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CARBON SEQUESTRATION CAPACITY OF THE LAGOS LAGOON: EXAMINING THE POTENTIALS OF A TYPICAL NIGERIAN COASTAL ECOSYSTEM FOR CLIMATE CHANGE MITIGATION

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ABSTRACT

Carbon sequestration capacity of the Lagos Lagoon was studied through a six-month analysis of carbon surrogates. The findings revealed that water samples from inorganic carbon surrogates yeilded higher values than those of organic carbon. Sediment samples recorded higher values of DOC, DIC, TOM, TIM, and TOC. Correlation studies indicate that DOC, DIC, and TOM were the principal determinants of the trends observed in most parameters. A total of 1.5 x 5.3 x 10^{-11} t CO_2 eq ha^{-1}, was sequestered in the surface water, while in sediment, the lagoon demonstrated a sequestration potential of 2.13 x 10^{-6} t CO_2 eq ha^{-1}. Biomass of benthic macrofauna populations was a major contributor to the carbon stock and CO_2 sequestered. The low value of carbon sequestered in the lagoon can be attributed to the wide-scale human disturbances taking place in the lagoon.

RÉSUMÉ: Capacité de séquestration du carbone dans la lagune de Lagos: examen du potentiel d'un écosystème côtier typique du Nigéria pour l'atténuation du changement climatique.

La capacité de séquestration du carbone de la lagune de Lagos a été étudiée par analyse de substituts de carbone pendant six mois. Les valeurs des paramètres étudiés ont révélé que les échantillons d'eau enregistraient des valeurs plus élevées de substituts de carbone inorganique que celles de carbone organique. Les sédiments ont enregistré des valeurs plus élevées de DOC, DIC, TOM, TIM et TOC. Des études de corrélation indiquent que le COD, le DIC et le TOM étaient les principaux déterminants des tendances enregistrées pour la plupart des paramètres. Au total, 1,5 x 5,3 x 10-11 t CO_2 eq ha-1 ont été séquestrées dans les eaux de surface, tandis que dans les sédiments, le la lagune a démontré un potentiel de séquestration de 2,13 x 10-6 t CO_2 eq ha-I. La biomasse des populations de macrofaune benthique était un contributeur majeur au stock de carbone et au CO_2 séquestré. La faible valeur du carbone séquestré dans le lagon peut être attribuée aux perturbations humaines à grande échelle qui ont lieu dans le lagon.

REZUMAT: Capacitatea de sechestrare a carbonului a lagunei Lagos: examinarea potențialului unui ecosistem tipic de coastă Nigeriană pentru atenuarea schimbărilor climatice.

Capacitatea de captare a carbonului a lagunei Lagos a fost investigată prin analiza surogatelor de carbon timp de șase luni. Valorile parametrilor investigați au evidențiat că, probele de apă au înregistrat valori mai mari ale surogatelor carbonului anorganic decât cele ale carbonului organic. Sedimentul a înregistrat valori mai mari ale DOC, DIC, TOM, TIM și TOC. Studiile de corelare indică faptul că DOC, DIC și TOM au fost principalii determinanți ai tendințelor înregistrate pentru majoritatea parametrilor. Un total de 1,5 x 5,3 x 10-11 t CO_2 eq ha-1, a fost sechestrat în apa de suprafață, în timp ce în sediment, laguna a demonstrat un potențial de sechestrare de 2,13 x 10-6 t CO_2 eq ha-I. Biomasa populațiilor de macrofaună bentonică a contribuit major la stocul de carbon și CO_2 sechestrat. Valoarea scăzută a carbonului captat în lagună poate fi atribuită perturbărilor umane la scară largă din lagună.

INTRODUCTION

The Paris Agreement under the UNFCCC requires signatories to pursue ambitious measures to reduce the rising global temperature to 1.5°C. There is an urgent need for rapid decarbonization of the economy. Although this process alone will not be sufficient to achieve the desired result, IPCC scenarios for limiting global temperature rise to 1.5°C also require the removal of CO_2 from the atmosphere (IPCC, 2013). One of the main approaches to achieving this is through nature-based solutions (NbS) that conserve and expand natural carbon sinks, providing climate change mitigation benefits along with co-benefits to society and biodiversity (IUCN, 2020). Climate change is a major threat to natural ecosystems and a substantial barrier to sustainable development (IPCC, 2014). The topic of climate change has attracted significant research interest in the search for ways to slow down the process and reduce its impact.

Policies towards climate mitigation aim to store carbon in ecosystems, which can result in lower carbon dioxide levels in atmosphere. Intact, well-functioning ecosystems can store and conserve large amounts of carbon, and restoration of degraded aquatic ecosystems could contribute significantly to reducing further carbon dioxide emissions from these systems or even removing them from the atmosphere and sequesting the carbon in biomass and sediment (IPCC, 2014). Because of this, in both terrestrial and aquatic ecosystems, reforestation and restoration are recommended as methods of reducing CO_2 in the atmosphere.

Relying on ecosystem services to address climate change is the core principle behind the adoption of NbS for climate change mitigation. Carbon dioxide stored in aquatic environments can take a long time before it is released to the surface water from the sediment through geologic processes. Aquatic ecosystems, especially the oceans, are the largest long-term stock of carbon in the biosphere, capable of storing and cycling approximately 93% of the Earth's estimated 40 Tt of CO_2 (Moraes, 2019). It has been reported that a large percentage of carbon in the oceans occurs in the form of inorganic carbon, mainly as bicarbonate, carbonate, dissolved carbon dioxide, and carbonic acid (Hansell, 2013), and that carbon is stored in the ocean in three forms (Dickson et al., 2007): dissolved inorganic carbon (CO_2, HCO_3^-, CO_3^{2-}), dissolved organic carbon (both small and large organic molecules), and particulate organic carbon (live organisms or fragments of dead plants and animals).

