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Research Article
Climate Change Mitigation Potential and Carbon Stock Assessment of Mixed Mangrove Forest, of the Great Kwa River, Nigeria

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Abstract

Background and Objective: Carbon sequestration in growing forests is known to be a cost-effective option for the mitigation of global warming and global climate change. Mangrove forests have the potential for high levels of carbon sequestration. Mangroves provide many important ecosystem services including coastal protection, nursery grounds for coastal fish and crustaceans among other services. However, these forests are being threatened by anthropogenic activities. This study was to quantify the total carbon stock and estimate the relative carbon capture and storage potential in the mangrove forest of the Great Kwa River, Cross River, Nigeria. **Materials and Methods:** Ten line transects (LT 1-LT 10) of 150 m each were established 500 m apart systematically in the study site along which three rectangular plots of 250 m^2 (10×25 m) were established. A total of 30 plots were sampled within which tree and soil data were collected. **Results:** Total carbon stock density estimate in the mangrove was 424.28 Mg C ha^{-1}. Total carbon in soil ranked highest, constituting the total carbon stock density with 89.59%, followed by aboveground biomass with 8.41%, belowground biomass 1.68% and dead and downed wood biomass with 0.03%. **Conclusion:** This study has shown that mangrove forests in Cross River, Nigeria show promise in their potential of mitigating climate change and global warming by sequestering carbon from the atmosphere and storing them in their aboveground, belowground and soil pools.

Key words: Carbon stock, mangrove, aboveground, belowground, biomass, climate change

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Mangroves provide immense benefits to humans and biodiversity, however, they are among the most threatened ecosystems on earth with an estimated 35% lost globally in the last 40 years[1].

Mangrove forests have the potential for high levels of carbon sequestration and are responsible for approximately 10% of global carbon burial, with an estimated carbon burial rate of 174 g C m^{-2}/year [2].

They account for 3% of the global carbon sequestration by tropical forests and 14% of the global coastal ocean's carbon burial[3]. Mangroves provide many important ecosystem services including global carbon sequestration, coastal protection, nursery grounds for coastal fish and crustaceans, forest products, recreation and nutrient filtration[4].

However, these forests are being threatened by deforestation, urban development, aquaculture, pollution from oil/mineral exploitation and overexploitation of timber and aquatic resources[5].

The study aimed to quantify the total carbon stock and estimate the relative carbon capture and storage potential in the mangrove forest of the Great Kwa River, Cross River, Nigeria.

MATERIALS AND METHODS

The study was done in the mangrove forest along the Great Kwa River, Calabar. The Great Kwa River originates from the Oban Hills in Cross River State, Nigeria and flows into the Cross River estuary. The Great Kwa River has a continuous band of forested mixed mangrove wetlands extending from the mouth of the river up to the reaches of the tidal flushing near Atimbo. This area estimated to be 195,000 hectares lies within latitudes 04°45 and 04°15 north of the equator and longitudes 008°15 and 008°30 east of Greenwich Meridian. Diurnal tides exist in the area varying from high to low tides. The dominant species in the area are *Nypa fruticans* Wurmb (Family: Arecaceae), *Rhizophora racemosa* Meyer (Family: Rhizophoraceae) and *Avicennia africana* Palisot de Beauvois (Family: Avicenniaceae). The study was carried out at the Department of Plant and Ecological Studies, University of Calabar, Nigeria from December, 2017-May, 2018.

Study design and plot establishment: Ten line transects (LT 1-LT 10) of 150 m each were established 500 m apart systematically in the study site along which three rectangular plots of 250 m^2 (10×25 m) were established. A total of 30 plots were sampled with the first plot established 30 m from the river ecotone at Esuk Atu.

Trees sampling: Tree species in the sample plots were measured at 1.37 m above ground level to obtain diameter at breast height (DBH) using a diameter tape (Forestry Suppliers Inc. Jackson, MS, USA). All tree measurements were done non-destructively. Tree height was measured using a Nikon Forestry Pro rangefinder (Nikon Corporation, Tokyo, Japan).

