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Blue Carbon Stocks in Coastal Wetlands as Eco-Friendly Means for Carbon Sequestration: Challenges, Mechanisms, and Prospects

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Abstract

Worldwide consensus on achieving a low-carbon environment has induced general sustainable goals of eradicating atmospheric carbon dioxide and decreasing carbon-based pollutant discharge by employing eco-friendly measures that will facilitate positive global climate change. Numerous wetlands including seagrass meadows, salt marshes and mangroves keep ecological balance by improving the quality of water, stabilizing the various shorelines, and keeping essential aquatic habitats. These various wetlands act as carbon sinks through improved greenhouse gas (GHG) flux. There is hence an increasing concern in understanding and managing the blue carbon stocks. The blue carbon trapped by the wetlands greatly affects the concentration of global greenhouse gas. An acclaimed remediation technique is by retaining the tidal exchange to keep coastal wetlands to uptake reduced methane gas emissions. Reports suggest that spatial variability varies in carbon dynamics probably as a result of the difference in the assembly of soil nutrient content, salt content, and other geomorphic parameters, these confer importance for the quantification of carbon stocks and accumulation rates. The objective of this paper is to give a comprehensive review of the blue carbon stock and GHG flux in coastal wetlands. An additional goal is to offer more light on the methodologies, and procedures of blue carbon stock assessment amid coastal wetland regeneration as an essential factor for the conservation of crucial coastal resources and anticipating future situations and prospects.

Keywords: Coastal wetland; Blue carbon; Ecosystems; Sequestration; Accumulation; Carbon sinks; GHG flux

Abbreviations

BCESs: Blue Carbon Ecosystems, CAR: Carbon Accumulation Rate, CH4: Methane, GA: Geographic Area, GHG: Green House Gas, GBR: Great Barrier Reefs, LGA: Local Government Area, MAT: Mean Annual Temperature, MAP: Mean Annual Precipitation, NRM: Natural Resource Management, Rcps: Representative Concentration Pathways, RSLRR: Relative Sea-Level Rise Rate, SLR: Sea-Level Rise, SOC: Soil Organic Carbon, TSM: Total Suspended Matters

Background

There is recently a global consensus on returning to a low-carbon environment [1]. This has induced global sustainable goals of eradicating atmospheric carbon dioxide and decreasing carbon-based pollutant discharge by employing eco-friendly measures that will facilitate positive global climate change [2,3]. An estimated half of the entire world's carbon dioxide gas is sequestrated in the ocean making ocean and coastal wetlands essential components in maintaining global ecosystem services and the carbon cycle [4]. Appreciable amounts of "blue carbons" are accumulating in particularly coastal wetland vegetation such as mangroves, seagrass, and salt marshes [4,5]. It is possible that "blue carbon" may be discharged into the environment, - under such instances, these ecosystems play vital roles in the land-sea carbon cycle.

The capacity for mutual conversion and carbon sequestration from a carbon source to a carbon sink displays dubiety and complexity resulting from coastal wetlands conferred with two-fold effects of conditions of the site and land cover [6,7]. Therefore, intelligibly defining the extent and depth of the sediment carbon pool in an ecosystem is paramount to surgically and convincingly quantifying the "blue carbon" stocks in the said ecosystem [5]. Yet, there's limited literature to support that assertion. The pressing need to name strategies that can mitigate global climate change has sparked a quantum leap in the number of studies in blue carbon research.

Assessment of blue carbon at the domestic, national and global levels to inform inventors of carbon and also equip policymakers and scientists with baseline knowledge needed to implement and monitor initiatives to offset blue carbon and their inclusion is important within nationally determined contributions [8]. Regardless, gathering a good estimate of carbon stock at the national and global levels is hampered by the variability in and within the largescale carbon stock at the domestic levels [9]. Furthermore, knowledge about carbon accounting and crediting schemes on the disturbances and/or restoration resulting from greenhouse gas (GHG) fluxes and carbon stocks hindering the involvement of the blue carbon ecosystem with carbon accounting is limited [10]. A large number of coastal wetlands have existed at their present locales for decades regardless of differences in sea-level rise (SLR) [11]. Yet current studies suggest that these wetlands may not be existent with the current rate of the global SLR [10].

Soil is the largest storage for coastal wetland carbon, utilizing dynamic interactions between the production of organic matter and inorganic minerals, their retention, supply, and preservation [12]. Accumulation of soil and carbon burial in the soil is facilitated by inorganic and organic sediments that may be sequestered in the locales made by rising seawater levels, hence, acting as carbon sinks by allowing a healthy ecosystem [13]. Large-scale hydrological deviations such as construction works and mosquito ditching, however, directly or indirectly regulate several coastal wetland systems thereby inducing ecological stress. Thus, organic matter production is lowered and the inorganic matter sediment impact is limited. Coastal wetland soils are known to have relative degradation and reduction with an increase in hydrological stress combined with the increased rise of sea level, thus leading to an overall loss of sequestrated carbon in the said habitat [11]. The preservation, regeneration, and long-term administration of coastal wetlands and their surrounding habitats and watersheds help to maintain and increase carbon sequestration [12].

