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Review Assessment of Carbon Sequestration Potential of Different Wetlands Site in India

Ashish Shukla* and Satyendra Nath
Department of Environmental Science and Natural Resource Management,
SHUATS, Prayagraj (Uttar Pradesh), India.

(Corresponding author: Ashish Shukla)*
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ABSTRACT: The capacity of wetland ecosystems to absorb and store carbon is exceedingly beneficial to the environment. The net uptake fluxes of both forest and non-forest environments can be calculated by eliminating photosynthesis from oxidation. The regrowth of forests and the use of timber products made the biggest contribution to the net absorption of CO_2. Non-forest ecosystems, such as vegetation and agricultural soils, as well as wetlands, rivers, and reservoirs, absorb a lesser and less certain amount of carbon. The effects of ocean acidification and ocean fertilization on coastal and marine food webs, in addition to their effects on other resources, are poorly understood. On significant habitats, the effects of diverse carbon sequestration methods (including geology sequestration, ocean sequestration, and terrestrial sequestration) were investigated. In this study, we examined the carbon sequestration that occurs in a diversity of wetland ecosystems and identified the potential of such sequestrations. Depending on the type of wetland habitat, the capacity for carbon sequestration fluctuates, making wetland ecosystems a valuable carbon sequestration resource.

Keywords: carbon, sequestration, wetlands, harvest, ecosystem.

INTRODUCTION

Wetlands are one-of-a kind ecosystems that can be found in nature, and they offer a wide variety of important services to the human community. Wetlands serve an important ecological purpose and contribute to the mitigation of the negative impacts of global warming on the surrounding environment because of the carbon that is absorbed by and stored within their sediments (Bridgham *et al.,* 2008). However, the capacity and effectiveness of various types of wetlands can vary greatly depending on the nature of the wetland as well as its hydrology, biogeochemistry, meteorological conditions, and a vast variety of other elements (Nag *et al.,* 2023).

Wetlands offer a wide variety of beneficial ecological and economic services, such as water resources for irrigation, aquaculture, and fisheries; food control; preventing soil erosion; natural remediation of water pollution; a repository of biodiversity; eco-tourism; and a source of income (De Groot *et al.,* 2012; McInnes, 2013). These services are provided by wetlands (De Groot *et al.,* 2012; McInnes, 2013). These services not only help people make a living but also contribute to the preservation of the environment. The existence of wetland habitats makes the biogeochemical cycling of nutrients, most notably carbon (C), significantly easier. According to de Groot *et al*. (2012), depending on how biogeochemical processes and hydrology interact, these resources may either net-sequester or net-emit carbon.

According to research carried out by Pant *et al*. (2003), the net primary production of ecosystems that are comprised of freshwater wetlands is significantly higher than that of other terrestrial ecosystems, even those comprised of tropical forests.

According to Mitsch and Gooselink (2015), the greater carbon store in wetland soils compared to other terrestrial locations is a result of higher primary production and diminished breakdown of organic matter due to the anaerobic conditions that are prevalent in wetland habitats. Gorham (1991) estimates that the various varieties of wetland contain between 350 and 535 g/t of carbon, which is equivalent to approximately 20–25% of the organic soil C found across the globe. According to Bernal and Mitsch (2008), the carbon concentration at a depth of 35 cm in five natural habitats in Ohio (United States) and Costa Rica ranged from 58 to 349 mg/ha. This carbon concentration was significantly higher than that of the reference upland site. Mitra *et al*. (2005) found that the carbon density of the top 100 cm of soil in a diversity of wetland types, including peatlands, ranged from 375 to 710 mg/ha. This spectrum included peatlands.