Dead downed wood on the forest floor was measured using a Haglof Mantax caliper (Haglof Inc Madison, MS, USA). Dead and downed wood was non-destructively sampled using a modified planar intersect technique by Vakili *et al*.[6]. Downed wood was categorized into size classes and particle diameter as those determined for woody debris in upland tropical forests by Kauffman and Cole[7]. Canopy cover of tree species in sample plots was measured using a spherical densiometer[8].

Forestry suppliers Inc. Jackson, MS, USA). Only trees $\geq$10 cm dbh were measured. This is because smaller trees often constitute a relatively insignificant proportion of the total ecosystem carbon stock[9,10].

Soil sampling: Soil samples were collected from the centre of established plots in the forest. Four depths were sampled for bulk density, total carbon and nitrogen analysis, 0-15, 15-30, 30-60 and 60-100 cm, using a modified Russian open face peat auger, allowing for the collection of undisturbed soil cores. Soil cores for bulk density determination were collected by the intact core method using a fabricated hollow cylindrical steel ring of diameter and height 7 and 10 cm, respectively[11]. The collected soil samples for total carbon and nitrogen analysis and bulk density determination were carefully placed in properly labelled polythene bags, respectively for transport to the laboratory for drying in the Postgraduate laboratory of the Department of Plant and Ecological Studies, University of Calabar. Soil samples were dried at 60°C for 48 hrs in a hot air oven.

Laboratory analysis

Total carbon and nitrogen determination in soil: Soil total carbon and nitrogen were determined by dry combustion method[12] using a Thermal Scientific Flash EA 2000 CN analyzer (Thermo Fisher Scientific Inc. Waltham, MA, USA) at the ICRAF Soil-Plant Spectral Diagnostics Laboratory, Nairobi, Kenya.

Data analysis: Above-ground biomass (AGB) and below ground biomass (BGB).

The allometric equation for moist rainforest and mangrove by Chave *et al*.[13] was used for the estimation of above-ground biomass. The equation is as follows:

$$AGB_{est} = 0.0509 \times \rho D^2 H$$

Where:
AGB_{est} = Above ground biomass estimate (kg)
D = Diameter at breast height (cm)
H = Tree height (m)
ρ = Wood density (g cm^{-3})

Wood density of species was accessed from Goussanou *et al.*[14]. Where wood density was unknown, the standard average of 0.6 g cm^{-3} was used[15].

Below ground biomass was computed as 20% of above-ground biomass[16]. Biomass and carbon stock density.

Biomass stock density was calculated by taking the sum of all the individual weights (in kg) of a sampling plot and dividing it by the plot area. This value was converted to tonnes per hectare by multiplying by 10. Biomass stock density was converted to carbon stock density by multiplying with the carbon fraction of 0.47[17].

Dead and downed wood biomass: Biomass of downed wood was calculated using formulas by Kauffman and Cole[7]. The formulas are listed below:

$$\leq 0.64 \text{ cm diameter}, \rho\times 100\ \frac{\pi^2 NQMD^2}{8\,L}$$

Where:
ρ = 0.48
QMD = 0.43

$$0.65\text{-}2.54 \text{ cm diameter}, \rho\times 100\ \frac{\pi^2 NQMD^2}{8\,L}$$

Where:
ρ = 0.64
QMD = 1.47

$$2.55\text{-}7.5 \text{ cm diameter}, \rho\times 100\ \frac{\pi^2 NQMD^2}{8\,L}$$

Where:
ρ = 0.71
QMD = 4.52

$$>7.6 \text{ cm diameter}, \rho\times 100\ \frac{\pi^2 \sum D^2}{8\,L}$$

Where:
ρ = 0.69
ρ = Specific gravity
QMD = Quadratic mean diameter
L = Transect length
N = Number of pieces of wood present along transect

Carbon stock of dead and downed wood was calculated by multiplying with the same value as with live tree biomass.