Anthropogenic activities associated with climate change have led directly or indirectly to the depletion of almost half of the entire blue carbon ecosystems (BCESs) the world over [14]. A key factor to understand the earnestness of the issue is the destruction of coastal habitats and landscape change [15]. These changes lead to the release of soil-stored carbon back into the environment at a drastic rate. The maintenance of blue carbon has hence become an issue of great concern drawing the attention of both public and private institutions, researchers and lawmakers [16]. Anthropogenic activities continue to pose detrimental effects on the already vulnerable coastal wetland. But due to the great primary productivity, high carbon density and carbon stock potential of coastal wetlands, they are widely considered an ecologically friendly response to the reduction of carbon dioxide concentration in the environment and lighten climate change. In this paper, findings from various studies on blue carbon assessment are explored, the role of past and future carbon sequestration measures are reviewed, as well as exploring information and data from various studies to better understand ways of restoring, enhancing, and managing coastal wetland carbon services.

The methodology used – Review of published literature

Using the Web of Science (WoS), the reported publications in the area of "Blue Carbon Stocks in Coastal Wetlands" was searched. 145 manuscripts on the topic were published since 2014. Of these, 124 were published in the last half a decade making up 85.5 % of the total publications. Furthermore, 213 manuscripts were published in all databases since 2012. 177 of which were published in the last 5 years making up 83.1 % of all published research on the said topic (as shown in Figure 1 below). Using the WoS, the reported publications in the area of "Blue Carbon Stocks for Carbon Sequestration" have been searched. 302 manuscripts on the topic have been published since 2010. Of which, 250 have been published in the last 5 years making up 82.8 % of the total publications. Furthermore, 351 manuscripts were published in all databases since 2005. 233 of which were published in the last half a decade making up 66.4 % of all published research on the said topic (as shown in Figure 2 below).

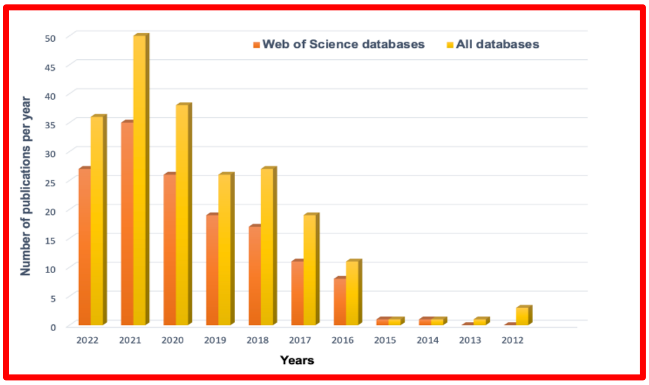

Figure 1: Historical evolution of published research on Blue Carbon Stocks in Coastal Wetlands in the Web of Science database (assessed on 10th January 2021; https://www.webofscience.com/wos/woscc/summary/d25608b7-de4d-4b71-8e48-c5070e157db4-744a2b01/relevance/1) and all databases (Web of Science, Chinese Science Citation Database℠, Derwent Innovations Index, KCI-Korean Journal Database and SciELO Citation Index) (assessed on 10th January2023; https://www.webofscience.com/wos/alldb/summary/911031f3-6d3b-4534-9614-57d9329d3b4f-744a579f/relevance/1.

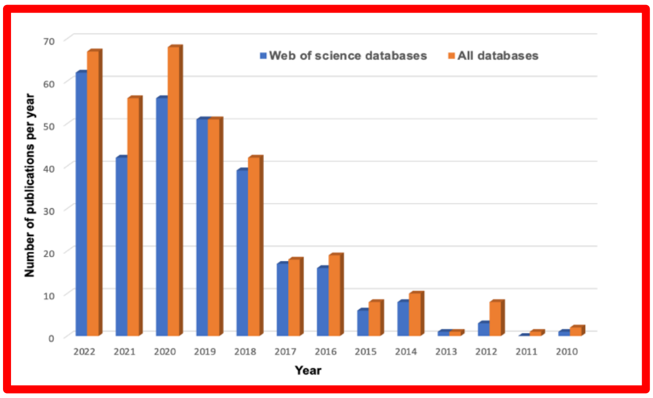

Figure 2: Historical evolution of published research on Blue Carbon Stocks for Carbon Sequestration in the Web of Science database (assessed on 20th January 2023; https://www.webofscience.com/wos/woscc/summary/16dff757-bf06-43bb-aad8-73b4ec146046-744a9f63/relevance/1) and all databases (Web of Science, Chinese Science Citation Database℠, Derwent Innovations Index, KCI-Korean Journal Database and SciELO Citation Index) (assessed on 20th January 2023; https://www.webofscience.com/wos/alldb/summary/ef9321e6-b918-41ce-9fb2-6ad6d6680552-744a7c7a/relevance/1).