Planetary carbon cycling involves the transfer and exchange of carbon among its four main reservoirs: the atmosphere, the terrestrial biosphere, the ocean, and the sediment (Tank et al., 2012). Aquatic ecosystems can have a major impact on the reduction of atmospheric CO_2 concentrations, thereby reducing climate change, through CO_2 sequestration from the atmosphere and the uptake of CO_2. Climate change mitigation can be more cost-effective if it involves an integrated approach that combines measures to reduce energy use and the greenhouse gas intensity of end-use sectors, decarbonize the energy supply, reduce net emissions, and enhance the storage of carbon stocks (IPCC, 2014).

Nigeria is blessed with enormous aquatic resources including a large network of rivers, coastal lagoons, adjacent ocean mass, creeks, etc. However, the potential of these ecosystems to sequester or store carbon has not been appraised and fully integrated into the nation's Nationally Determined Contribution (NDC) as part of its nature-based solutions to climate mitigation. This is primarily due to scarce or nonexistent data on the potential of aquatic systems in climate mitigation in Nigeria. In this study, therefore, we have investigated the capacity of one of the largest lagoons in Nigeria, the Lagos Lagoon, to sequester carbon with the aim of determining its potential for climate mitigation. This study is likely the first to provide such information. This will help policymakers and other stakeholders by supplying data to implement actions toward national and regional strategies on carbon storage and the adoption of blue carbon in climate mitigation endeavors.

MATERIAL AND METHODS

Background

The Lagos Lagoon located in the heart of the commercial nerve center of the city of Lagos is a major sink for over 70% of the surface runoffs, drainage channels, and important rivers flowing from Nigeria hinterland to the Atlantic Ocean. The surrounding densely populated and industrialized areas often result in the introduction of large quantities of organic waste into the lagoon. The city of Lagos has been recognized as the most populous in Nigeria and the fifth most populous city in the world. The city hosts about 75% of the industries in Nigeria, and owing to the large population, coupled with the high number of industries, enormous quantities of waste are discharged into the lagoon. In addition, active dumping of solid waste into the lagoon continues unabated. The lagoon serves as a major waste sink. The lagoon geology is dominated by a continuous repetition of clay and sand (Olatunji and Abimbola, 2010). The lagoon is bounded in the north by a broad land area, housing a large human population and industrial centers, and to the south by highbrow business and residential areas. The lagoon is lined with several shanty settlements along its banks. The depth of the lagoon ranges mostly between 2-3 m, with some areas reaching 10-15 m deep. The lagoon maintains a fairly constant volume of water throughout the year. During the wet season, the lagoon is fed by numerous rivers and creeks, while in the dry periods, the loss of water due to evaporation and the reduced input from rivers and creeks are compensated by the underground seepage through the active sandy barrier formation and inflow of tidal waters from the sea to the Lagos Harbor and other lagoon outlets originating in southwest Nigeria.

Field studies

In-situ measurements were taken for three parameters: air temperature, water temperature, and surface water pH. Air temperature was measured using a mercury-in-glace thermometer, while water temperature and pH of surface water were measured with a hand-held Horiba U-10 water quality checker.

Collection of samples

Samples of water, sediment, and benthic macrofauna were collected from five stations spanning about one-third of the entire length of the lagoon, for six consecutive months from June to November 2023, representing the rainy season.

The water samples were collected in pre-washed one-litre plastic bottles which were properly corked, labeled, and kept in a cooler for transport to the laboratory. Sediment and macrofauna samples were collected with a benthic van Veen Grab of 1 x 1 sqm. Three successfully retrieved grab samples were taken from each sampling station, on each sampling day. All samples were immediately homogenized after collection. A portion of the homogenized sample was taken with a plastic spatula, wrapped with aluminum foil, and properly labeled. The remaining sediment was washed through a 0.5 mm sieve to extract the macroinvertebrates. The materials retained in the sieve were placed in a wide-mouth plastic bottle with a screw cap and properly labeled. All collected samples were kept in a well-sealed cooler and taken to the laboratory for analyses of carbon and organic matter.

Laboratory studies

The laboratory studies involved the determination of carbon content and organic matter of samples, including: dissolved organic carbon (DOC) in water and sediment, dissolved inorganic carbon (DIC) in water and sediment, total organic carbon (TOC) in water and sediment, total inorganic carbon (TIC) in water and sediment, total organic matter (TOM) in water and sediment, and biomass of macrofauna.

Dissolved organic carbon in sediment and water was determined by the Dittmar et al. method (2008). 10.0-g sediment samples were sieved with a 2 mm sieve, mixed with 50 mL of 2 M KCl in a polyethylene bottle (100 mL), then shaken for 1 h in an oscillator. 100 Ml of water was filtered on a Whatmann filter paper. After shaking, centrifugation, and filtration, of both the sediment and water samples, the DOC of the samples were determined by a total-C analyzer (TOC-L CPN, Shimadzu, Japan) using a standard curve method (Yang et al., 2021).

Dissolved inorganic carbon determination in water and sediment was accomplished by converting bicarbonate ions (HCO_3^-) and carbonate ions (CO_3^{2-}) to undissociated CO_2, which is then extracted as a gas for quantification. Five grams of sediment was extracted with 100 mLs of CO_2-free water and filtered. Similarly, 100 mL of water sample was filtered to remove particulates and stored in an airtight borosilicate bottle. The water and sediment extracts were acidified by adding a strong acid (e.g., phosphoric acid) to convert HCO_3^- and CO_3^{2-} to CO_2. The evolved CO_2 gas was extracted using a dynamic headspace system that trapped the CO_2 gas for subsequent analysis. An Apollo SciTech DICOMAT dissolved inorganic Carbon Analyzer (DIC Analyzer), specifically designed for DIC measurement utilizing infrared detection of CO_2, was used to measure total DIC directly.