Soil bulk density: Soil bulk density was calculated using the formula by Cresswell and Hamilton[18]:

$$\text{Bulk density (g cm}^{-3}) = \frac{\text{Dry soil weight (g)}}{\text{Soil volume (cm}^3)}$$

$$\text{Soil volume} = \text{Ring (tin) volume}$$

$$\text{Ring volume} = \pi\times r^2\times h$$

Where:
π = 3.14
r = radius of ring (tin)
h = height of ring (tin)

Total soil carbon and nitrogen: Total soil carbon was calculated using the formula Hughes *et al.*[10]:

$$\text{Soil carbon (Mg ha}^{-1}) = \text{Bulk density (g cm}^{-3})\times\text{Soil depth interval}\times \text{C or N (\%)}$$

Where:
C (%) = Total carbon concentration
N (%) = Total nitrogen concentration
C:N = Ratio

The carbon/nitrogen ratio was calculated by dividing the mass of carbon by the mass of nitrogen per depth.

Total carbon stock density: Total carbon stock density was calculated by summing the mean carbon stock density (Mg C ha^{-1}) of the individual carbon pools using the formula below[17]:

$$TeC = Cagb + Cbgb + Cddw + TCsoil$$

Where:
TeC = Total ecosystem carbon pool
Cagb = Aboveground biomass carbon stock density
Cbgb = Belowground biomass carbon stock density
Cddw = Dead and downed wood carbon stock density
Tcsoil = Total soil carbon

Carbon dioxide equivalent (CO_2-eq): Carbon dioxide equivalent (CO_2-eq) was calculated by multiplying the total carbon stock density by 3.67[19].

Means and standard deviations were computed using SPSS version 25 for windows.

RESULTS

Canopy closure in the mangrove ranged between 18.61±9.23 and 29.45±3.00 with a mean of 24.11±4.62% (Table 1). Total mean aboveground biomass and carbon stock and belowground biomass and carbon stock in the mangrove was 76.08±22.40 t ha^{-1}, 35.71±10.49 Mg C ha^{-1} and 15.21±4.48 t ha^{-1}, 7.13±2.09 Mg C ha^{-1}, respectively. Mean dead and downed wood biomass and carbon stock in the mangrove increased with increasing size class ranging from 7.45±5.82 kg and 0.01±0.01 Mg C ha^{-1}-549±1087.44 kg and 1.09±2.17 Mg C ha^{-1}, respectively. Mean soil bulk density in the mangrove ranged from 0.40±0.08 g cm^{-3} at 15-30 cm to 0.39±0.07 g cm^{-3} at 30-60 cm depth (Table 2).

The mean total soil carbon and nitrogen was 380.13±41.09 Mg C ha^{-1} and 18.55±1.99 Mg N ha^{-1} (Fig. 1), respectively and the mean carbon/nitrogen ratio in the mangrove was 20.48±0.27:1. The total carbon stock density estimate in the mangrove was 424.28 Mg C ha^{-1}.

Total carbon in soil ranked highest, constituting the total carbon stock density with 89.59%, followed by aboveground biomass with 8.41%, belowground biomass 1.68% and dead and downed wood biomass with 0.03% (Fig. 2).

Table 1: Mean and standard deviation of forest attributes in the mangrove forest of Great Kwa River, Nigeria

Transect	Canopy closure (%)	Aboveground biomass stock (t ha^{-1})	Belowground biomass stock (t ha^{-1})	Aboveground carbon stock (Mg C)	Belowground carbon sock (Mg C)	Total soil carbon (Mg C)	Total soil nitrogen (Mg N)	C:N ratio
1	24.16±4.97	56.94±5.04	11.38±1.00	26.76±2.37	5.34±0.47	373.91±57.63	18.31±3.00	20.43±0.40
2	29.45±3.00	103.84±23.37	20.76±4.67	48.80±10.98	9.75±2.1	404.66±28.23	19.82±1.30	20.41±0.17
3	23.81±3.41	104.67±6.57	20.93±1.31	49.19±3.08	9.83±0.61	373.06±51.45	18.30±2.45	20.37±0.09
4	18.61±9.23	65.47±14.70	13.09±2.93	30.77±6.91	6.15±1.38	385.58±56.40	18.72±3.04	20.62±0.33
5	22.69±2.99	60.62±20.21	12.12±4.04	28.49±9.49	5.69±1.90	366.51±26.53	17.90±1.00	20.45±0.45
6	25.37±4.97	97.32±16.37	19.46±3.27	45.27±7.77	9.04±1.55	416.55±23.66	20.21±1.20	20.60±0.20
7	25.55±3.23	75.63±22.03	15.12±4.41	35.54±10.35	7.10±2.06	366.66±45.98	17.87±2.01	20.49±0.44
8	21.73±1.19	75.99±4.37	15.19±0.87	35.71±2.05	7.14±0.40	366.84±26.32	17.93±1.12	20.44±0.29
9	23.47±3.25	62.27±17.71	12.45±3.54	29.26±8.32	5.85±1.66	353.31±46.32	17.26±2.36	20.48±0.20
10	26.33±3.20	58.02±6.50	11.60±1.30	27.27±3.05	5.44±0.61	394.23±55.28	19.21±2.56	20.50±0.30
Grand mean	24.11±4.62	76.08±22.40	15.21±4.48	35.71±10.49	7.13±2.09	380.13±41.09	18.55±1.99	20.48±0.27