Habitats dependant blue carbon stocks

Are ecosystems other than angiosperm habitat carbon-dominated ecosystems? this has Recently, researchers are seeking to investigate whether ecosystems other than angiosperm habitats are carbon-dominated ecosystems [17]. This led to a debate point as research progresses on the mangroves, seagrass, and tidal habitat for blue carbon stocks. Table 1 demonstrates the possible territory appropriate for mangrove and tidal marsh relocation by 2100 under representative concentration pathways (RCPs) 4.5 and 8.5, as well as the possible reward in soil organic carbon (SOC) stocks (Mg C) under future SLR circumstances for the whole Great barrier reefs (GBR) catchments, as well as each natural resource management (NRM), geographic area (GA) and local government area (LGA) [18]. Other questions are whether, in climate change mitigation, these other non-angiosperm habitats (e.g., coral reefs, and oyster reefs) can be controlled to aid in it and also, whether the outcomes could be realized through conservation with adaptable ramifications [19]. Calcifying organisms in their ecosystems, such as coral reefs, contribute to climate change adaptations through energy distribution and input to sediments, but not through GHG reduction. This is because the progress of calcification releases carbon dioxide gas making this ecosystem a net carbon dioxide source and not a sink [17,20].

Possible locations fit for mangrove and tidal marshes relocation by 2100 (ha)	**Likely increase of carbon gas (Mg C) - Representative Concentration Pathways (RCPs)**			
	4.50	**8.50**	**4.50**	**8.50**
Great barrier reefs (GBR) catchment	2832.00	4194.00	163,700.00	465,800.00
NRM regions	14.00	21.00	780.00	2,238.00
Burnett Mary Regional Group	16.00	20.0	980.00	2,390.00
Cape York Peninsula	1,843.00	2,742.00	102,648.00	294,007.00
Fitz Roy, Munich	837.00	1,256.00	51,260.00	148,625.00
Whitsunday Islands, Australia	47.00	68.00	2,878.00	8,046.00
Wet Tropics of Queensland	75.00	97.00	4,180.00	10,439.00
Regions of Bundaberg	13.40	17.20	821.00	2035.00
Region of Burdekin	4.20	6.00	134.00	656.00
Region of Cairns	9.30	12.20	527.00	1324.00
Cassowary Coast	20.2	27.8	1144	2992
Regions of Cook Shire	1733.00	2567.50	98.163.00	266.609.00
Main Douglas Shire Regions	39.30	46.60	2226.00	5059.00
Regions of Fraser Coast	2.50	2.90	153.00	343.00
Region of Gladstone	0.00	0.00	0.00	0.00
Regions of Hinchinbrook Shire	01.38	2.70	78.00	290.00
Hope Vale Aboriginal Regions	1.10	1.40	63.00	152.00
Region of the Isaac	11.70	17.30	704.00	2029.00
Region of Livingstone Shire	837.20	1256.50	50, 403.00	147,380.00
Region of Lockhart River Aboriginal	0.60	0.90	34.00	98.00
Region of Mackay	12.00	18.80	735.00.00	2244.00
Region of Northern Peninsula	0.20	0.30	11.00	32.00
Region of Rockhampton	0.00	0.00	0.00	0.00
Region of Torres Shire	118.20	177.40	6,583.00	18,924.00
Region of Townsville	1.05	1.30	58.00	140.00
Region of Whitsunday	31.40	45.50	1923.00	5384.00
Region of Wujal Wujal Aboriginal Shire	0.00	0.00	0.00	0.00
Region of Yarrabah Aboriginal Shire	0.00	0.00	0.00	0.00

Table 1: The possible locations fit for mangrove and tidal marshes movement 2100 under Representative Concentration Pathways (RCPs) 4.5 and 8.5 and the likely SOC stocks increases (Mg C) under imminent sea-level growth circumstances for the entire GBR catchments, and each natural resource management (NRM) region and local government area (LGA). Adapted from [51].

The viewpoint on organic matter sequestration by calcifying organisms in coral reefs may however be altered by future research [17]. Habitats concentrated by mobile marine fauna and phytoplankton like those in pelagic ecosystems have also been considered in recent research to be BCESs [12]. They are known to contribute to long-term carbon dioxide preservation, but it is uncertain how or if that contributes to global climate change mitigation. Phytoplankton on the other hand has seen great research and hence widely agreed upon to be a great contributor to climate change mitigation since the late 1900s post the first investigations into ocean fertilizers [21]. Phytoplankton biomass is produced by fertilizing the ocean surface with iron which then sinks to the thermocline [22]. It can be stored for thousands of years with controversial implications because of its large amounts in the form of fixed carbon deep in the sea with unintended consequences [21].

Tidal-influenced freshwater forests habitats such as the bald cypress forest and melaleuca forest are other coastal ecosystems of interest [17]. They used to contain huge soil carbon stocks which have recently been depleted. Other candidates for rich blue carbon sequestration are the sabkhas, which are inhabited by microbial mats in high inter-tidal salt flats [23]. Although the information on carbon stock and flux is limited now, these microbial mats are extensive in arid environments and are largely involved in blue carbon-based conservation for climate change adaptation [24]. Seaweed beds and some kelps are also considered BCESs. Seaweed aquaculture offers other opportunities for mitigation and adaptation of climate change other than covering wild kelp beds [25]. Fortifying scientific research on carbon storage and its management, and enactment of policy guidelines and regulations on the relevance of the various ecosystems in greenhouse accounting are the ways forward in the quest to include these habitats as blue carbon ecosystems [26].