The organic compounds in the samples were converted to CO_2 by oxidation. The CO_2 produced was analyzed using high temperature combustion. The samples were combusted at 1,200°C in an oxygen-rich atmosphere and the resulting CO_2 was measured using a Shimadzu TOC-V non-dispersive infrared (NDIR) absorption spectrometer (Yang et al., 2021).

Organic forms of carbon are oxidized in the presence of excess dichromate. Total organic carbon was determined using the back titration method (Walkley and Black, 1934). 10 g of dried sediment was weighed and transferred to a 500 mL Erlenmeyer flask and 10 mL of 1 molar solution of potassium dichromate was added. Then, 20 mL of concentrated sulphuric acid was added. The flask was agitated by rotation for one minute to homogenize at a reaction of temperature 120°C. The flask was placed on an insulating plate and the oxidation was allowed to continue for another 30 minutes. Two hundred (200) mL of distilled water was added, followed by 10 mL of phosphoric acid. Five g of sodium fluoride was also added. The flask and its contents were homogenized. Three drops of diphenylamine were added as a titration indicator. The excess dichromate was titrated with 0.5 mol ferrous iron solution. The titration was continued until the color changed from purplish blue to luminous greenish blue. Determination of the endpoint was facilitated by the addition of 1-2 drops of indicator as soon as the color began to change. Total organic carbon of dried sediment was 100 x 3.9 (10-V)/ P, where P is the sample mass in g and V is the volume (mL) of Fe^{2+} solution at a concentration of 0.5 mol per liter. Total organic matter (g kg^{-1}) = Total organic carbon x (1.1-1.7). For total organic matter in water, this method was repeated with 100 mL of water sample.

Five grams of dried sediment and 100 mL of water were used for TOM determination. The dried homogenized sediment sample was combusted at 1,350°C in an oxygenated atmosphere. Carbon in the sample oxidized to form CO_2 gas. The CO_2 gas flowed through a non-dispersive infrared (NDIR) detection cell. A LECO CR-412 Carbon Analyzer, designed for TIC measurement., provided weight-corrected results as percentage carbon. The process was repeated for the 100 mL water sample. (Bernard et al., 1995)

Biomass was determined by wet method, weighing all specimens of *Pachmylenia aurita* in macrofauna samples (Holme and Mclntyre, 1971). These specimens were dried for five minutes after puncturing the shells with a needle. The mantle cavity water was absorbed using filter paper. The specimens were then weighed with a balance and values were recorded as the total weight (TWT) approximated to the nearest gram (g). Tissue weight (TSW) was obtained after weighing deshelled specimens and values were recorded in grams.

RESULTS AND DISCUSSION

Spatial and temporal patterns in parameters investigated

Table 1 shows the summary of values recorded for the parameters investigated, and spatiotemporal variations in values observed are depicted (Figs. 1-10). While seven parameters (DOC, DIC, TOM, TIM, TIC, temperature, and pH) were studied for water samples, five (DOC, DIC, TOM, TIM, and TIC) and two (TWA and TWT) parameters were investigated for sediment and macrofauna respectively. Values of DOC in water samples varied from 0.1 to 1.6 $mgCL^{-1}$. Relatively higher values of DOC were recorded in station 4 where recorded ranged from of 0.7 to 1.6 mgCL-1 was observed. Mean values for study stations fluctuated from 0.3 to 1.0 $mgCL^{-1}$ while monthly mean values varied from 0.4 to 0.8 $mgCL^{-1}$. Values of DIC in water were significantly higher than those of DOC. The range of values observed for DIC were from 208 to 9,600 $mgCL^{-1}$. Spatially, mean values fluctuated from 566 to 5,023 $mgCL^{-1}$, while temporal changes in mean values fell from 227.2 to 4,272 $mgCL^{-1}$.

Values of TOM did not show notable variation during the study. All values encountered were between 2.0 to 7.2 $mgCL^{-1}$. Among the study locations, mean values varied from 4 to 11 $mgCL^{-1}$, while mean values recorded for sampling months ranged from five to eight $mgCL^{-1}$. The concentrations of TOC varied greatly among stations and sampling months. Values recorded were ffrom 1.6 to 5.0 $mgCL^{-1}$ which is closely related to TOM concentrations. While temporal ranges in mean concentration fluctuated from 2.1 to 4.0 $mgCL^{-1}$, ranges in mean spatial concentrations varied from 1.4 to 4.2 $mgCL^{-1}$. Values of TIM were similar in range (280 to 10,200 $mgCL^{-1}$) to those recorded for DIC. At the study locations mean concentration of TIM varied from 727 to 5,267 $mgCL^{-1}$, whereas in sampling locations, the mean concentration ranged from 308.4 to 4,537 $mgCL^{-1}$. The temperature of surface water did not show remarkable variations during the study period. Values recorded for pH also demonstrated the same trend. While values encountered for temperature were ranged from 25.3 to 29.99°C, pH fluctuated from 4.6 to 7.7.

Sediment samples recorded higher values of DOC, DIC, TOM, TIM, and TOC. Dissolved organic carbon varied between 2.0 and 14.0 $mgCkg^{-1}$. On the spatial scale, mean values ranged from 2.0 to 12.0 $mgCkg^{-1}$, while a range from 6.0 to 7.0 $mgCkg^{-1}$ was observed at the temporal scale. Similar to the pattern recorded for water samples, DIC values for sediment were higher than those of DOC. Values fluctuated from 7.5 to 32.6 $mgCkg^{-1}$. Mean values recorded in the study location ranged from 10.0 to 44.0 $mgCkg^{-1}$, while monthly mean values obtained during the six-month sampling period were from 24.0 to 30.0 $mgCkg^{-1}$. Concentrations of TOC were similar in range (3.0 to 13.6 $mgCkg^{-1}$) to those observed for DOC. Spatially, mean concentrations varied from 4.0 to 11.4 $mgCkg^{-1}$ and temporarily fluctuated from 6.7 to 8.2 $mgCkg^{-1}$. Concentrations of TOM and TIM in the study stretch varied remarkably both at spatial and temporal scales. Overall values of TIM were higher than TOM in all the sampling stations during the study period. Whereas a range from 5.0 to 20.7 $mgCkg^{-1}$ was observed for TOM, TIM concentrations fluctuated from 14.2 to 80.0 $mgCkg^{-1}$.

