**ROLE OF MANGROVES IN CARBON SEQUESTRATION**

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 **Abstract:**

Mangrove forests are very productive, providing carbon at rates equivalent to tropical wet forests. Mangroves have higher belowground-to-aboveground carbon mass ratios than terrestrial trees. The vast bulk of mangrove carbon is stored in large pools of soil and dead roots. Mangroves contribute 10- 15% (24 Tg C y-1) to coastal sediment carbon storage and release 10-11% of particulate terrestrial carbon to the ocean despite occupying just 0.5% of the global coastal area. Disparate carbon sequestration contributes to conservation, restoration, and emissions reduction strategies. Potential carbon losses owing to deforestation (90-970 Tg C y-1) are of immediate concern because they exceed the rates of carbon storage in certain ecosystems. Large pools of dissolved inorganic carbon in deep soils, transported to nearby streams via subterranean conduits, are a substantial source of carbon loss, accounting for up to 40% of yearly primary production.

**Keywords:** Carbon sequestration, Mangrove ecosystem, Sedimentation, Wetland.

**Introduction**

The mangrove forests in tropical and subtropical areas are regarded as a distinctive and intricate main component of coastal zones. They stand for transitional environments where freshwater, land, and the ocean intersect. Their principal vegetation is often composed of evergreen trees or shrubs that occur along beaches, saltwater estuaries, or delta habitats. Mangrove habitats are easily recognisable since they are situated on tideland mud or sand flats that are inundated by the sea on a daily basis. They are essential for maintaining the viability of coastal ecosystems as well as providing significant socioeconomic advantages to coastal communities.

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| Global distribution of mangroves , largely lying between latitudes 5ºN and 5ºS (Giri et al. 2010) |
| **Fig. 1 -** Global distribution of mangroves |

Mangroves grow in swampy environments where there is little oxygen present below a few centimetres of mud. Aerial roots produced by mangrove trees serve the three purposes of supporting elder plants, facilitating gas exchange, and absorbing water. More than one-third of the world's mangroves are found in Southeast Asia, which also has the richest species composition. To compensate for the low levels of oxygen, numerous mangrove trees, such as *Sonneratia* spp., *Avicennia* spp., *Brugueira* spp., *Ceriops* spp., and *Rhizophora* spp., grow there. Develop aerial root systems above the anaerobic substrate to enable root lenticels to exchange gas (Tomlinson, 1986; FAO, 1985). Tropical coastal waters may benefit from vital nutrients and organic carbon provided by mangrove forests (Alongi, 1996). Mangroves are found all across the world, primarily between latitudes 5o N and 5o S (Giri *et al*. 2011).

**Carbon cycle in mangrove ecosystem**

 Mangrove habitats in low latitudes also contribute a disproportionate quantity of various types of carbon to the coastal ocean. Mangrove ecosystems contribute 5% of net primary production and 12% of ecosystem respiration in low latitudes, occupying only 1.5% of the world's coastal ocean area (Alongi, 2020).Mangrove forests contain the most organic carbon (CORG) reserves of any tropical terrestrial or marine environment.

These significant levels of organic carbon are a result of the high primary productivity of mangroves, which is comparable to that of coral reefs and tropical wet evergreen forests, as well as the fast rates of soil deposition on the forest (Donato *et al.,* 2011; Alongi, 2014). The second-largest source of atmospheric carbon dioxide is microalgae and macroalgae that colonise aboveground roots and a portion of the forest floor. The third-largest carbon input is caused by the transport and deposition of materials from upstream and the surrounding coastal zone. The relative contributions of terrestrial and marine sources are determined by the location of forests and the rate of river flow in relation to the strength of tidal pulses. The bulk of carbon is produced in situ and eventually deposited underground as peat over the long term (Krauss et al., 2010, Ray et al., 2011, Osland et al., 2012).