Dynamics of global salt marshes and mangroves

The landscape positions in inter-tidal zones of salt marshes and mangroves share similarities with low-energy coastlines [27]. In mangrove habitats, most species are concentrated in tropical and subtropical areas with less temperature and aridity because they are constrained primarily by latitude [17]. By contrast, salt marshes are in tropical areas with arctic climates but in higher latitudes, and the extent of their aridity and diversity in species is greater [28]. Salt marshes and mangroves overlap in inter-tidal zones and form ecotonal communities. Recently, rapid, and global changes have been associated with the interface nature and location of mangroves and salt marshes [28,29] Such changes include an expansion of the extent of mangroves nearing the poles on all the continents (Africa, Asia, Australia, North/South America, New Zealand) where mangroves and salt marsh co-locate [30]. The pole-ward expansions result in the mangrove encroaching un-vegetated tidal flatlands and other fringe coastal vegetation [31]. Regardless of this localized expansion of mangrove habitats, on a global scale, there is a net decline of mangrove habitats due to issues like deforestation and primarily anthropogenic activities [32]. In recent decades, a decline in extreme weather (winter temperature) conditions have been identified as a primary influencer of the expansion and survival of mangrove in North America more than what can be predicted for loss associated with temperature changes alone [33]. The combined effects of interaction between mangrove and marsh species, and biological feedback such as increased resistance to frost damage might affect the distribution and expansion of mangrove and salt marsh habitats [33,34]. The functions of coastal wetlands can be strongly altered due to such changes conferring implications that may result in a reduction in human livelihood and environmental disarray [17]. Although there has been little assessment of the consequence of mangrove expansion on coastal wetland distribution and functions, there is a strong likelihood that the implications are dire.

Carbon sequestration in wetlands

Wetlands (seagrass, mangrove, and salt marsh), because of their exceptional capability to retain and store carbon has for centuries now been referred to as “blue carbon” habitats [35]. Table 2 summarizes the assessment of whether coastal ecosystems meet the Blue Carbon criteria. This ability of wetlands to accumulate carbon is identified based on three very vital points: the amount of carbon that they can retain - termed as carbon stocks, the measure of the rates of sequestration of carbon by the habitat - termed as accumulation rate and finally, the flux- which indicates the number of emissions leaving the said ecosystem [36]. In general cases, the potential for storage of carbon in ground biomass in the vegetation of woody mangroves is higher in comparison with that of herbaceous salt marshes. Also, in comparison with carbon buried in the soil, above-ground carbon storage has a shorter residency time as well as higher mean and maximum carbon stocks within the surface soils of mangrove habitats in comparison with that in salt marsh environments [17].

Coastal habitat	The extent of removals of greenhouse gas	Permanent sequestrate-on of CO_2	Unwanted anthropogenic environmental influences	Improvement of carbon storage and reduction of greenhouse gas via proper management	Social and/or environmental harm is not affected by measures	Positioning over numerous guidelines: justification and adaptation
Mangrove habitat	Yes	Yes	Yes	Yes	I	Yes
Salt flats (sabkhas)	I	I	Yes	I	I	I
Phytoplankton	Yes	I	I	I	I	No
Oyster reefs	No	I	Yes	No	Yes	Yes
Tidal marsh	Yes	Yes	Yes	Yes	I	Yes
Freshwater tidal forest	I	Yes	Yes	Yes	I	I
Coral reef	No	No	Yes	No	I	Yes
Mudflat habitats	I	I	Yes	I	Yes	Yes
Seagrass habitats	Yes	Yes	Yes	Yes	Yes	Yes
Macroalgae habitats	Yes	I	Yes	Yes	I	Yes
Marine fish habitat	No	No	Yes	No	I	No

*I = inconclusive

Table 2: Valuation of coastal habitats capacity as blue carbon sequestrates; criteria for induction as actionable blue carbon ecosystem. Adapted from [45].

As reported by a group, there is no great change in the mean rates of mangrove and salt marsh habitats because of variations [1]. These global findings have induced localized experimentation within coastline habitations targeted at the implications of the encroachment of carbon sequestration at local and smaller spatial scales. Such investigation is currently done at the Spartina alterniflora salt marsh in the United States [37]. It has been a pivoting state for most carbon encroachment sequestration studies to date. A surface soil carbon stock was detected in increasing levels at the created inter-tidal wetland in the Tampa Bay region, United States [38]. Doughty et al 2016 reported an enormous increase in carbon storage over a decade of encroachment [39]. Table 3 shows carbon dioxide and methane (CH4) emissions before and after tidal reinstatement for both high and low-raised spots, along with standard errors. Emissions were computed after tidal flooding (Nov–Jul) when a change in the surface bacterial community was discovered (Mar–Jul), and when rain was removed, event effects were assessed. The group documented that the phenomenon was driven by the increment of biomass above the ground [39]. The group's further attempts to describe changes in the carbon stocks below the land surface in the Southern parts of the United States have been fruitless probably due to the short period. Findings from experiments in the Nahoon Estuary in South Africa support said assessment, while mangrove marsh ecotone also reported the higher significance of the organic matter in transition areas [40]. Other research results from the afforestation of mangrove ecology indicate that when an area is given ample time for the establishment, it can increase its below-ground carbon stocks thereby increasing in function [17].

