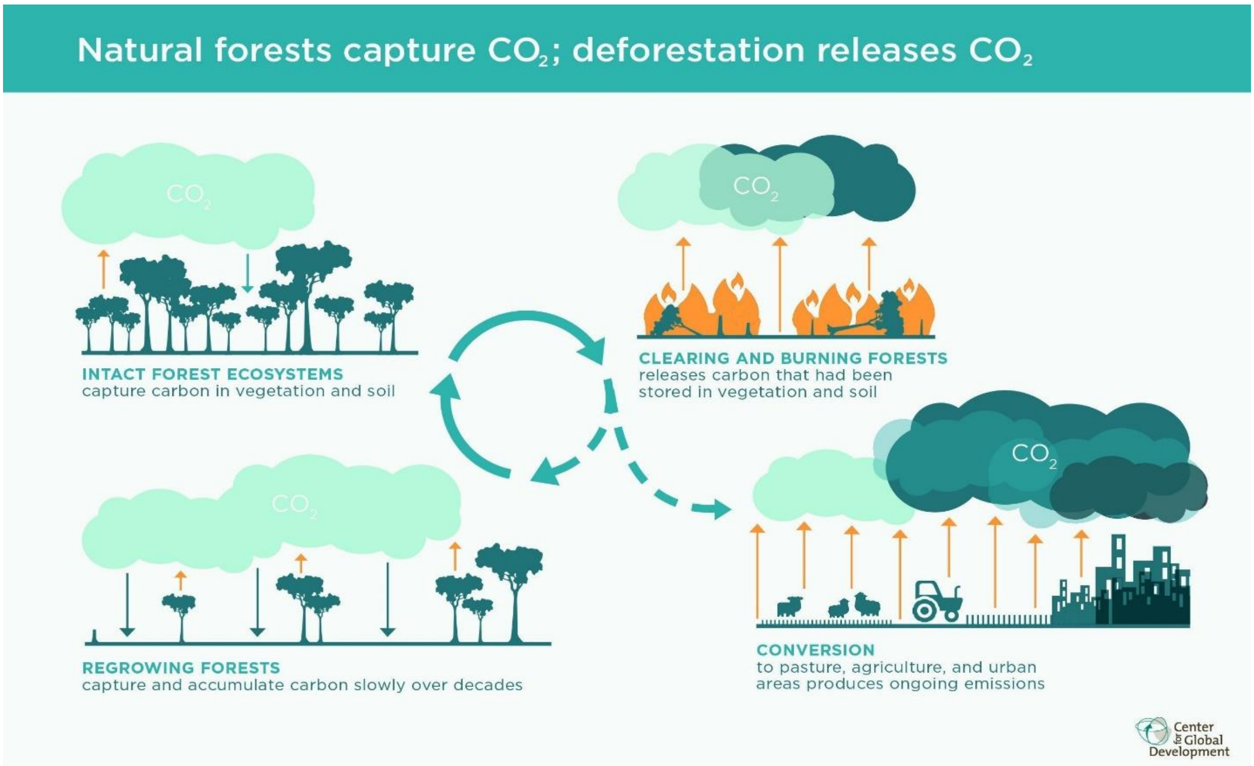
The impact of climate change alone on the global net land CO_2 sink is highly variable, with different dynamic global vegetation models (DGVMs) even predicting opposite effects (Huntzinger *et al.,* 2017). Reduced global burned area, leading to lower fire emissions of CO_2 and enhanced vegetation carbon uptake, has contributed to the increasing global net land CO_2 sink in recent decades (Arora and Melton 2018 and Yin *et al.,* 2020). Satellite observations indicate a global decline in burned area of approximately 20% over the past two decades (Andela *et al.,* 2017; and Forkel *et al.,* 2019), particularly in regions like northern Africa and Mediterranean Europe (Turco *et al.,* 2016; Forkel *et al.,* 2019 and Bowman *et al.,* 2020). The Amazon basin and Australia experienced record-breaking fires in 2019 and 2020 (Boer *et al.,* 2020) and the long-term impact of these events on burned area trends remains to be assessed. Both human-induced