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| **Fig. 2- C**arbon and nutrient cycling within mangrove and sandflat ecosystems (Bulmer *et al.,* 2017) |

**Sedimentation**

Mangroves absorb carbon from tidal water and river water, accumulating fine sediment particles. Researchers have identified processes for sediment and carbon accretion and estimated deposition onto the forest floor. These processes include tidal prism, tidal pumping, trapping, baroclinic circulation, flocculation, microbial mucus formation, and disaggregating cohesive sediment flocs (Wolanski, 1995). These mechanisms regulate the transit of suspended solids in overlying water (Wolanski, 1995). Sedimentation is influenced by tree size, form, and distribution, creating turbulent waves that keep flocs stationary when tides approach the forest (Mazda et al., 1997, 1999). A brief period of particle settling happens as the tide shifts from high to low and the waters become calm. This is made possible because the particles attach to mucus on surfaces. Larger particles with quicker settling velocities are produced by particle flocculation, and high tree densities additionally impede water velocity.

Soil accretion measurement techniques vary in accuracy, with some being incorrect and others measuring short-term accumulation rates. The least controversial technique is measuring the vertical reduction in radioactive element concentrations from atomic bomb fallout (excess 210Pb and 137Cs), which can provide a chronology of sedimentation over the last century or more. Mangroves experience soil accretion rates ranging from 0.1 to 10.0 mm/yr, with an average of 5 mm/yr (Alongi 2012). Net erosion and significant accretion are observed in some forests. The rate of sedimentation is influenced by tidal upwelling frequency of tidal upwelling (Adame et al., 2010). As surface elevation increases, particles accumulate less, resulting in less soil accretion in forests farther from sea interaction (Cahoon et al. 2006). Some forests may experience stronger vertical accretion due to belowground root growth, surface algal mats, and litter accumulation (McKee, 2011).

The sedimentation of mangroves is currently keeping up with local sea level rises over the majority of the tropics (Alongi, 2008). This is not the case in the Caribbean, the South Atlantic, or the Pacific islands (Lopez-Medelle et al., 2011, McKee, 2011), where sedimentation fluctuates dramatically in relation to variations in climatic variability. Storms, hurricanes, and other climatic disturbances have a major impact on net sedimentation in mangrove ecosystems (Smith et al., 2009; Whelan et al., 2009; Smoak et al., 2013).

**Carbon sequestration**

Mangroves, coral reefs, and sea grasses dominate coastal habitats, transitional zones between terrestrial and oceanic areas. Factors like primary productivity and decomposition influence carbon cycling through the ecosystem. Temperature and precipitation significantly impact these processes. Autotrophs absorb atmospheric CO2 through photosynthesis, integrating it into their biomass. Respiration uses some biomass as a carbon source, and terrestrial and coastal ecosystems are connected to the atmosphere through photosynthesis and respiration. The release of carbon during respiration counteracts the carbon loss caused by photosynthesis.

Although photosynthesis and respiration play a significant role in ocean ecosystems, the interaction of CO2 with water makes the carbon cycle more complicated. Carbonate and dissolved CO2 react to make bicarbonates and carbonate ions when they are combined with water to create carbonic acid. Bicarbonates are transformed back to CO2 via the photosynthesis process, which uses CO2. As a result, bicarbonates act as a storage space for CO2, and some aquatic autotrophs can utilise dissolved bicarbonates as a direct supply of carbon. By trapping atmospheric CO2 and storing it as carbon in organic materials and soils, mangrove forests may have a big influence on the carbon cycle. Because approximately half of a tree's biomass is made up of carbon, mangrove forests have the capacity to store a huge amount of carbon and may be the greatest carbon reservoirs in coastal areas.

**Services and Functions Provided by Mangroves**

1. **Resources and Socio-economic Contribution**

Only over 8% of the world's coastline is covered by mangrove forests (World Resources Institute, 2000). Nevertheless, despite their small size, they play a vital role in the ecosystem. Indigenous and local people have historically utilised mangrove forests in many tropical developing countries for a variety of purposes. They have relied on fish, prawns, crabs, and mollusks from mangrove habitats for a very long time and will continue to do so. Mangroves also provide a variety of lumber for use in construction, fuel, charcoal, poles, fishing equipment, and other items. Fruit, honey, pulp, tannin, and traditional medicines manufactured from various plant parts are other mangrove products.