In contrast, wetland sediments serve as long-term carbon reservoirs, whereas plants, animals, microorganisms, and fungi only serve as short-term carbon reservoirs. According to Hanson & Hanson (1996), wetland soil normally is fully saturated, located well below the water table and this wetland condition creates anaerobic (anoxic) soil, which can store carbon dioxide and release methane by decreasing the decomposition rate. Bernal & Mitsch (2012) also agreed on this and stated that wetland ecosystems are so productive that they are capable to generate large amounts of organic matter and store it in semi-decomposed state due to the anaerobic condition. Characteristics such as high productivity, high water table, and low decomposition rate related to a wetland lead to carbon storage in the soil, sediment and detritus (Whitting & Chanton 2011). Wetland ecosystems store approximately one-third of the 450 petagrams (Pg) of carbon that can be found in soils, according to Roulet (2000) ; Mitsch and Gosselink (2007). The quantity of carbon sequestered in the soils of wetland ecosystems is proportional to the ratio of various inputs to outputs (decomposition and erosion). The two fundamental categories of inputs are the amount of organic matter created in-situ, also known as primary production, and the amount of organic matter received ex-situ, also known as dissolved and particulate organic matter through inflow and precipitation. The quantity of in-situ organic matter formation is also known as primary production. The principal type of output is gaseous refuse emission, and the primary contributors to this emission are decomposition of stored organic matter, respiration of aquatic biota, erosion of organic matter, and discharge of organic matter. Wetland type and ecology, vegetation, topography, hydrology, soil type, catchment area, depth, climate, and management practices are among the most significant factors that influence the inputs and outputs of organic matter in wetlands (Anderson *et al.,* 2009; Bills *et al*., 2010; Boyd *et al.,* 2010; Mitsch 2016; Wang *et al*., 2014a, b).

CARBON SEQUESTRATION

"Carbon sequestration" refers to the process of removing carbon dioxide from the atmosphere or redirecting it away from emission sources and depositing it in the ocean, terrestrial habitats (vegetation, soils, and sediments), and geologic formations. This can be accomplished by either extracting carbon dioxide from the atmosphere or redirecting it away from emission sources. The phrase "carbon dioxide removal from the atmosphere" can be applied to both natural and artificial methods of removing carbon dioxide from the atmosphere. Prior to the advent of CO_2 emissions caused by humans, the natural processes that now comprise the global "carbon cycle" (figure 1) maintained a balance between the amount of CO_2 that was taken in and the amount that was released back into the atmosphere.

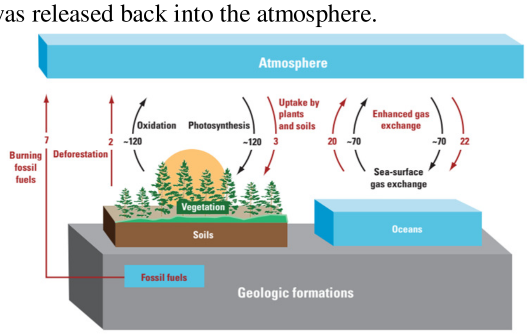

Fig. 1. The global carbon cycle (Bridgham *et al*., 2008).

However, the systems that are already in place to absorb CO_2, which are usually referred to as "sinks" for either carbon or CO_2, are not sufficient to compensate for the escalating rate of emissions that are generated by human activity. In the United States, the burning of fossil fuels leads to annual carbon emissions of around 1.6 gigatons (billion metric tons), but annual absorption levels are only approximately 0.5 gigatons, which results in a net annual release of approximately 1.1 gigatons (Fig. 2) of carbon dioxide. Active mitigation measures, employing a strategy that combines a reduction in emissions with an increase in storage capacity, will be required in order to bring CO_2 levels in the atmosphere under control so that they can be brought under control by active mitigation measures.

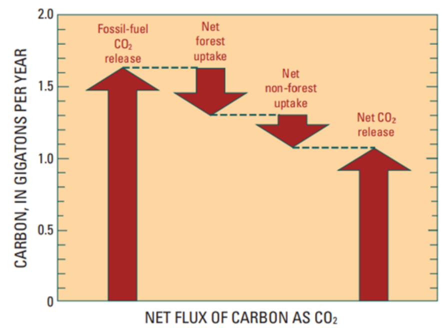

Fig. 2. Estimated annual net CO_2 (Bridgham *et al*., 2008).