Table 2: Mean dead and downed wood by size class/soil bulk density in the mangrove forest of Great Kwa River, Nigeria

Size class (cm)/depth (cm)	Biomass (kg)	Carbon stock (Mg C ha^{-1})	Soil bulk density (g cm^{-3})
0-0.64/0-15	7.45±5.82	0.01±0.01	0.40±0.08
0.65-2.54/15-30	35.26±31.66	0.05±0.05	0.40±0.07
0.65-2.54/30-60	85.31±121.94	0.16±0.24	0.39±0.07
>7.6/60-100	549±1087.44	1.09±2.17	0.39±0.07

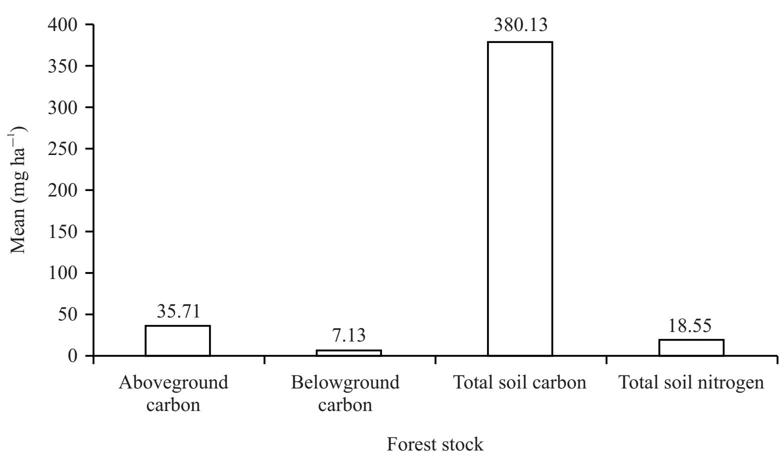

Fig. 1: Overall mean of forest carbon and nitrogen stock in the mangrove forest of Great Kwa River, Nigeria

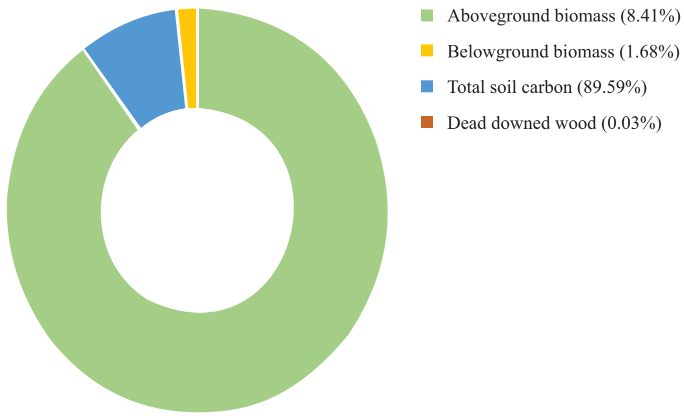

Fig. 2: Percentage of carbon stock density by pools in the mangrove forest of Great Kwa River, Nigeria