1. **Ecological and Biodiversity Conservation**

Mangroves are vital for protecting biodiversity and providing other ecological functions, according to several research. One of mangroves' most well-known and hotly contested functions is coastal protection from storms, waves, and water currents, which reduces erosion and floods. In order to stop saltwater incursion, mangroves are essential. Mangrove forests have the ability to stabilise coastal areas and defend against storms since they are found in tropical regions that are prone to hurricanes and typhoons. Prop roots help with soil consolidation and stability since they are deeply ingrained in mud, offering a natural kind of coastal protection. A 100-meter-wide area of mangroves with a density of two or three trees per metre might lower wave height by up to 70%, according to Danielsen et al., 2005. Although natural disasters might destroy some young mangroves, adult mangroves can survive due to their complex root systems.

Many studies have been done to show the benefit of mangroves' inherent traits in minimising the harm done by extreme natural events like tsunamis. Since mangroves are one of the most dominant ecosystems along the shore, especially in tsunami-affected regions, several publications highlighted mangrove habitats. Dahdouh-Guebas (2006) estimates that mangrove-covered areas in the Andaman Islands only received 7% of the damage whereas degraded mangrove areas took 80% to 100% of the toll. In comparison to areas without mangroves, Ghosh (2005) found that in southern India's mangrove-rich regions, fewer people had been hurt by a tsunami and less property had been damaged. In Malaysia, Emmanuel and John (2005) noted that Penang Island's mangrove trees lessened the waves' influence.

 Mangrove habitats are crucial for biodiversity conservation as they provide a safe haven for spawning, nursery, and feeding juvenile fish and crustaceans. They contribute to fisheries by supplying nutrients, exporting nutrients offshore, and providing habitat for wildlife. Mangroves also support a diverse range of animals, amphibians, and reptiles, as well as birds and marine and terrestrial mammals for roosting, breeding, and foraging (Hamilton and Snedaker, 1984). The variety of plants and animals in mangrove ecosystems offers opportunities for scientific study as well as tourism development. Healthy coastal ecosystem growth depends heavily on mangroves. Adeel and Pomeroy (2002) claim that mangroves' high output of organic matter makes their leaf litter a major source of nutrients for trophic feeding. For instance, despite relatively modest standing biomass accumulation, which averages 1,500 g/m-2, the average rate of leaf litter intake is 100 g/m-2/year-1. The high productivity is frequently linked to high rates of trash decomposition and effective nutrient recycling.

**Future perspectives**

The importance of mangroves is currently being emphasised in climate change efforts like REDD+ and blue carbon. Blue carbon projects need to solve the following specific actions and problems, according to McLeod *et al.* (2011) and Alongi (2011).

* When selecting a site, it's crucial to take into account aspects that are thought to influence carbon sequestration rates, including as the frequency of wave action, primary production, and rates of exchange with surrounding ecosystems. Preferably, the site should be on the seaward edge. It is necessary because, all mangrove forests do not accumulate carbon.
* By measuring and mapping the spatial and temporal oscillations in carbon sequestration and burial rates, and connecting these parameters to environmental and biological forces, provide a set of indicators that may be used to swiftly analyse changes in carbon storage and fluxes.
* Remote sensing and aerial photography may be useful for promoting changes in restoration/rehabilitation methods and identifying changes in land usage.
* Standardization of techniques for calculating carbon stocks and burial rates in soil and biomass.
* Planting with a variety of species to increase ecosystem productivity, food web connectedness, and biodiversity.
* Studies should be carried out simultaneously to evaluate the circumstances that decide whether or not climate change consequences, such as sea level rises, will occur.

Although there are many unknowns regarding future ocean climate scenarios, it is necessary to assume that regional changes in ocean circulation, temperature, salinity and pH patterns, and sea level will likely have a significant impact on the capacity of mangroves to store carbon (Sen and McNeil, 2012).

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