Table 1: Summary of values of parameters investigated.

Parameter	Sampling location									
	1		2		3		4		5	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Water										
DOC ($mgCL^{1}$)	0.1 – 0.5	0.3	0.2 – 0.6	0.4	0.2 – 0.8	0.4	0.7 – 1.6	1.0	0.3 – 0.5	0.4
DIC ($mgCL^{-1}$)	218 – 960	566	208 – 4800	1806	280 – 5200	2198	210 – 9600	5023	220 – 1000	694
TOM ($mgCL^{-1}$)	2 – 5	4	4 – 6	5	3 – 6	5	6 – 17	11	3.1 – 7.2	5
TIM ($mgCL^{-1}$)	280 – 1560	727	320 – 5200	2402	300 – 5425	2436	280 – 10200	5267	298 – 1200	835
TOC ($mgCL^{-1}$)	2.0 – 4.0	3.0	4.0 – 5.0	4.0	2.8 – 4.2	3.5	1.6 – 4.9	3.0	0.56 – 2.6	1.4
Tempt °C	26.1 – 29.99	28.4	26.2 – 29.51	28.4	25.4 – 29.68	28.2	25.3 – 29. 9	27.7	25.9 – 29.9	28.3
pH	6.0 – 7.0	7.0	5.8 – 6.8	6.3	5.3 – 6.7	6.2	4.6 – 7.4	6.2	5.5 – 7.7	6.7
Sediment										
DOC ($mgCkg^{-1}$)	2 – 3	2	5.2 – 6.6	6	5.3 – 7.6	6	9.8 – 13.6	12	4.6 – 6.4	6
DIC ($mgCkg^{-1}$)	40 – 50	44	25.6 – 30.6	28.6	27.0 – 32.6	29.7	7.5 – 15.6	10.4	16.4 – 23.7	20.4
TOC ($mgCkg^{-1}$)	3 – 5	4	6.0 – 9.5	7.8	6.1 – 9.3	8.2	8.6 – 13.5	11.4	5.3 – 8.9	6.8
TOM ($mgCkg^{-1}$)	5 – 10	6	11.6 – 13.5	12.5	11.6 – 15.2	13.7	17.2 – 20.7	19	7.2 – 12.5	10
TIM ($mgCkg^{-1}$)	68.5 – 80.0	73	46.2 – 52.6	49.3	50.2 – 56.6	53.3	14.2 – 23.6	17.6	30.6 – 44.6	38.4
Macrofauna										
Total Weight (g)	21 – 750	190	35.1 – 56.0	49.0	12.0 – 536.0	208.0	10.3 – 36.0	27	28.0 – 200	67
Tissue weight (g)	1.2 – 16.0	5.1	1.0 – 12.0	4.1	0.5 – 13.0	4.4	0.5 – 10.0	2.6	1.1 – 17.0	4.7

Total and tissue weights of collected macrofauna specimens varied significantly. The total weight (TWT) values ranges from 10.3 to 750.0 g, while tissue weight (TSW) values ranged between 0.5 and 7.0 g.

A critical evaluation of the patterns demonstrated in values of parameters investigated in this study revealed two outstanding features. Firstly, water samples recorded higher values of parameters related to inorganic carbon (DIC and TIM) than organic carbon (DOC, TOM, and TOC). This trend is expected as most of the carbon in the aquatic systems exist as DIC, in the forms of bicarbonate, carbonate, dissolved CO_2, and carbonic acid (Hansell et al., 2009). Dissolved inorganic carbon in aquatic environments originates from different sources including sediment carbonate dissolution, organic matter decay, and carbonate rock disintegration with source contribution depending on flora composition, climatic conditions, and lithology (Lloret et al., 2011). A similar relationship was observed in the waters of Port Blair, Andaman Islands, and India, consistent with the findings in this study (Mohan et al., 2016). Carbon in organic matter such as DOC, is subject to microbial mineralization and most of the organic carbon will be converted back to DIC within a few decades (Soria-Reinoso et al., 2022). It is estimated that about 1% of TOC from the surface is exported to deeper sediment where it can be buried for thousands of years. The variation of DOC and DIC in aquatic systems is usually dependent on the subsurface dissolved carbon transport dynamics (Jantze et al., 2015). The rate at which water percolates through the sediment significantly impacts the degree of mineralization from organic to inorganic carbon (Ågren et al., 2007).

Carbon (iv) oxide is the raw material with which organic materials are synthesized. The catalysis of these organic molecules results in the release of CO_2 and the formation of inorganic carbon, meaning that, the breaking down of organic materials results in an increased release of inorganic carbon. Thus, the inverse relationship recorded between DIC and DOC in this study is valid and represents the opinions of many researchers in this field. Values (0.1-01.6 $mgCL^{-1}$) of DOC recorded in water compare favorably with the data (2.02± 0.91 mgCL-1) reported for Godavari River (Bouillon et al., 2002), but were lower than values (2.4-16.1 $mgCL^{-1}$) recorded for major world rivers (Spitzy and Leenheer, 1991).

Secondly, the values of the parameters studied were generally higher in sediment than in surface water samples, confirming the postulation that sediment serves as a sink to materials entering the aquatic ecosystem. This observation is consistent with the results of similar studies (Niemirycz et al., 2006).