	Period	CO_2 gCm^{-2}y/r	CH_4 gCm^{-2}y/r	CO_2 gCm^{-2}y/r	CH_4 gCm^{-2}y/r
		High altitude		Low altitude	
All-weather conditions	Following that (Mar-Jul)	430.00: ±28.0	-1.92: ±0.08	-152.00: ±29.00	1.03: ±0.12
	Before (Aug-Nov)	420.00: ±22.00	-1.74: ±0.04	-57.00 ±31.00	-0.07: ±0.08
	Previously (Aug-Nov)	191.00: ±23.00	0.82: ±0.07	-94.00: ±32.00	2.40: ±0.08
Absence of rain	Following that (Mar-Jul)	522.00: ±28.00	-2.59±0.09	-217.00: ±27.00	0.67: ±0.01
	Previously (Aug-Nov)	420.00: ±23.00	-1.67: ±0.05	-63.00: ±32.00	-0.12: ±0.08
	Following that (Nov-Jul)	350.00: ±24.00	-0.65: ±0.07	-180.00: ±29.00	1.54: ±0.09

Table 3 shows carbon dioxide and CH4 emissions before and after tidal reinstatement for both high and low raise spots, along with standard errors. Emissions were computed after tidal flooding (Nov–Jul) when a change in the surface bacterial community was discovered (Mar–Jul), and when rain was removed, event effects were assessed. Adapted from [41].

To date, investigations have indicated that spatial variability varies in carbon dynamics probably as a result of the difference in the assembly, rainfall, soil nutrient content, salt content, and other geomorphic parameters [41]. These confer importance on the quantification of carbon stocks and accumulation rates. It is still not enough information to comfortably verify if atmospheric flux is altered by mangrove encroachment. BCESs and their sedimental carbon deposits are strongly affected by global climate change through a vast array of processes ranging from spatial and provisional scales [42]. The exposure, adaptive ability, and sensitivity of blue carbon to climate change make it vulnerable to the latter varying in effect from different ecosystems and within specific ecosystems based on their global distribution. The characteristic nature of specific ecosystems such as SLR invariability determines how climate change influences its blue carbon accumulation and loss both regionally and temporally [43]. In the mangrove ecosystem, droughts and storms are associated with subtropical latitudes more than in equatorial subregions. While saltmarshes are exposed to blue carbon mangrove altering sediment carbon storage [44]. At their lesser latitudinal restrictions, temperate seagrasses are shown to be marine heatwaves resulting in degradation and are more typical of tropical ecosystems [42]. The aptitude of an ecosystem to adapt to climate change, thereby reducing potential damage, maintaining carbon density, maintaining accumulated carbon stocks, fostering the advantageous utilization of opportunities, and continuing to sequester and accumulate blue carbon, thereby inhibiting the consequences, differs among ecosystems in different geomorphological locations [45]. Human encroachment and modification of virgin ecosystems play an intrinsic role in the adaptive capacity of ecosystems [40,44,45].

Lovelock and the group reported their findings on the stimulus of climate change on blue carbon sequestration at coastal wetlands [45]. The group did so by considering the exposure and sensitivity climate change confers on blue carbon capture and storage. Sea upsurge was foremost concentrated since it forms the foundational ramification for impacting composition and distribution in coastal ecologies and their carbon sediment deposits. Furthermore, the essence of changing temperature systems, ranging precipitation, and changing conditions at ocean surfaces also affect BCESs and were also investigated. Human developmental activities (like mining) especially those in coastal areas contribute to nutrient contamination and enhance negatively, climate change on blue carbon. An estimate of sea upsurge in blue carbon storage and how measures such as quality of data and policy can help mitigate climate change was made evident. Figure 3 illustrates the (A) worldwide blue carbon stocks, (B) sequestration of carbon at various ecosystems – indicating their prospective role in alleviating climate change and restoring blue carbon ecosystems, and (C) in comparison with other natural solutions. Coastal squeeze is found to be an essential means of maintaining salt marsh, mangrove, and seagrass ecosystems because of their capacity to sequester carbon, and other important services [36,39].

