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Mangrove ecosystems' role in climate change mitigation

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ABSTRACT. Mangrove forests are crucial to ecosystems for their benefits, and role in climate change mitigation. Across marine and terrestrial boundaries, they shield coastal areas from tidal waves and storms, with dense roots that dissipate wave energy effectively. These roots also trap carbon-rich particles from the water, storing them in sediments and fostering sediment accretion and carbon burial. Mangrove ecosystems have declined over the past five decades, largely due to aquaculture. This decline reduces coastal resilience, exacerbating risks from storms, sea-level rise, and erosion, while releasing stored carbon as CO_2 emissions. Mangrove degradation is crucial for climate mitigation. Mitigation strategies should prioritize conserving ecosystems with high carbon sequestration rates, reducing anthropogenic CO_2 emissions, and rehabilitating mangrove habitats converted for aquaculture. We must expand our knowledge and understanding of the significance of mangroves in delivering coastal protection, how mangrove ecosystems serve as carbon sinks, how future changes could impact them, and how anthropogenic activities and climate change can impact their carbon storage.

Keywords: *Climate change, mangrove ecosystem, marine and terrestrial ecosystem.*

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Mangrove ecosystems are essential to our ecosystem and economy (Carugati et al., 2018). It delivers multiple benefits to humankind (Cuenca-Ocay et al., 2019) including protection from storm, erosion, flood, and prevention from salt-water intrusion (Brander et al., 2012); provision of food as it is the key nutrient source for many species from various trophic levels; serving as nurseries and dwellings to numerous species, providing habitat connectivity with other valuable marine ecosystems such as coral reefs and seagrass beds; serving as bioindicators (Cuenca et al., 2015); carbon sequestration (Cuenca-Ocay et al., 2019); helping local communities increase their economic gains or food security, and providing recreation, tourism, education, and other cultural ecosystem services to coastal populations living nearby mangrove forests (Friess, 2016).

Mangrove ecosystems are also fundamental in the milieu of climate change as it imparts critical climate change mitigation and adaptation ecosystem services. This is attributed to their capability to protect the coastal zone against waves and tropical storms and to their carbon supply, which is amid the largest per hectare storage of carbon worldwide (Duncan et al., 2016). Mangrove forests are densely vegetated mudflats that span at the frontier of marine and terrestrial environments. With this, they are able to attenuate wave energy which stabilizes the coastal zone. The rate of wave energy attenuation is greatly dependent on several factors including the thickness of the mangrove forest, breadth of mangrove trunks and roots, and on the spectral characteristics of incident waves. On the other hand, the two focal mechanisms of energy dissipation of waves are the multiple interactions of wave motion with the trunks and roots of mangroves, and the bottom friction. The waves that penetrate through the mangrove forest dissipates in energy due to its trunks and roots that are thicker in the bottom layer than in the upper layer. When waves make their way through the mangroves, they encounter numerous interactions with the trunks and roots leading to its substantial energy loss. (Massel et al., 1999).

The complex root systems that can slow down tidal waters can also enable mangroves to entrap carbon rich particles from the water column and storing them in sediments. This inclines them to be greatly efficient in locking in sediment and associated internal and laterally imported carbon from riverine and oceanic sources that would otherwise remain as atmospheric CO_2 and aggravate climate change (Mcleod et al., 2011). This is why mangrove ecosystems are amid the most carbon-rich biomes with a carbon stock of 937 tC ha-1 on average. This enables the accumulation of fine particles and cultivates speedy rates of sediment accretion and carbon burial (Alongi, 2014), making mangrove ecosystems one of the blue carbon ecosystems (Taillardat et al., 2018). Blue carbon pertains to the carbon sequestered by oceans and coastal ecosystems specifically by the seagrass meadows, tidal marshes, and mangrove forests (Macreadie, 2019). Blue carbon ecosystems are distinguished by their disproportionately large organic carbon storage capacity mainly within the sediments, even at maturity (Taillardat et al., 2018) over longer periods of time (Mcleod et al., 2011). Hence, blue carbon has gained attention internationally as a tool for mitigating climate change particularly on anthropogenic CO_2 emissions (Taillardat et al., 2018).