Global forest Carbon Sequestration Potentials

The carbon sequestration potential of an ecosystem is measured by its ability to increase net carbon sequestration beyond baseline levels through natural or human-induced factors (Wang *et al.,* 2017). Different tree species exhibit varying carbon sequestration potentials, making their selection crucial for effective carbon sequestration projects and optimized forest management (Wang *et al.,* 2017). Trees play a vital role in mitigating global warming by reducing the accumulation of greenhouse gases in the atmosphere (Hisano *et al.,* 2018). In southern China, extensive afforestation efforts have led to forests absorbing over 65% of the country's carbon emissions during the 1980s, surpassing the absorption rate in northern China (Chen *et al.,* 2020). Accurately assessing forest ecosystems' carbon sequestration capacity is essential for understanding their role in the carbon cycle, informing forest management decisions and quantifying their impact on global warming (Dai *et al.,* 2021).

Deforestation and other forest disturbances, as observed by satellites, contributed to 8.1 ± 2.5 $GtCO_2e$ yr−1 of global gross greenhouse gas emissions between 2001 and 2019 (Hariss *et al.,* 2021) and carbon dioxide (CO_2) was the primary greenhouse gas emitted, while nitrous oxide (N2O) and methane (CH4) from forest fires and drained organic soils held about 1.1% of gross emissions (0.088 $GtCO_2e$ yr−1). Forest ecosystems experienced gross carbon losses of −15.6 ± 49 $GtCO_2e$ yr−1 during this period. Considering the contrasting fluxes of gross emissions and gross removals, the net global green house gas forest sink was −7.6 ± 49 $GtCO_2e$ yr−1 (Hariss *et al.,* 2021).

Tropical and subtropical forests accounted for the largest portion of the world's gross forest fluxes, contributing 78% of gross emissions (6.3 ± 2.4 $GtCO_2e$ yr−1) and 55% of gross removals (−8.6 ± 7.6 $GtCO_2e$ yr−1) (Hariss *et al.,* 2021). While temperate and subtropical forests removed more carbon dioxide from the atmosphere on a gross basis (−8.6 versus −4.4 and −2.5 $GtCO_2e$ yr−1, respectively), they only represented 30% of the global net carbon sink. The majority of the global net sink was found in temperate forests (47%) and boreal forests (21%), primarily due to their significantly lower gross emissions compared to subtropics and tropics (0.87 and 0.88 versus 6.3 $GtCO_2e$ yr−1, respectively) (Hariss *et al.,* 2021). Global forest related Green House Gas Fluxes by Climate Domain and Forest Type was presented in table 1.



Source: Center for Global Development

Table 1: Global forest related Green House Gas Fluxes by Climate Domain and Forest Type

Climate domain	Forest type	Forest extent 2000 (Mha)	$GtCO_{2}e\ yr^{-1}$, 2001–2019					
			Gross emissions	Percentage of global total	Gross removals	Percentage of global total	Net GHG flux	Percentage of global total[d]
Boreal	Primary[a]	38	0.26	3.2	−0.044	0.28	0.22	
	Old secondary (>20 yr)	1,030	0.60	7.4	−2.4	15	−1.8	
	Young secondary (≤20 yr)	22	0.015	0.19	−0.037	0.24	−0.022	
	Plantations/tree crops[b]	0.21	0.000056	0.00070	−0.0027	0.017	−0.0027	
Total boreal		1,090	0.88 ± 0.42	11	−2.5 ± 0.96	16	−1.6 ± 1.1	21
Temperate	Primary[a]	2.3	0.036	0.45	−0.0092	0.059	0.027	
	Old secondary (>20 yr)	560	0.71	8.8	−4.2	27	−3.5	
	Young secondary (≤20 yr)	16	0.049	0.60	−0.039	0.25	0.0092	
	Plantations/tree crops[b]	12	0.071	0.88	−0.14	0.92	−0.073	
Total temperate		590	0.87 ± 0.60	11	−4.4 ± 48	28	−3.6 ± 48	47
Subtropical	Primary[a]	3.6	0.0062	0.076	−0.0058	0.037	0.00035	
	Old secondary (>20 yr)	270	0.46	5.7	−0.84	5.4	−0.38	