Terrestrial sequestration, also referred to as "biological sequestration," is typically achieved through forest and soil conservation practices. These practices either increase the amount of carbon that can be stored (by restoring and establishing new forests, wetlands, and grasslands) or reduce the amount of carbon dioxide that can be emitted (by reducing agricultural tillage and suppressing wildfires). The sequestration process is an organic event that occurs over time. In the United States of America, these methods are routinely employed to accomplish a variety of land management objectives. When making decisions regarding the terrestrial sequestration of carbon, it is essential to carefully weigh the relative significance of a variety of resources. For example, converting farmland to forests or wetlands may increase carbon sequestration, improve wildlife habitat and water quality, and increase flood storage and recreational opportunities; however, the loss of farmland would reduce the amount of food that could be produced. The conversion of existing conservation lands to intensive farming may result in the production of profitable crops (such as those used to produce biofuels), but it also has the potential to destroy wildlife habitat, degrade water quality and supply, and increase carbon emissions (Lukas, 2022).

Researchers are attempting to determine the effects that changes in climate and land use have on the potential for carbon sequestration and the benefits that ecosystems can offer, as well as disseminate information about these effects for use in resource planning. Another naturally occurring mechanism that can be used to store carbon is ocean sequestration. Carbon is accumulated annually in the ocean at a rate of approximately 38,000 gigatons (Gt) (Houghton and Nassikas 2017). A gigaton is equivalent to a billion tons. Marine organisms consume plankton, resulting in the incorporation of carbon into the marine ecosystem. Marine organisms ultimately perish and sink to the ocean floor, where they decompose and store carbon in the accumulating sediment layers. Carbon molecules are believed to have resided in deep ocean detritus for at least 3,800 years, preventing them from exchanging with the atmosphere for millennia. This is because the residence period of the deep ocean is approximately 3,800 years.

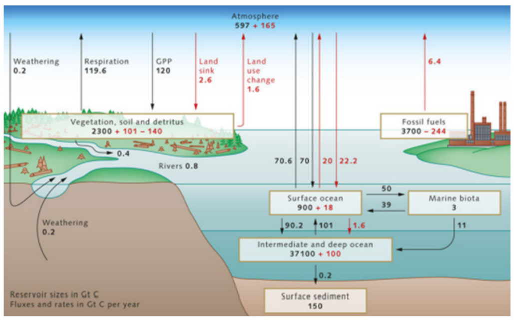

Fig. 3. Ocean Sequestration, Source (Lukas, 2022).

When sperm whales consume their meal, they bring iron from the depths of the ocean to the surface, where it is deposited as floating iron-rich particles in the surface waters. This stimulates the growth of phytoplankton, which in turn absorbs more carbon from the air and follows the biological pathway that leads to sedimentation.

Geologic carbon sequestration. The initial stage of geologic sequestration is the removal of carbon dioxide (CO_2) from the atmosphere via the emissions of fossil fuel power plants and other significant sources (Sundquist *et al.,* 2008). It is a human strategy. The gathered carbon dioxide is then injected into porous rock formations through a tube located between one and four kilometres below the earth's surface (Fig. 3). Currently, geologic sequestration is only used to store small annual quantities of carbon, especially when compared to the rates of terrestrial carbon uptake shown in Fig. 1 and 2. It is anticipated that much higher rates of carbon sequestration will be necessary to maximize the potential permanence and storage capacity of geologic storage. Long-term CO_2 storage in geologic reservoirs is dependent on the efficacy of various CO_2 capture techniques. After carbon dioxide is injected into the earth, the gas will rise due to its buoyancy until it encounters an impermeable barrier, also known as a seal (USGS, 2008).

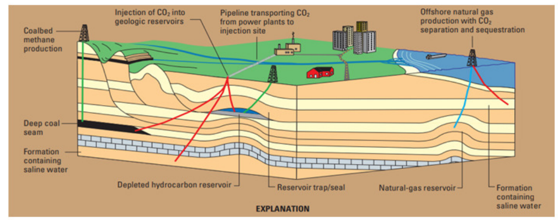

Fig. 4. Types of geologic CO_2 sequestration source (http://serc.carleton.edu.).