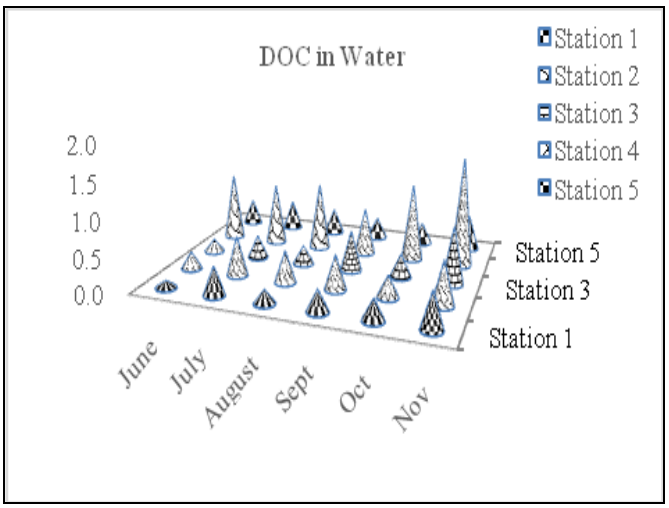

Figure1: Spatiotemporal variations in surface water DOC.

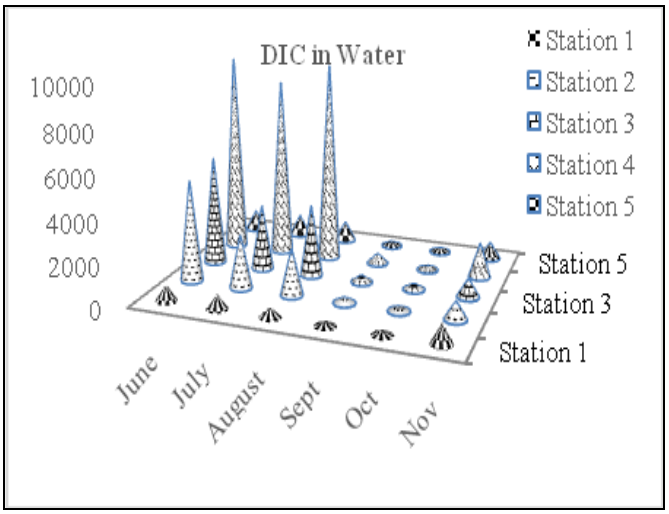

Figure 2: Spatiotemporal variations in surface water DIC.

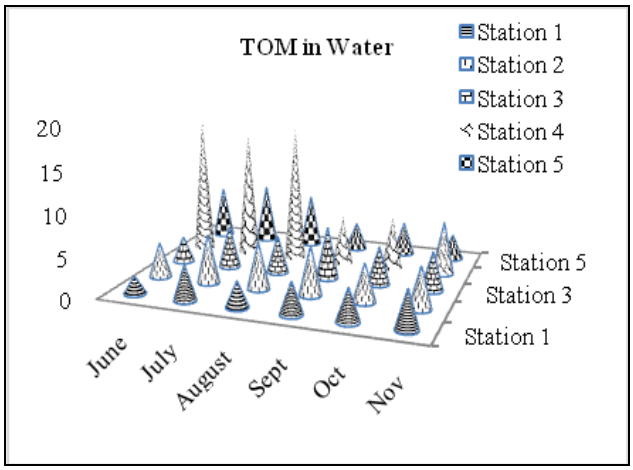

Figure 3: Spatiotemporal variations in surface water TOM.

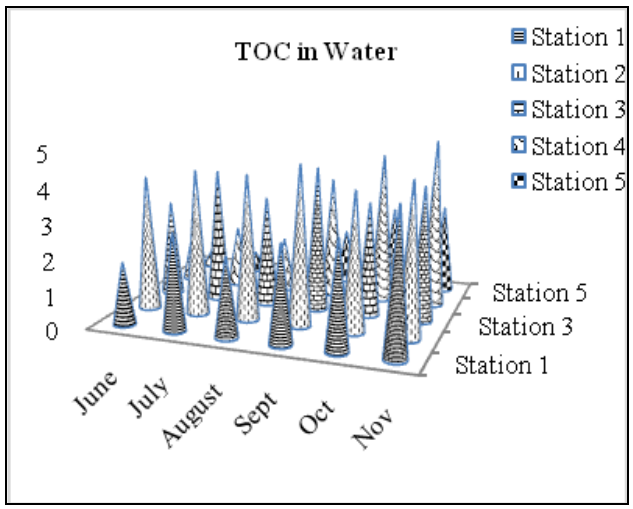

Figure 4: Spatiotemporal variations in surface water TOC.

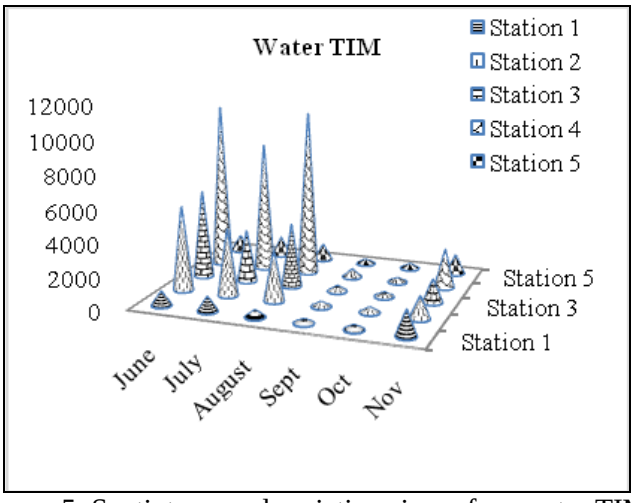

Figure 5: Spatiotemporal variations in surface water TIM.