	Young secondary (≤20 yr)	13	0.11	1.3	−0.067	0.43	0.040	
	Plantations/tree crops[c]	54	0.40	5.0	−0.71	4.6	−0.31	
	Mangroves	0.070	0.000066	0.00082	−0.0040	0.026	−0.0040	
Total subtropical		340	1.0 ± 0.59	12	−1.6 ± 0.56	10	−0.65 ± 0.81	8.6
Tropical	Primary[a]	1,010	1.8	22	−1.9	12	−0.12	
	Old secondary (>20 yr)	880	1.9	23	−3.8	24	−1.9	
	Young secondary (≤20 yr)	47	0.76	9.5	−0.40	2.5	0.37	
	Plantations/tree crops[c]	47	0.89	11	−0.73	4.7	0.16	
	Mangroves	7.2	0.010	0.12	−0.16	1.0	−0.15	
Total tropical		1,990	5.3 ± 2.4	66	−7.0 ± 7.6	45	−1.7 ± 8.0	22
Global	Primary	1,060	2.1	26	−2.0	13	0.13	
	Old secondary (>20 yr)	2,750	3.7	45	−11	72	−7.7	
	Young secondary (≤20 yr)	99	0.9	12	−0.54	3.5	0.39	
	Plantations/tree crops	113	1.4	17	−1.6	10	−0.23	
	Mangroves	8.7	0.012	0.14	−0.20	1.3	−0.19	
Total global		4,029	8.1 ± 2.5	100	−16 ± 49	100	−7.6 ± 49	100

Source: adapted and modified from Hariss *et al.*, (2021)

The carbon sequestration in China's biomass reached 320.29 Tg by the end of the Grain for Green Program (GGP) in 2010 (Wang *et al.,* 2018). During the late GGP implementation stage (2005–2010), carbon sequestration was higher compared to the early GGP implementation stage (1999–2004) due to the growth of trees planted earlier (Wang *et al.,* 2018). East China had the lowest forest carbon sequestration at 22.39 Tg (7% of China's total), while Central South China had the highest at 80.26 Tg (25.06% of China's total) (Wang *et al.,* 2018). China's forest carbon sequestration potential is estimated to reach 397.34, 604.00, 725.53, 808.90 Tg by 2030, 2040 and 2050, respectively (Wang *et al.,* 2018).

Suleiman and Anakhu (2023) assessed the reduction in forest cover and the carbon stock of trees in all 36 states of Nigeria, including the Federal Capital Territory. The period from 2010–2022 were considered in the study. States like Kano, Sokoto and Borno had lower carbon stores (averaging 500 tC/ha), while states with greater forest cover, such Cross River, Ondo and Osun, had larger carbon stocks (averaging 2000 tC/ha). See (table 2). Deforestation significantly affects Nigeria's carbon stores, according to Suleiman and Anakhu (2023). With a 30% drop in carbon stocks as a result of the 35% decline in tree cover between 2010 and 2022, focused actions are required to increase carbon sequestration and strengthen mitigation methods for climate change.

Adekunle *et al.* (2014) reported the carbon stock of Eda protected forest as 156.73 tons/ha. Agbelade and Adeagbo (2020) compared the strict nature reserve Akure and the Osun sacred grove Osogbo, finding significant differences in species diversity, aboveground biomass (AGB), individual stems and maximum DBH among the woods. The Akure strict nature reserve had the highest biomass at 1235.72 mg ha -1, while the Osun Sacred Grove had the lowest at 418.54 mg.

Table 2: Tree cover loss and carbon stocks 36 state of Nigeria's and FCT

State/FCT	**Tree Cover Loss** Kha		**Carbon Stocks (2022)** tC/ha	
	2010	**2022**	**2010**	**2022**
Abia	12,500	10,000	1,200,000	1,000,000
Adamawa	10,000	8,000	900,000	700,000
Akwa Ibom	15,000	12,000	1,500,000	1,300,000
Anambra	8,000	6,000	800,000	600,000
Bauchi	5,000	4,000	500,000	400,000
Bayelsa	18,000	16,000	1,800,000	1,600,000
Benue	7,000	5,500	750,000	550,000
Borno	4,000	3,000	400,000	300,000
Cross River	20,000	18,000	2,000,000	1,800,000
Delta	14,000	11,000	1,400,000	1,100,000
Ebonyi	6,000	4,500	600,000	450,000
Edo	9,000	7,500	900,000	750,000
Ekiti	10,500	8,500	1,050,000	850,000
Enugu	8,500	6,500	850,000	650,000
Gombe	4,500	3,500	450,000	350,000
Imo	11,000	9,000	1,100,000	900,000
Jigawa	3,000	2,000	300,000	200,000
Kaduna	6,500	5,000	650,000	500,000
Kano	2,500	1,500	250,000	150,000
Katsina	2,000	1,000	200,000	100,000
Kebbi	3,500	2,500	350,000	250,000
Kogi	12,000	10,500	1,200,000	1,050,000