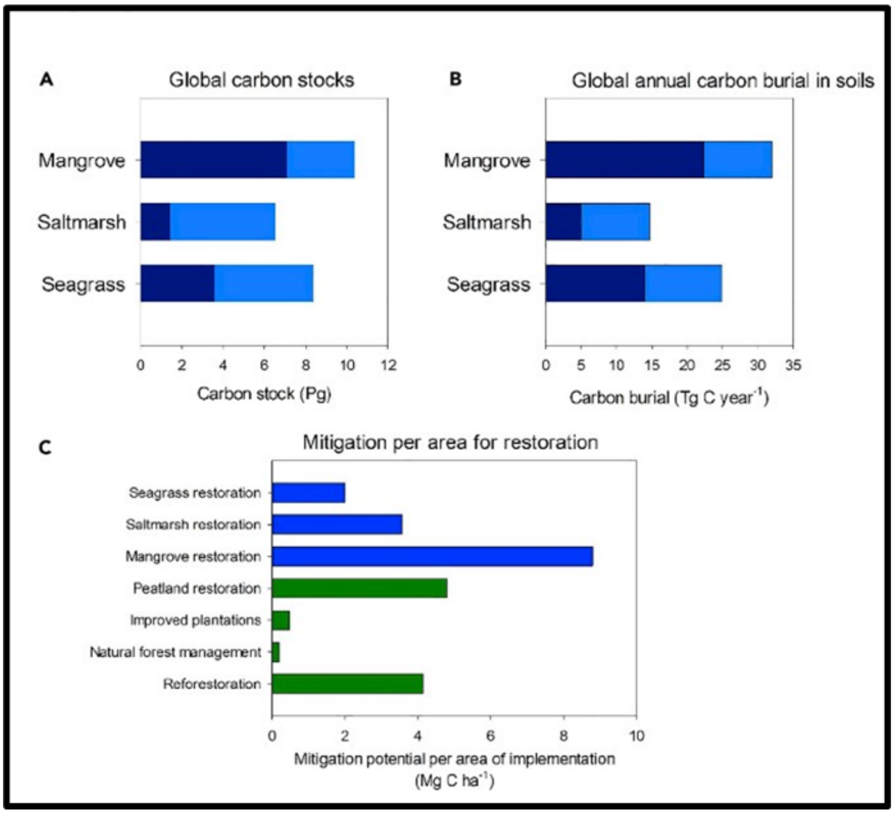

Figure 3: Worldwide blue carbon sequestration in various coastal wetlands. Adapted from [45].

Carbon accumulation rate (CAR) drivers

Drivers such as fluctuations in sea level and coastal geography are essential to increasing patterns of global blue carbon capture, sequestration, and storage [46]. These factors need to be maintained to secure future blue carbon stocks [47]. Most of the important BCESs (mangroves, salt marshes, seagrass, swamp forests, and salt marsh) are sited on coastal shorelines, exhibiting a great sloping landscape and with high sediment supply and high wave energy [48]. These macro-scale trends provide the low wave energy prerequisites for vegetation acquisition and expansion, as well as the conditions required for carbon sequestration [49]. Figure 4 shows the blue carbon stock drivers over an ecosystem. Blue carbon stocks in ecosystems (landscape) are yielded through the production of carbon and its storage. The rate of decomposition, disposal, and transfer is essential. Climate change threatens competing actions of degradation, eroding, and emigration, as well as the ecosystem's (green) area. It also covers those that are landscape properties (grey) and are modified by human guidance (orange).

The sequestration of coastal wetland carbon is driven by a variety of environmental and anthropogenic factors [50]. In the quest to determine the main factors that drive carbon sequestration, mean annual temperature (MAT), mean annual precipitation (MAP), tidal range, elevation, relative sea-level rise rate (RSLRR), total suspended matters (TSM), tropical cyclone frequency and numerous other climatic parameters were researched, targeting carbon accumulation in the salt tidal marsh and mangrove ecosystems [48,51]. In global and local sites, a comprehensive and robust dataset has been employed to determine the main drivers of carbon accumulation rates [52]. A mixed-effect model provided results indicating the detected main environmental factors on carbon build-up rates in the form of standard coefficients to indicate a proportional change in the carbon accumulation rates in response the e to the change in deviation of a driving factor [53]. This model showed no bias in the normal distribution, and it is a better fit for the observations recorded [17,54]. Using MAT and RSLRR in a linear mixed model, a covariate effect completely explained 51% of the variability in CAR in tidal marshes - this result was garnered following mode and regional field evidence. Further linking carbon accumulation with these environmental factors [49].

MAP and MAT were used to explain 57% of the carbon accumulation variation in mangrove habitats. Increasing temperature is known to increase plant yield, soil carbon stocks and soil surface elevation [55]. There is hence a positive relationship between mangrove carbon accumulation rates and temperature change [56]. In climatic mangrove regions, precipitation is demonstrated as another useful driver of soil carbon but not in tidal marshes especially in cooler regions [57]. In previous investigations, precipitation was found to control canopy height and regulates organic carbon decomposition by modifying the green gas supply to the soil [57].