DISCUSSION

The canopy closure estimates in this study ranged between 18.61±9.23 and 29.45±3.00. Canopy closure in forests has been directly related to light supply and microclimate, therefore affecting plant growth and survival at the point of measurement[20]. Parker[21] noted that percent canopy closure measured with a densitometer helped to predict the gap light index of forests. Mangrove canopy closure estimates in this study were slightly higher than that reported by Loría-Naranjo *et al.*[22] of 17.2% in Santa Rosa National Park, Costa Rica. The canopy closure estimate in the mangrove was generally low and may be due to large canopy gaps which are a common feature in mangroves facing disturbance regimes such as selective harvesting and natural mortality of trees[23]. However, gaps created that reduce canopy closure provide an opportunity for tree recruitment within the mangroves, due to an increase in light reaching the forest floor[24]. Also, with photosynthetic rates being proportional to growth, more biomass and slower decomposition rate occur where there is high closure and less biomass and higher decomposition rates where closure is low[25].

The total mean aboveground biomass and carbon stock and belowground biomass and carbon stock in the mangrove was 76.08±22.40 t ha^{-1}, 35.71±10.49 Mg C ha^{-1} and 15.21±4.48 t ha^{-1} 7.13±2.09 Mg C ha^{-1}, respectively. Above-ground biomass and carbon stock estimate of the mangrove forest in this study were lower than estimates reported by Sitoe *et al.*[26] of 134.6 t ha^{-1} and 58.6 Mg C ha^{-1} in Sofala bay, Central Mozambique, Abino *et al.*[27], 561.2 t ha^{-1} and 263.8 Mg C ha^{-1} in a natural mangrove forest in Palawan, Trettin *et al.*[28], 113 t ha^{-1} in mangroves of the Zambezi River delta. Kauffman *et al.*[29] reported mean above-ground biomass stock estimates in the range of 254-406 t ha^{-1} in Micronesian mangroves, which were greater than the results of this study. Higher mangrove above-ground biomass carbon stocks were reported by Kridiborwon *et al.*[30] of 140.5 Mg C ha^{-1} in Thailand. These differences may be as a result of variations in allometric equations as some equations are species-specific and this study made use of general equations generated for the tropics[13]. However, the estimates of this study were comparable and slightly higher than the reports by Subasinghe and Khanh[31] of 63.04 t ha^{-1} and 22.05 Mg C ha^{-1} in the mangroves of Muthurajawela wetland, Sri Lanka and Fatoyinbo *et al.*[32] of 67 t ha^{-1} in Inhambane, along the Mozambique coasts, Harishma *et al.*[33] of 56.25 t ha^{-1} in the Southern zone of Kerala, India. Above-ground biomass and carbon stocks estimates of this study are also within the ranges reported by Borah *et al.*[34] of 32.47-261.64 t ha^{-1} and 16.24 Mg-130.82 Mg C ha^{-1} in Northeast India, although the upper limits are far greater. Hastuti *et al.*[35] and Bindu *et al.*[36] reported mangrove above-ground biomass estimates of 38.60 t ha^{-1} in Bali and 19.33 t ha^{-1} in Kerala, Indonesia, respectively using remote sensing. These estimates were lower than the estimates in this study and may be due to the method employed in biomass estimation. Lu[37], stated that field measurements are the most accurate in biomass data collection though expensive, time-consuming and labour were intensive.

Below ground biomass stock estimates for dwarf mangroves in Mexico have been reported by Adame *et al.*[38] as 8.7 t ha^{-1} and Trettin *et al.*[28] reported a combined below-ground biomass stock of 11.40 t ha^{-1}. These estimates are comparatively lower than the estimates in this study and may be due in part to the height differences of tree species within sampled forests. High below-ground biomass stock and carbon stock estimates compared to the results of this study, were reported by Abino *et al.*[27] of 196.50 t ha^{-1} and

92.30 Mg C ha^{-1}, Kauffman *et al.*[29] of 171.0 t ha^{-1} in Palau 80.0 Mg C ha^{-1} and 312.0 t ha^{-1} and 144.0 Mg C ha^{-1} in Yap. These high estimates may be attributed to marked differences in tree trunk diameters of species in their sample sites as tree trunk plays a major role in the estimates of biomass using allometric equations[39]. Santos *et al.*[40] stated that marine processes and frequency of inundation could influence belowground biomass and carbon stock in mangroves. The variation in estimates compared to the estimates of this study may be due to variations in carbon dynamics within tree species and soil in these locations as well as different vegetation types.