Kwara	7,000	5,500	700,000	550,000
Lagos	3,000	1,500	300,000	150,000
Nasarawa	6,000	4,500	600,000	450,000
Niger	9,000	7,000	900,000	700,000
Ogun	11,000	8,500	1,100,000	850,000
Ondo	15,000	12,000	1,500,000	1,200,000
Osun	8,000	6,000	800,000	600,000
Oyo	10,000	7,500	1,000,000	750,000
Plateau	6,500	5,000	650,000	500,000
Rivers	18,000	15,000	1,800,000	1,500,000
Sokoto	3,000	2,000	300,000	200,000
Taraba	12,500	10,000	1,250,000	1,000,000
Yobe	2,500	1,500	250,000	150,000
Zamfara	4,000	3,000	400,000	300,000

Source: Adapted and modified from Suleiman and Anakhu (2023)

ha -1. The carbon stock estimate in Osun Sacred Grove was 209.26 Mg ha-1 and the highest was found in Akure's strict nature reserve (617.85 Mg ha-1) (Agbelade and Adeagbo 2020). Tropical forests' above-ground biomass (AGB) plays a crucial role in the global carbon cycle and local AGB estimates provide valuable information for extrapolating biomass stocks across ecosystems (Agbelade and Adeagbo 2020). Agbelade and Lawal (2021) reported above (ABG) and below ground biomass (BGB) of tree species southwestern part of Nigeria.

Table 3: Trees Volume and Carbon stock estimation of Ogun Oneri Community Forest

S/N	Species	Family	Vol/ha	AGB/ha	BGB/ha	CS/ha
1	*Albizia ferruginea*	Fabaceae	4.98	116.53	17.48	75.74
2	*Albizia lebbeck*	Fabaceae	3.35	876.97	131.55	570.03
3	*Albizia zygia*	Mimosoideae	5.69	325.17	48.78	211.36
4	*Allophyllus Africana*	Sapindaceae	2.25	32.55	4.88	21.16
5	*Alstonia boonia*	Apocynaceae	8.17	78.04	11.71	50.73
6	*Anthocleasta vogalii*	Potaliceae	11.82	654.41	98.16	425.36
7	*Antiaris Africana*	Fabaceae	3.80	40.95	6.14	26.62
8	*Baphia nitida*	Fabaceae	3.24	67.12	10.07	43.63
9	*Blighia sapida*	Sapindaceae	2.80	32.55	4.88	21.16
10	*Briddia micrantha*	Bridelieae	2.32	30.28	4.54	19.68
11	*Ceiba pentadra*	Malvaceae	12.54	190.87	28.63	124.07
12	*Cleistopholis patens*	Annonaceae	7.82	220.39	33.06	143.25
13	*Dracaena marginata*	Asparagaceae	3.70	74.08	11.11	48.15
14	*Dracaena spp*	Asparagaceae	9.66	1344.26	201.64	873.77
15	*Ficus exasperate*	Moraceae	2.87	19.69	2.95	12.80
16	*Ficus sur*	Moraceae	5.44	41.87	6.28	27.21
17	*Funtumia elastic*	Apocynaceae	6.09	679.38	101.91	441.59
18	*Gmelina arborea*	Lamiaceae	18.02	126.39	18.96	82.15