It is possible for this physical trapping mechanism, which is the same as the natural geologic entrapment of oil and gas, to store carbon dioxide for thousands to millions of years in the future. This is the case due to the fact that the two mechanisms are exactly the same. Some of the infused carbon dioxide may eventually be dissolved in the groundwater, while others may be preserved in the form of carbonate minerals generated by chemical reactions with the rock in the surrounding area. After the CO_2 was released into the atmosphere, each of these processes almost certainly went through a series of changes over time. The long-term viability of a variety of approaches for the sequestration of carbon dioxide is now being investigated by researchers, and researchers are also developing methodologies to evaluate the possibility that geologically stored CO_2 will be released into the atmosphere.

Table 1: Carbon Sequestration and Potential.

Carbon Sequestration Area Covered By Wetlands In India					
State	**Wetlands**	**Number of Wetlands**	**Area (Ha)**	**Carbon Seqestration Potential**	**REFERENCES**
Gujarat	Khijadia Wildlife Sanctuary	4	1270875	8.116 million ton	Pandey and Pandey (2013)
Karnataka	Ranganathituu BS	1	4250	2.5–7.5 t/ha	Ramachandra *et al.* (2022)
Kerela	Asthamudi Wetland Sasthamkotta Lake Vembanad Kol Wetland	3	213229	139.82 t/ha,	Harishma *et al.* (2020)
Uttar Pradesh	Bakhira Wildlife Sanctuary Haiderpur Wetland Nawabganj Bird Sanctuary Parvati Agra Bird Sanctuary Saman Bird Sanctuary Samaspur Bird Sanctuary Sandi Bird Sanctuary Sarsai Nawar Jheel SurSarovar Upper ganga river	10	12083	6977 tonnes per hectare.	Singh *et al.* (2022)
West Bengal	Sunderbans Wetland East Kolkata Wetlands	2	553090	48.53 to 143.17 Mg/ha	Nag *et al.* (2022)

Potential of Carbon Sequestration. It is anticipated that substantial adjustments in energy sources and consumption, as well as carbon management, will be necessary to stabilize atmospheric CO_2 concentrations. It is highly probable that a number of these shifts will have substantial and enduring effects on the land, water, and ecosystem resources. Continue the company's long-standing practice of disseminating accurate and objective scientific information to aid in the management of natural resources involved in carbon sequestration (including all types of carbon sequestration, such as natural or human sequestration), which has varying levels of potential, as illustrated in Fig. 5.

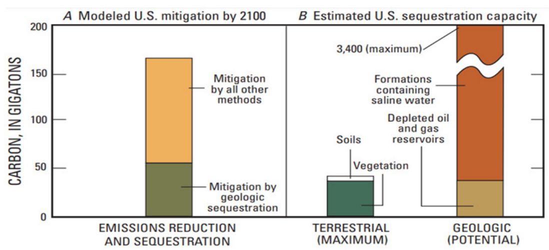

Fig. 5. Carbon Sequestration Potential source (pubs.usgc.gov).

The capacity for carbon sequestration varies considerably between wetland types. In countries with a high population density, such as India, there is a limit on the quantity of land that can be converted into forests. Agroforestry, on the other hand, is the cultivation of trees and vegetation on agricultural land to increase the proportion of land covered by trees (Chavan *et al*., 2015). According to Ajit *et al.* (2017), this practice is still prevalent throughout the majority of India, particularly in Rajasthan, Gujarat, and Maharashtra. In the Indian state of Rajasthan, it is a time-honored practice to protect young trees and ensure that they remain erect, both in agricultural areas and in pastures. It was estimated that the current agroforestry systems in India could store an average of 25 mega-grams of carbon per hectare and that these systems cover 96 million hectares. As per Table 1, we have explored the potential of the carbon sequestration and hence state-wise potential has been described below:

Kerala. There are three wetland areas in Kerala, with a total area of 2,132,29 hectares (ha) and an annual carbon sequestration rate of 139.82 t/ha. Mangroves are crucial carbon sinks in the tropics, and their role in mitigating climate change is well documented on a global scale. However, the carbon stocks of mangrove ecosystems in India have not been extensively studied. There is insufficient data from this region to provide sufficient insights and an accurate assessment of regional carbon stocks. This research assessed the ecosystem carbon stock and its spatial variation in the mangroves of Kerala, India's southeastern coast (Harishma *et al.,* 2020).