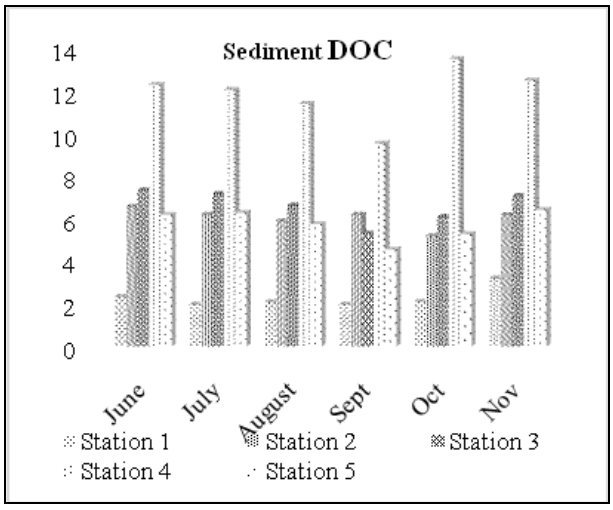

Figure 6: Spatiotemporal variations in sediment DOC.

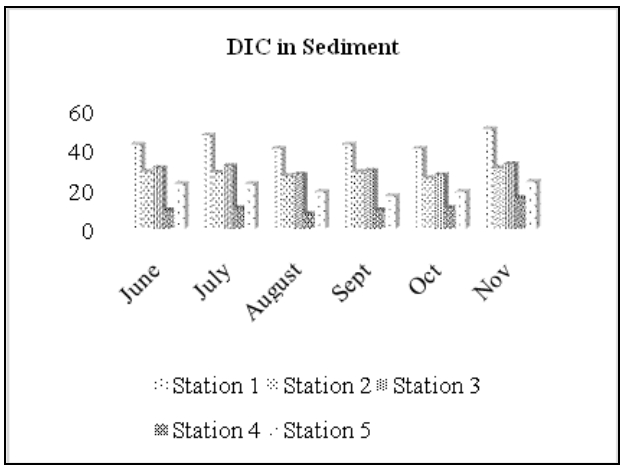

Figure 7: Spatiotemporal variations in sediment DIC.

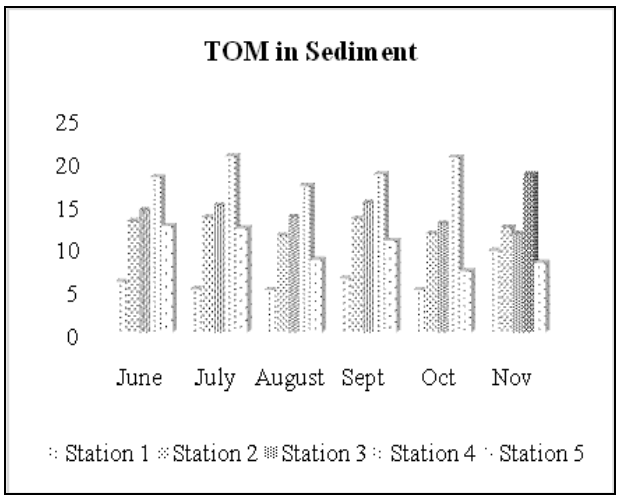

Figure 8: Spatiotemporal variations in sediment TOM.

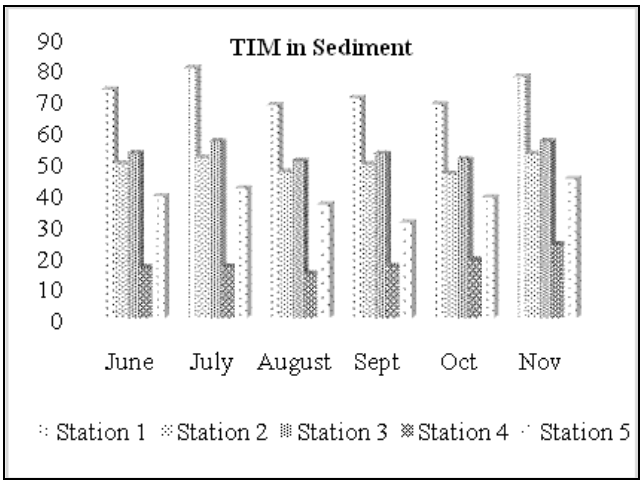

Figure 9: Spatiotemporal variations in sediment TIM.

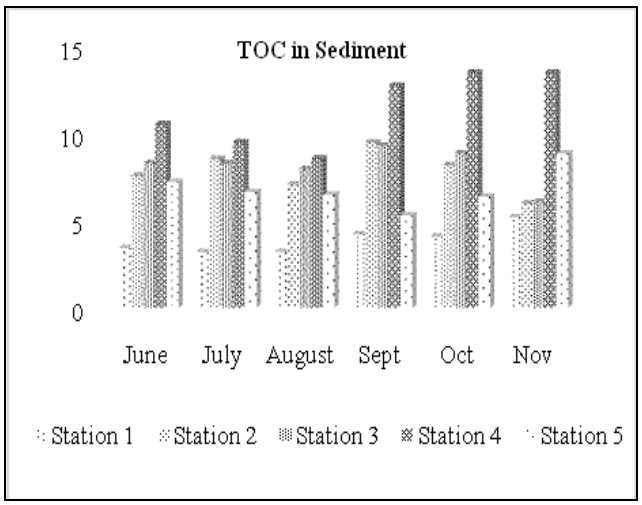

Figure 10: Spatiotemporal variations in sediment TOC.