The mean dead and downed wood biomass and carbon stock in the mangrove increased with increasing size class ranging from 7.45±5.82 kg and 0.01±0.01 Mg C ha^{-1} to 549±1087.44 kg and 1.09±2.17 Mg C ha^{-1}, respectively. Reports by Woodall *et al.*[41] on downed wood carbon stock averaged 0.9 Mg ha^{-1} in the United States and is comparable with the results of this study. Oswalt *et al.*[42] reported a range of 4.6-28.3 Mg ha^{-1}, Adame *et al.*[38], reported a range of 7.0-25.7 Mg ha^{-1}. Kauffman *et al.*[29] reported estimates in the range of 29.6 and 43.1 Mg ha^{-1} in mangroves in the Federated States of Micronesia. These estimates are greater than the estimates of this study and may be due to the inclusion of litter biomass estimates in those studies. Also, variations in the nomenclature of what constitutes dead and downed wood biomass have led to over or underestimation, depending on whether standing and down stems and branches, stumps and dead coarse roots belowground are collectively sampled or some components are excluded[43]. Differences in methods of estimation either directly or indirectly with the use of volume estimators and associated biomass conversion constants, which could be general or species-specific can give inconsistent estimates[44,45].

The mean soil bulk density in the mangrove ranged from 0.40±0.08 g cm^{-3} at 15-30 cm to 0.39±0.07 g cm^{-3} at 30-60 cm depth. Average soil bulk density in this study was similar to reports by Donato *et al.*[46] ranging from 0.35-0.55 g cm^{-3} in mangrove soils of Indo-Pacific regions. The reports by Sitoe *et al.*[26] with a range of 1.05-1.12 g cm^{-3} were higher than the results of this study. The soil bulk density variations may be due to differences in species-specific root growth.

The mean total soil carbon and nitrogen was 380.13±41.09 Mg C ha^{-1} and 18.55±1.99 Mg N ha^{-1} (Fig. 1), respectively. The mean total soil carbon in the mangrove in this study is typical of soil carbon stocks in mangroves of other regions. Comparable to the mangrove soil carbon stock results of this study are the report by Kauffman and Bhomia[47] of 392 Mg ha^{-1} in mangroves of the Ndougou Lagoon, Gabon. Lower than the results of this study were reported by Sitoe *et al.*[26] of 160 Mg ha^{-1} to a depth of one metre in a mangrove in Mozambique, Adame *et al.*[38] of 232.4 Mg ha^{-1} of soil carbon at Isla Pitaya, Savari *et al.*[48], found an average of 227 Mg ha^{-1} soil carbon in Gowatr mangrove forests, Gulf of Oman, Kauffman *et al.*[29] found 236 Mg ha^{-1} of soil carbon at Yap mangrove forest. Sahu *et al.*[49] found 54.3 Mg ha^{-1} and 57.6 Mg ha^{-1} in the soil to a depth of 30 centimetres in natural and plantation mangroves respectively, in the Mahanadi forest in India. These results were lower than the results in this study and may be attributed to the increment in depths sampled in this study. Kauffman *et al.*[50] reported soil carbon stocks in three mangrove forests in the Dominican republic of 546, 1084 and 713 Mg ha^{-1}, respectively. These results were higher than the results of this study and may be due to higher bulk density values of soils in those regions. Depth differences in carbon stock and variations in soil type and landscape could also be a contributing factor to the higher stocks recorded in those studies. The soil carbon stocks of the mangrove in this study are lower than the estimates reported for mangroves by other authors. The area covered by terrestrial forests is far larger than that covered by mangroves. However, mangroves store more carbon in their soils when compared to terrestrial forests[51]. Donato *et al.*[46] stated that tropical wetlands are among the highest reported ecosystem carbon pools on earth, with 49-98% of ecosystem carbon stored in their organic soils. This is due to high rates of primary productivity as well as anaerobic soil conditions that limit decomposition, making their carbon stocks among the highest of any forest type[52]. Also, the structural complexity of vegetated coastal ecosystems, root systems and vegetation, sets up mangroves to be highly efficient in trapping sediment and associated organic carbon originating from autochthonous and allochthonous riverine and oceanic sources[53]. The availability of nitrogen has been found to control carbon accumulation, increase primary productivity, increase carbon inputs to the soil and decrease soil respiration thereby decreasing carbon outputs from the soil in forests[54]. Kassa *et al.*[55], reported values greater than those presented here of 46 Mg N ha^{-1} Ethiopia. Similar to the results reported for the mangrove stocks is the report by Urakawa *et al.*[56] of 16.3 Mg N ha^{-1} in a Subtropical forest of the Japanese Archipelago. Variations in spatial distribution, forest type, climatic condition and land-use and soil parent material may be an explanation for the contrasts in soil nitrogen stocks[56]. Hungate *et al.*[57] stated that carbon sequestration in forests is sustained by the availability of nitrogen. Quantifying forest soil C and N stocks is critical to understanding the ecological responses of forests to changes in climate, land use and management and to improve global change models[58,59].