The average amount of biomass stored in the mangrove vegetation of Kerala is 117, 11 1.02 t/ha (ABG = 80,22 0.80, BGB =36,89 0.02 t/ha). Within the studied area, six species of mangroves were identified. Avicennia marina possessed the highest biomass (162,18 t/ha), whereas Sonneratia alba possessed the lowest biomass (0.61 t/ha). The estimated mean ecosystem carbon stock of mangrove systems in Kerala is 139.82 t/ha, or 513.13 t CO_2 equivalents per hectare, with vegetation and sediment accumulating 58.56 t/ha and 81.26 t/ha, respectively.

West Bengal. There are two wetland areas in West Bengal with a total area of 5,530,090 hectares (ha) and annual carbon sequestration ranging from 48.53 to 143.17 Mg/ha. As a result of their capacity to accumulate and store carbon in their soils, wetland soils provide a substantial ecological benefit. Therefore, they contribute to the reduction of climate change caused by global warming. However, the capability and efficacy of the various types of wetland differ greatly based on the wetland's hydrology, biogeochemistry, meteorological conditions, and a vast number of other variables. In this investigation, we examined carbon accumulation and sequestration in three distinct wetland habitats in the Indian state of West Bengal. These ecosystems comprised a lake fed by effluent and two oxbow lakes in a floodplain. Agricultural runoff, primary productivity, macrophyte coverage, and fisheries are among the ecological regimes that differ between wetland types. In addition, there are distinctions in water volume, depth, link channel, and macrophyte cover. The rate of carbon storage in marsh locations was significantly greater than that of upland sites, which ranged from 48.53 to 143.17 Mg/ha at 30 cm soil depth. In the floodplain wetland, the difference was significantly greater. Therefore, the findings of the study demonstrated that wetland carbon sinks are superior to similar reference sites and that the potential for carbon sequestration fluctuates depending on the type of wetland. The quantity of carbon stored in wetland ecosystems was also found to be positively correlated with the proportion of macrophytes present (Nag *et al*., 2022).

Karnataka. Microalgae are photosynthetic microorganisms sequestering carbon during photosynthesis in the presence of solar energy, converting to carbohydrates and oxygen (Asulabha *et al.,* 2018; 2022). Microalgae biomass is composed of carbohydrates, lipids, and proteins has been widely used in industries to produce fuel (biodiesel, bioethanol, methane, biobutanol, and biogas), feed (spirulina, and chlorella powder), biofertilizers, and medicines (pharmaceuticals and nutraceuticals). Select microalgal species are rich in proteins and produce proteins of 2.5–7.5 tonnes per hectare per year (Khan *et al.,* 2018a). The provisioning services provided by microalgae from wetlands accounts to INR110,467 per hectare per year (Ramachandra *et al.,* 2022).

Karnataka has one wetland of 4250 HA and 2.5–7.5 t/ha of carbon sequestration per year. Microalgae convert carbon into carbohydrates and oxygen during photosynthesis (Asulabha *et al*., 2018; 2022). Microalgae biomass, made of carbohydrates, lipids, and proteins, is utilized in businesses to make fuel (biodiesel, bioethanol, methane, biobutanol, and biogas), feed (spirulina and chlorella powder), biofertilizers, and pharmaceuticals and nutraceuticals. Protein-rich microalgae generate 2.5–7.5 metric tons per hectare per year (Khan *et al*., 2018a). Wetland microalgae provide INR 110,467 per hectare per year.