19	*Hymenocaido acida*	Phyllanthaceae	12.66	288.80	43.32	187.72
20	*Khaya grandifiola*	Meliaceae	5.94	147.27	22.09	95.72
21	*Lecaniodiscus cupanioides*	Sapindaceae	3.40	74.08	11.11	48.15
22	*Marcariteria discoidea*	Phyllanthaceae	4.18	84.91	12.74	55.19
23	*Margariteria discoidea*	Phyllanthaceae	10.52	61.72	9.26	40.12
24	*Milicia excels*	Moraceae	3.54	297.00	44.55	193.05
25	*Millettia thonningii*	Fabaceae	3.45	131.26	19.69	85.32
26	*Napoleonaea imperialis*	Lecythidaceae	2.70	61.72	9.26	40.12
27	*Olax subscorpioidea*	Olacaceae	4.02	41.87	6.28	27.21
28	*Parkia biglobosa*	Fabaceae	3.73	87.75	13.16	57.04
29	*Pterocarpus mildbraedii*	Fabaceae	6.43	89.92	13.49	58.45
30	*Ricinodendron heudelotii*	Euphorbiaceae	12.45	299.76	44.96	194.84
31	*Spathodea campanulata*	Bignoniaceae	2.83	74.73	11.21	48.57
32	*Spondias mombim*	Anacardiaceae	3.80	66.69	10.00	43.35
33	*Steculia Africana*	Malvaceae	14.65	440.87	66.13	286.56
34	*Lannea welwitschii*	Anacardiaceae	3.16	270.14	40.52	175.59
35	*Terminalia ivorensis*	Combretaceae	26.76	53.14	7.97	34.54
36	*Tetrapleura tetraptera*	Fabaceae	3.25	1752.49	262.87	1139.12
37	*Trichilia welwitschii*	Meliaceae	6.52	68.15	10.22	44.29

Source: Adopted and Modified from Agbelade and Lawal (2021).

The rate of carbon storage and sequestration in various carbon sinks is significantly influenced by a number of factors, including vegetation forms and patterns, land history, climatic conditions that are inherent to the area, land management techniques and so on (Zhang *et al.,* 2015). The Northeastern region of India has been shown to have significant potential as a carbon sink for plantation forestry (Singh *et al.,* 2018 and Kurmi *et al.,* 2020), agroforestry (Tamang *et al.,* 2021) and home gardens (Singh and Sahoo, 2021). similarly secondary forests contribute significantly to the storage of carbon (Gogoi *et al.,* 2020; Thong *et al.,* 2020).

Forest carbon stocks accumulated quickly at young ages and progressively saturated at later stages, according to studies by He *et al.* (2010), Zhu *et al.* (2018) and He *et al.* (2022). Mature and over-mature trees can also store carbon as stand age grows after variations in forest carbon density have stabilized (Luvssaert *et al.,* 2008). Despite their declining growth efficiency, these trees nevertheless play a critical part in the carbon cycle. Massive afforestation and regional expansion of ecological restoration initiatives are closely linked to forest growth and development as well as the capacity of the forest to sequester carbon (He *et al.,* 2022).

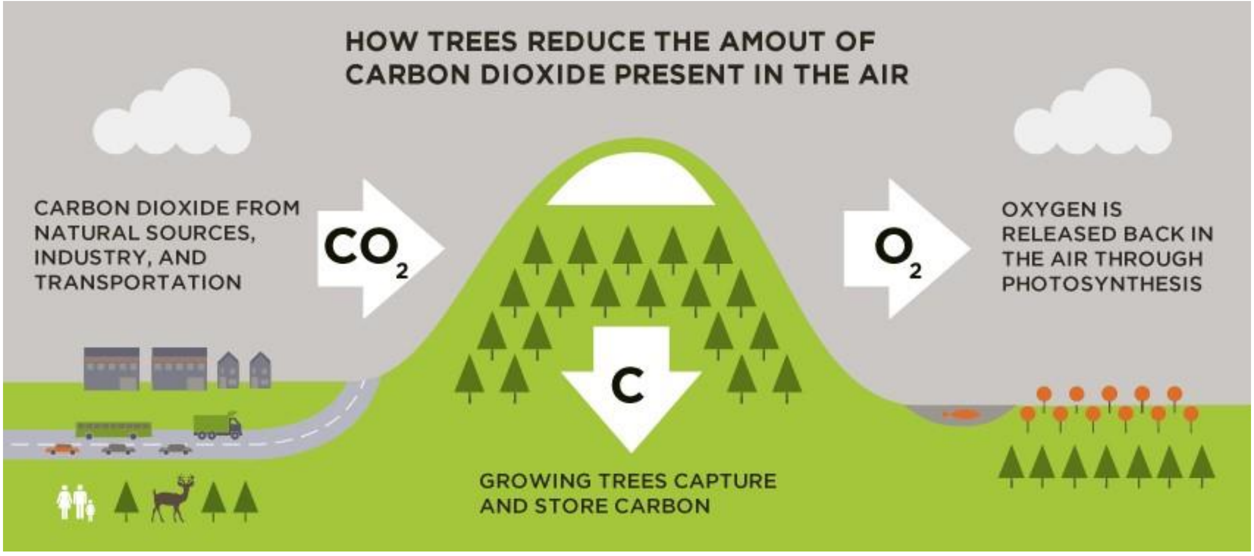
China's ecological restoration initiatives and sustainable forest management will boost the country's forest acreage and biomass carbon intensity over the next 50 years, converting forests of all ages into carbon sinks (Zhang *et al.,* 2010). The azimuth of solar radiation has a significant impact on carbon sequestration capacity, with the sunny slope, or south slope, potentially producing stronger carbon sequestration (Zhang *et al.,* 2021). Diverse management practices are a result of the different primary elements impacting the capacity of forests of different origins to sequester carbon (He *et al.,* 2022).