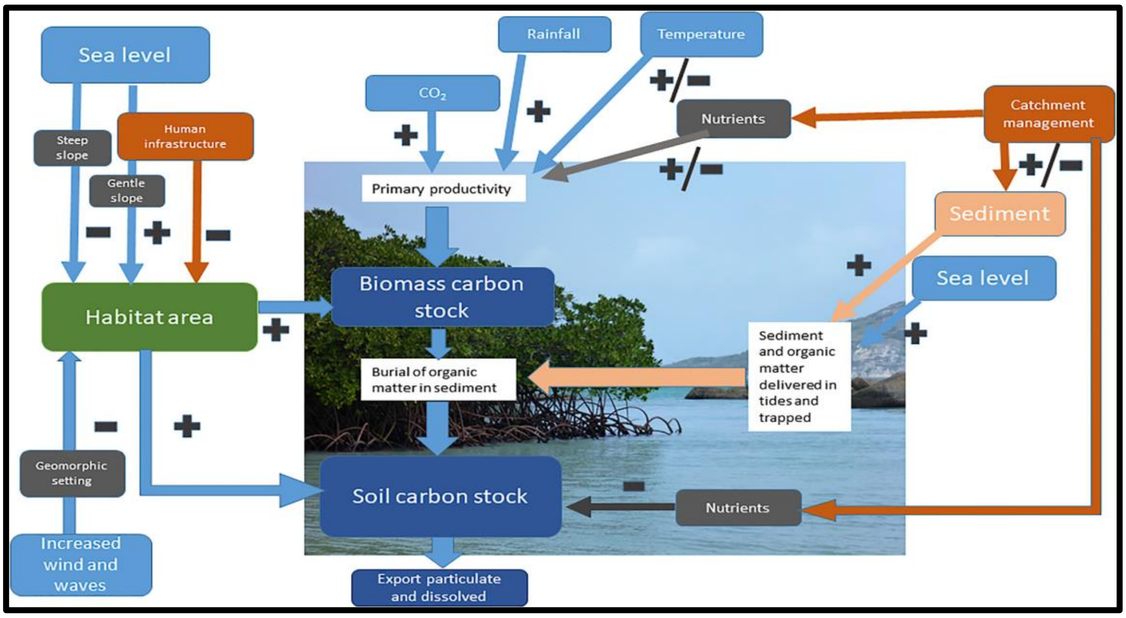

Figure 4: Blue carbon stock drivers over an ecosystem Adapted from [45].

Also, freshwater and nutrients are provided by precipitation to plants to increase productivity and growth [58]. Hence, in tropical coastal habitats especially, the rise in carbon accumulation is proportional to an increase in precipitation and should influence the mangrove carbon accumulation system in the Indo-Pacific and tropical South American regions [57,59]. Other localized environmental factors such as marsh altitude, tidal range, and tropical storm frequency are also important influences on carbon build-up rates in coastal wetlands (Illustrated by Figure 5) [60].

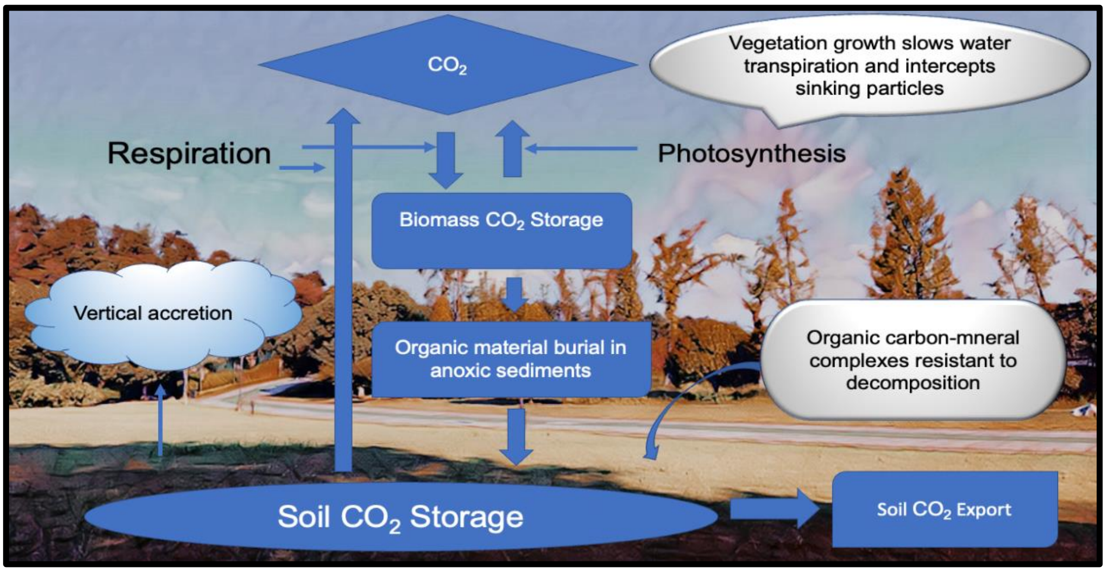

Figure 5: The mechanisms of carbon accumulation contributing to blue carbon sequestration and carbon accumulation rates.