Correlation analysis and the relationship between parameters

Tables 2 and 3 depict relationships among the investigated parameters. There were positive and significant relationships between most of the parameters. Correlation studies showed that DOC, DIC, and TOM were the principal determinants of the trends observed in most parameters. For water samples, DOC was positively and significantly correlated with DIC (p = 0.05; r = 0.96), TOM (p = 0.05; r = 099), and TIM (P = 0.05; r= 0.95). Dissolved inorganic carbon also exhibited a positive and significant correlation with TOC (P = 0.99; r = 0.99), TOM (p = 005; r = 0.94), and TIM (p = 0.05; r = 0.99). Additionally, a positive and significant relationship was found between TIM and TOC (p = 0.05; r = 0.73) and TOM (P = 0.05; 0.92). An outstanding feature of the results is the significant negative relationship between pH and all the surrogates of carbon. This observation aligns with the report of Wenxiang et al. (2019) that pH significantly influences TOC contents by controlling bioavailability of minerals, organic matter turnover and other sedimentary processes (Wenxiang et al., 2019). Furthermore, the solubility of organic matter is dictated by pH.

Table 2: Correlation coefficient for the parameters investigated in water samples.

Water	DOC ($MGCL^1$)	DIC ($MGCL^1$)	TOC ($MGCL^1$)	TOM ($MGCL^1$)	TIM ($MGCL^1$)	PH
DOC ($mgCL^1$)	1	–	–	–	–	–
DIC ($mgCL^1$)	0.96	1	–	–	–	–
TOC ($mgCL^1$)	0.08	0.99	1	–	–	–
TOM ($mgCL^1$)	0.99	0.94	0.003	1	–	–
TIM ($mgCL^1$)	0.95	0.99	0.73	0.92	1	–
pH	–0.6	–0.79	–0.66	–0.57	–0.83	1

In sediment samples, a slightly different trend was observed in the relationship and correlation analysis. While a significantly positive relationship was established between DOC and DIC (p = 0.05; r = 0.91), TOC (p = 0.05; r = 0.98), TOM (p = 0.05; r = 0.97), TIM (p = 0.05; r = 0.93), there was a significantly negative relationship between DIC and TOC (p = 0.05; r = –0.89) and TOM (p = 0.05; r = –0.83). Biomass, expressed in the forms of TWT and TSW of the benthic macrofauna, exhibited different relationships with non-animal parameters. Total weight demonstrated a significant negative relationship with parameters of organic carbon (DOC, TOC, TOM), and inorganic carbon (DIC and TIM). A similar trend was demonstrated between TSW and parameters of sediment.

Values recorded for TWT and TSW showed a significant positive correlation (p = 0.05; r = 0.64) in the area during the period of the study, indicating the importance of shell size in determining the size of tissue accommodated.

Table 3: Correlation coefficient for the parameters investigated in sediment sample.

Sediment	DOC ($mgCkg^{-1}$)	DIC ($mgCkg^{-1}$)	TOC ($mgCkg^{-1}$)	TOM ($mgCkg^{-1}$)	TIM ($mgCkg^{-1}$)	TWT (g)	TSW (g)
DOC ($mgCkg^{-1}$)	1	–	–	–	–	–	–
DIC ($mgCkg^{-1}$)	0.91	1	–	–	–	–	–
TOC ($mgCkg^{-1}$)	0.98	–0.89	1	–	–	–	–
TOM ($mgCkg^{-1}$)	0.97	–0.83	0.99	1	–	–	–
TIM ($mgCkg^{-1}$)	0.93	0.99	–0.9	0.84	1	–	–
TWT (g)	–0.61	0.77	–0.59	–0.51	0.78	1	–

Carbon sequestration and storage

From the parameters investigated, a total of 1.5 x 10^{-11} t C ha^{-1}, approximately 5.3 x 10^{-11} t CO_2 eq ha^{-1}, was sequestered and stored in the surface water of the lagoon during the study period. The contributions of the different parameters were as follows: DIC was 6.8 x 10^{-12} t C ha^{-1}, approximately 2.5 x 10^{-11} t CO_2 eq ha^{-1}; DOC was 1.7 X 10^{-15} t C ha^{-1}, approximately 6.3 x 10^{-15} t CO_2 eq ha^{-1} and TIM was 7.7 x 10^{-12} t C ha^{-1}, approximately 2.8 x 10^{-11} t CO_2 eq ha^{-1}. Others were TOM, which recorded 1.98 x 10^{-14} t C ha^{-1}, approximately 7.3 x 10^{-14} t CO_2 eq $ha^{-1}$and TOC which contributed a value of 9.8 x 10^{-15} t C ha^{-1}, approximately 6 x 10-^{14} t CO_2 eq ha^{-1}. Evaluation of the results indicates that, TIM (53%) and DIC (47%) were the major contributors to the carbon stock and sequestered CO_2 in surface water. Contributions by other parameters were negligible (Fig. 11).

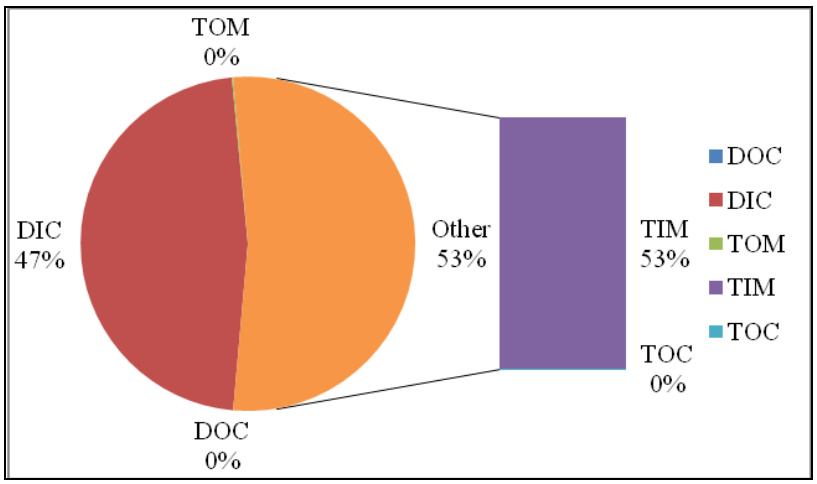

Figure 11: Percentage contribution of parameters of CO_2 sequestration and storage in surface water.