The mean carbon/nitrogen ratio in the mangrove was 20.48±0.27:1. Mean carbon/nitrogen ratios in this study can be compared with the results of Weiss *et al.*[60], which is within the range of 9-28 and Kusumaningtyas *et al.*[61] ranging from 9-26.6 in mangroves in Indonesia. Carbon and nitrogen in soils are the main components of organic matter, which depicts soil fertility. Both carbon and nitrogen status associated with the C/N ratio may play a key role in regulating soil organic matter mineralization. The ratio of C/N indicates the rate of decomposition of organic matter and this results in the release or immobilization of soil nitrogen[62].

The total carbon stock density in the mangrove was 424.28 Mg C ha^{-1}. The soil carbon constituted the highest percentage in total carbon stock density of 89.59% and this is coherent with the reports of Adame *et al.*[38] and Donato *et al.*[46], who reported a percentage in a range of 78-99 and 49-98% respectively, further supporting evidence that most of the carbon stored in mangroves is in the soil and sediments. Within the range of the results in the mangroves of this study are reported by Alavaisha and Mangora[63] of a range of 414.6-684.9 Mg C ha^{-1} in Tanzania, Abino *et al.*[27] of 529.9 Mg C ha^{-1} in a mangrove forest in the Philippines. Lower estimates were reported by Sahu *et al.*[49] of 147 Mg C ha^{-1}, respectively. Overall, observed differences in total carbon stock densities to other regions may be attributed to variances in forest densities, forest age, conservation and management status and soil depths investigated. With a carbon dioxide equivalent of 1,557.10 CO_2^- eq, the mangrove forest of the Great Kwa River, Calabar, covering about 195,000 hectares may store up to 82.73 million Mg of carbon at the landscape scale.

CONCLUSION

This study has shown that mangrove forests in Nigeria show promise in their ability of mitigating climate change and global warming by sequestering carbon from the atmosphere and storing them in their aboveground, belowground and soil pools. Long-term monitoring and research into the dynamics controlling mangrove growth and survival under environmental and anthropogenic pressures are critical to increasing our understanding of mangrove survival in the face of sea-level rise and changing climatic conditions. Variations in stocks among mangrove forests are existent due to confounding factors that include species that constitute the vegetation, soil type, elevation effects, watershed, climate and previous land use. Ongoing exploitation of forests for timber and conversion to agricultural land has highlighted the need to conserve mangrove forests and to accurately quantify carbon stocks.

SIGNIFICANCE STATEMENT

This study discovers the carbon sequestration potential of the mangrove forest of the Great Kwa River, Calabar Nigeria. This study is the first attempt to quantify the carbon stock of the area of interest which is of great importance to mitigation of climate change effects in Nigeria. This study will help the researcher and other researchers interested in mangrove research to uncover the mechanisms of carbon sequestration in plants and soil and how to manage the ecosystem for continuous productivity. Thus, this study will serve as the baseline for further research to explore the dynamics of carbon sequestration rates in the mangrove ecosystem.

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