Capacity of natural ecology for environmental sequestration

The capacity of the natural ecological environment to sequester and save atmospheric carbon dioxide gas is gaining elevated interest owing to the quest to adopt an efficient means of curtailing the consequences of climate change (as shown by Figure 6). Salt marshes, mangroves, seagrass, meadows, and others have received significant attention for their characteristic properties for eco-friendly CO2 trapping and storage. Management activities and their relevance in atmospheric carbon stock and GHG flux in the blue carbon ecosystem have attracted little attention despite numerous studies reporting the mechanisms involved in blue carbon flux. Hence, several researchers performed a meta-analyzed 111 studies worldwide and reported their measured atmospheric carbon stocks and GHG fluxes in natural blue carbon environments, and numerous strategies for managing coastal areas, indicating that sediment manipulation strategies, replenishment, and reformed hydrological strategies demonstrate a capacity for a positive effect on the sequestration of BCESs owing to the enhancement of numerous carbon gas matrixes. The experiment further unveiled the consequences carbon stock matrices have on the blue carbon ecosystems, in changes in the land activities affecting biomass, soil sedimentation, and its hydrology. Finally, the meta-experimentation revealed using empirical and robust data, the low number of management reports.

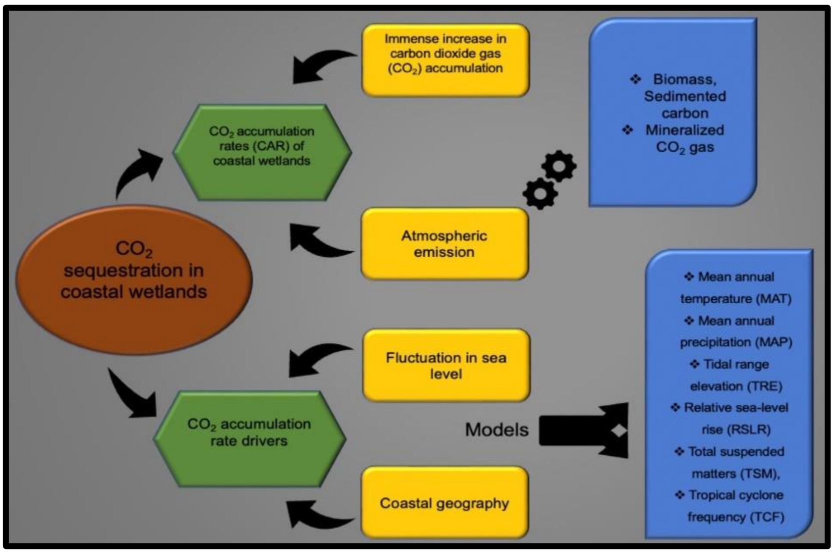

Figure 6: Illustrations of the mechanism leading to carbon dioxide (CO2) sequestrations.

Recently, tremendous efforts have been focused on restoration strategies, leading to great strides in blue carbon ecosystems. In the assessment of carbon stock in blue carbon ecosystems, biomass and soil carbon are the essential parameters used, owing to the advantage current strategies have in the form of effortlessness and limited technical pieces of equipment in comparison with GHG flux and sequestration rates. However, the reliability and efficiency of this strategy are still under debate among researchers because of their overreliance on estimates of carbon stock data and also the doubts surrounding sampling design, processing, and special variation. The concentration of blue carbon stocks in coastal wetland were comprehensively investigated to define the carbon sources of numerous anthropogenic and natural processes that emit carbon dioxide into the atmosphere. Also, the sequestration of carbon dioxide from carbon sinks was researched comprehensively. Natural landscape transformation to artificial wetlands is the most urgent change to carbon storage leading to much higher carbon density in natural wetlands than in artificial wetlands. On the other hand, the conversion of artificial landscapes to natural and other land types is characterized as a carbon sink. Ergo, the monitoring of carbon emissions in response to land reclamation is made possible by identifying carbon sources and sinks and quantifying the carbon concentrations.

Conclusion

The irreversible decrease in carbon accumulation rates and essence blue carbon stocks in coastal wetland ecosystems is a routine result of the reclamation of natural wetlands due to the rapid urbanization of coastal environments. In the last two and a half decades, land reclamation has led to a decrease in blue carbon concentration in coastal wetlands leading to a great and drastic disruption of ecological services and carbon loss. National coastal wetland habitats converted to artificial wetlands resulting from land reclamation is the single most influential change with the tendency of causing the net decline in carbon storage. We suggest that the incline of artificial wetlands and the decline in the natural wetland is the main concern of carbon emission in land reclamation areas. To ensure proper sequestering and storage of blue carbon and reduction of carbon dioxide emission into the atmosphere, adequate rules and guidelines for the development and operation of anthropogenic processes and procedures must be laid down. Coastal wetlands must also have proper management and laid-down plans must be followed to the latter to safeguard ecosystem services. It is further recommended that a specific detection of carbon loss from wetland use should be cooperated (as well as others like sea-level rise) into the criteria for studying and enacting readiness policies. The use of blue carbon change estimates under coastal wetland reclamation is also advocated as an important consideration for the protection of critical coastal resources and for predicting future scenarios.

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Author contributions

Eliasu Issaka: Conceptualization, Investigation, Data Curation, Resources, Validation, Formal analysis, Writing-Original Draft, Writing-Review and Editing, Supervision, Resources; Mabruk Adams: Writing-Original Draft, Validation, Formal analysis, Writing-Review and Editing;

Jesse Nii Okai Amu-Darko: Resources, Methodology, Data Curation, Resources, Writing-Review and Editing, Writing-Review and Editing.

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Declaration of competing interest

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