Table 4: Estimated amount of Carbon sequestered by some tree species of northern Nigeria

Trees	Total Height (m)	Total DBH(cm)	AGB (Mg/ha)	BGB (Mg/ha)	AGC (Mg/ha)	BGC (Mg/ha)	TCS (Mg/ha)	CO_2 (Megatons/ha)
Magnifera indica	4799.44	11531.39	113,179.69	22,635.92	56,589.85	11,318.01	67,907.85	249.22
Elaeis guinensis	2065.01	3321.55	4,376.82	875.38	2,188.41	437.64	2,626.05	9.64
Newbouldia laevis	159.65	536.30	10.25	2.01	5.08	1.05	6.13	0.02
Carica papaya	496.00	1688.47	290.42	58.05	145.21	29.02	174.23	0.64
Termanalia mantaly	310.00	746.07	37.26	7.47	18.68	3.74	22.32	0.09
Pakia biglobosa	279.00	1302.00	99.71	19.92	49.90	9.96	59.87	0.22
Acacia senegalensis	1372.68	2493.30	1,678.45	335.73	839.18	167.82	1,007.09	3.70
Azadirachta indica	1959.85	2408.70	2,221.17	444.25	1,110.63	222.13	1,332.66	4.89
Psidium guajava	439.00	1289.54	152.30	30.46	76.15	15.23	91.38	0.34
Eucalyptus tereticornis	21246.23	29365.35	2,997,611.59	599,522.32	1,498,805.75	299,761.11	1,798,566.95	6,600.74
Gmelina arborea	601.40	1473.53	268.68	53.74	134.39	26.92	161.21	0.59
Tectona grandis	1062.68	3410.00	2,409.00	481.80	1,204.50	240.90	1,445.40	5.31

Source: Adapted and modified from Hyong *et al.,* (2024)

The increases in temperature and precipitation substantially prolonged the growing season and enhanced photosynthetic capacity, microbial activity and plant growth and respiration (Chen *et al.,* 2013). This enhanced the trees' ability to store carbon (Chen *et al.,* 2020). Consequently, it is possible to think about include the climatic combination characteristics in the prediction model, which would enable the establishment of several climate condition scenarios and a more accurate estimation of the future carbon sequestration potential of forests.



Source: http://kingcounty.gov/services/environment/stewardship/one-million-trees/why.aspx

The capacity of a tree to sequester carbon can also be influenced by its age, size and growth type. In general, older trees store more carbon and have larger biomasses than younger ones. Furthermore, bigger trees can absorb more carbon than smaller trees because of their larger root systems and thicker trunks. IPCC, 2021). A tree's capacity to store carbon can also be influenced by its development type. Conifers and other tall, thin trees have the potential to absorb more CO CO_2 from the atmosphere and have a higher leaf area index.

The potential for sequestering carbon has been estimated using a variety of methodologies. The region's carbon stock is estimated using the mean ratio method (MRM) (Turner *et al.,* 1995). It is believed that a fairly reliable method of assessing carbon stocks is the biomass expansion factor (BEF), which fixes the ratio between the volume of the forest and its biomass (Sun & Liu 2019). When estimating aboveground biomass levels, the allometric equation showed to be more accurate (Agbelade and Lawal 2021; Agbelade and Adeagbo 2020; Adekunle *et al.,* 2013). The remote sensing technologies used to evaluate carbon sequestration potentials are LiDAR, aerial surveys and satellite imagery (Dossa and Miassi 2024).

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