Uttar Pradesh. In Uttar Pradesh, there are only 10 wetland areas with a total area of 12083 hectares (HA), and the annual carbon sequestration from this state is 6,977 t/ha. Urbanization is responsible for global climate change, rising sea levels, an increase in floods and droughts, and a decline in human well-being. 68% of the world's population will reside in urban areas by 2050, harming the environment. Urban areas are the primary source of carbon emissions caused by human activities such as heating homes and vehicles. Urban trees have a high potential for carbon sequestration. However, few studies have quantified the carbon stock of urban vegetation. To effectively manage regional carbon stocks, it is necessary to quantify the urban tree cover carbon sequestration. In Varanasi, we investigate tree-based carbon dioxide sequestration. Our study found that above- and below-ground biomass sequestered an average of 6,977 metric tons of carbon dioxide per hectare and contained an average of 1,901 metric tons of carbon per hectare. This suggests that urban tree plantings can store carbon produced by humans locally and for an extended period of time. Expand urban green cover and plant fast-growing native species to increase carbon dioxide sequestration (Singh *et al.*, 2022).

Gujarat. There are just four wetland areas in Gujarat, covering a total area of 1270875 hectares (HA), and the state as a whole is responsible for an annual carbon sequestration total of 8.116 million tons. With a total area of 1058 square kilometers, Gujarat possesses the mangrove cover that is the second greatest in the country. The substantial significance that mangroves play as carbon sinks in coastal areas can be attributed to the fact that they are largely made of woody ecosystems. The latest study looked into the mangroves of Gujarat to determine how effective they were at absorbing carbon dioxide. In conjunction with stratified random sampling, various methods of tree harvesting were used in order to provide an accurate assessment of the total biomass (both above and below ground). This was done so that the researchers could make informed decisions. In addition to that, the carbon that was stored in the soil (up to a depth of thirty centimeters) was analyzed as well. The mangrove forests of Gujarat have been responsible for the sequestration of a total of 8.116 million metric tons of carbon during the course of their existence. When it comes to the entire process of carbon sequestration, the contribution that mangrove soils contribute is far greater than that of mangrove plants Pandey and Pandey (2013).

CONCLUSIONS

This study analysed and discussed the potential for carbon sequestration in various wetland-use systems. To attain this objective, each sequesters potential was investigated. It is feasible for this physical trapping technique, which is the same as the natural geologic entrapment of oil and gas, to store carbon dioxide for thousands to millions of years into the future. This might be a significant step in mitigating the effects of climate change. This is the case because the two systems are indistinguishable from one another in any respect. Some of the infused carbon dioxide may eventually be dissolved in the groundwater, while others may be stored in the form of carbonate minerals created by chemical reactions with the rock in the surrounding area. These reactions may take place over time. Following the emission of carbon dioxide into the atmosphere, each of these processes probably underwent a series of shifts over the course of some amount of time. Researchers are currently investigating the long-term viability of a range of technologies for the sequestration of carbon dioxide. In addition, researchers are creating methodologies to evaluate the chance that CO_2 that has been geologically stored will be released into the atmosphere.

FUTURE SCOPE

Global warming, which causes climate change, poses a serious threat to the world. Due to anthropogenic activities especially urbanization leads to degrading the carbon sequestration capacity of other land use patterns so it is important to conserve and highlight an alternative *i.e.* wetlands. Wetlands are also called kidney of Earth because of their filtration and carbon sequestration function. Wetlands have immense potential to store atmospheric carbon in biomass, soil and other forms with this it also enhance the biodiversity cover of the area. Covering all the advantage and functioning it can be concluding that enhancing and conserving all types of wetlands can mitigate the climate change effects. There is a great uncertainty in finding the C sequestration potential of different wetlands system in India due to which we are unable to get actual statistics for conserving them. So we need to do some ground check experiments to remove all the uncertainty with great extent. More investigating studies are required to evaluate the activities to promote wetlands ecosystem services especially carbon sequestration. This is not in the hand of single person it require a collaborative efforts of all the stake holders, local people and one who are directly and indirectly got affected by implementation of wetland management decision. There is a huge gap between review and actual practice so it an alarming time to bridge the gaps and enhancing the areas of wetlands for mitigating the climate change.

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