In sediment, the lagoon demonstrated a sequestration and storage potential of 5.8 x 10^{-7}t C ha^{-1}, approximately 2.13 x 10^{-6} t CO_2 eq ha^{-I}. Analysis shows that the biomass of the benthic species *Pachmylenia aurita* contributed the highest percentage of carbon stock and the sequestered 2.13 x 10^{-6} t CO_2 eq ha^{-I} recorded in sediment (Fig. 12). Specificlly, TWT contributed with 76% of the carbon stock and CO_2 sequestered carbon, and TWS contributed 24%. The contributions of DIC, DOC, TOM, TIM, and TOC were highly infinitesimal.

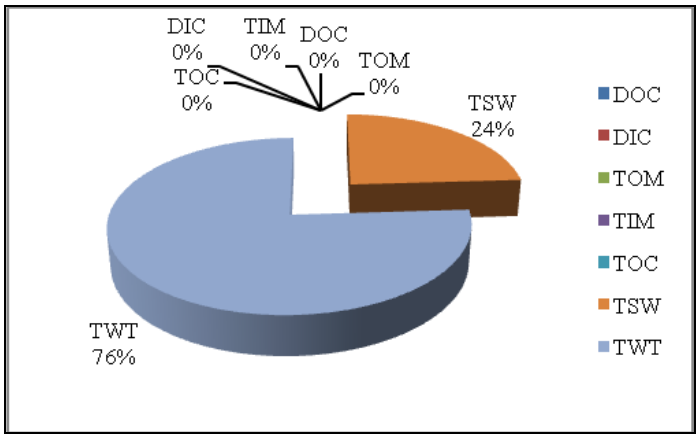

Figure 12: Percentage contribution to parameters of C to CO_2 sequestration and storage in sediment.

To the best of our knowledge, this is the first scientific study on the carbon sequestration potential of an aquatic system in Nigeria. Therefore, making comparisons with indigenous data from similar ecosystems to determine the performance of the studied ecosystem in carbon sequestration is difficult. However, the level of CO_2 sequestered in the study area is low when compared to levels recorded in relatively pristine environments (Santos et al., 2022). Although the Lagos Lagoon receives a lot of organic inputs from adjoining rivers, creeks, and runoffs, the ability of the system to accommodate and store these materials is hampered by the large-scale human activities taking place in the area, such as sand mining (Uwadiae and Felix, 2015). Other human activities including dumping of waste, boat transportation, bottom trawling, port activities, and diverse unsustainable environmental practices taking place in the lagoon may be blamable for the low CO_2 sequestration recorded. Based on Davidson and Janssens (2006), water column and sediment stability play a major role in supporting the storage of carbon in aquatic ecosystems. The low carbon sequestration recorded is expected due to the degraded nature of the area investigated.

The conditions necessary for the accumulation of carbon in water bodies include low water temperature and the predominance of fibrous vegetation (Davidson and Janssens, 2006). The rate of carbon accumulation depends largely on the quantity and quality of organic matter input. Other factors like altered salinity regime and extreme pH levels result in poor biomass production and reducion of organic matter. For example, the pH of aquatic systems is known to affect detrital formation. In a hgihly acidic or highly alkaline environment, the growing conditions for microorganisms are poor, resulting in low levels of biological oxidation of organic matter.

In the natural aquatic environment, without human disturbance, the biotic and abiotic components are in dynamic equilibrium (Yue et al., 2014). Organic matter in the aquatic system typically supports high biomass production and results in increased biological activity in the water column and at the sediment-water interface (Yue et al., 2014). Yang et al. (2021) and Yue et al. (2014) suggest that effective carbon sequestration and storage requires a rich cover of biofilm on the sediment-water interface. This biofilm, along with the sediment architecture, facilitates the capture and infiltration of water, protects the sediment, and supports decomposing organic matter, which provides an unbroken energy source for macro-, micro-, and meio-organisms. Additionally, well-aerated sediment at different depths allows effective

distribution of nutrients and active interaction with microorganisms. The major period of nutrient release by microorganisms coincides with the major period of nutrient demand by benthic biota, leading to nutrient recycling by benthic organisms. This equilibrium creates a closed-cycle circulation of nutrients between sediment and the biota, as well as the overlying water, resulting in almost perfect physico-chemical conditions for biotic development through the bentho-pelagic coupling process (Santos et al., 2022). On the other hand, in anthropogically perturbed systems, this equilibrium is disrupted due to the distortion created by the unregulated use of aquatic environments for various human needs.

In order to improve the capacity of aquatic ecosystems for climate change mitigation, the IPCC (2019) recommends two management approaches. These approaches include: 1) regulating anthropogenic activities and adopting actions that maintain the integrity of natural carbon stores, thereby decreasing their potential release of greenhouse gases, and 2) encouraging actions that enhance the long-term removal of greenhouse gases from the atmosphere by aquatic systems. This can be achieved primarily through biological means, enhancing the natural carbon uptake of some aquatic habitats. This includes increasing their spatial coverage through habitat restoration and new habitat creation, as well as implementing management measures to maximize the carbon uptake and storage for existing coastal ecosystems.

CONCLUSIONS

This study is an eye-opener and a major breakthrough in the quest for indigenous data for computations of carbon sequestration and stock accounting in the Nigerian aquatic ecosystems. However, the limited scope and extent covered create the need for a more comprehensive invesitagtion to understand the lagoon's full capacity for carbon sequestration and the roles played by various influencing factors.

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