The net sink of carbon supplied by an ecosystem will only mitigate anthropogenic emissions of CO_2 if its rate of carbon sequestration is acceleratedover time, which can be achieved through increased primary production or through an increase in areal extent. The carbon sequestered by mangroves is predominantly from locally produced carbon burial and from laterally imported carbon sources (Mcleod et al., 2011). As sea level rises, a lot of the mangrove forest soils are accumulating, which maintains constant carbon sequestration of 1.3 – 2.0 Mg C ha-1 yr-1 (Sanderman et al., 2018). This sequestration potential of mangroves indicates that they can clearly play a role in mitigating carbon emissions if its degradation is reduced (Taillardat et al., 2018). Climate change can switch an ecosystem from being a net sink of carbon into a net source of carbon. When aquaculture ponds replace mangroves, carbon is discharged back to the atmosphere due to the removal of mangrove forest and the perturbation of its sediments during the construction of ponds. The activity of waves may erode carbon deposits when the protective cover of mangroves is lost, thereby leading to the shortfall of carbon sink capacity of earlier storage (Mcleod et al., 2011). Since mangroves account for 14% of carbon sequestration in worldwide ocean as coastal habitats, the disruption of their carbon stocks may lead to a very high emission of CO_2 (Alongi, 2014). From various sorts of deforestation globally, mangrove deforestation may yield as much as 10% of greenhouse gas emissions (Cameron et al., 2019). This clearly signifies that the decline of ecosystems that act as natural carbon sinks like the mangrove ecosystem can lead to CO_2 emissions. Other factors that can lead to the shift of an ecosystem to a net source of carbon include atmospheric composition effects and land-use change effects.

Mangrove ecosystems have declined over the last 50 years with aquaculture as the chief culprit for its decline (Cuenca-Ocay et al., 2019). The conversion of mangrove forests to shrimp ponds has led to the shortfall of 90% of carbon sequestered from the top 3m of soil (Sanderman et al., 2018). Other anthropogenic activities that contributed to mangrove degradation include urban development, mining, and over-exploitation of its economic services (Cuenca-Ocay et al., 2019). The worldwide losses of these vegetated ecosystems can menace their role as long-term carbon sinks (Mcleod et al., 2011). In addition, with climate change, mangrove degradation leads to decreased protection against coastal storms, sea level rise, as well as saline intrusion and erosion. In developing countries, the global losses of mangrove ecosystems have the foremost impact on the susceptibility of the goods and populaces settling in the coastal zones. Moreover, other coastal and near-shore ecosystems are possibly threatened by the changes tied up with climate change, which include the changes in precipitation, temperature, and hydrology (Barbier, 2016).

Hence, preventing or decelerating the rate of mangrove conversion activities is undoubtedly a key to mitigating climate change. Its protection and restoration, especially to countries with large mangrove forests can play a significant role in climate mitigation goals (Sanderman et al., 2018). With this, strategies on mitigating climate change effects should refocus not only on supporting CO_2 uptake and storage through the conservation of natural ecosystems that have high rates and capacity of carbon sequestration, but also on reducing anthropogenic sources of CO_2 (Mcleod et al., 2011). Mangrove rehabilitation of those that were converted to economic usage like aquaculture ponds, can also possibly mitigate greenhouse gas emissions (Cameron et al., 2019). More so, it is vital that we expand our knowledge and understanding on how these ecosystems serve as carbon sinks, how the future changes could impact them, how anthropogenic activities and climate change can impact their carbon storage (Mcleod et al., 2011), and on the significance of mangroves in delivering coastal protection (Barbier, 2016).

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