SIGNIFICANCE OF BLUE CARBON IN CLIMATE CHANGE MITIGATION

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Blue Carbon (BC), the term coined a decade ago, refers to organic carbon that is captured and stored by the oceans and vegetated coastal ecosystems. Increasing global interest in BC is based on its prospective to mitigate climate change along with the co-benefits of coastal protection and fisheries enhancement. The BC ecosystems comprising of mangrove forests, tidal marshes and seagrass, microalgae play a vital role in the global carbon cycle. They occupy 0.07-0.22 percent of the Earth's surface and bury 0.08-0.22 Pg C yr^{-1}, which is comparable to 0.2 Pg C yr^{-1} transferred to the seafloor and equivalent to ~10 percent of the entire net residual land sink of 1-2 Pg C yr^{-1} (The National Academies Press, 2019). Henceforth, it has got immense focus in the UN Decade on Ecosystem Restoration (2021-2030) for raising awareness and to instigate actions towards the preservation and restoration of BC ecosystem.

DEVELOPMENT OF BLUE CARBON SCIENCE

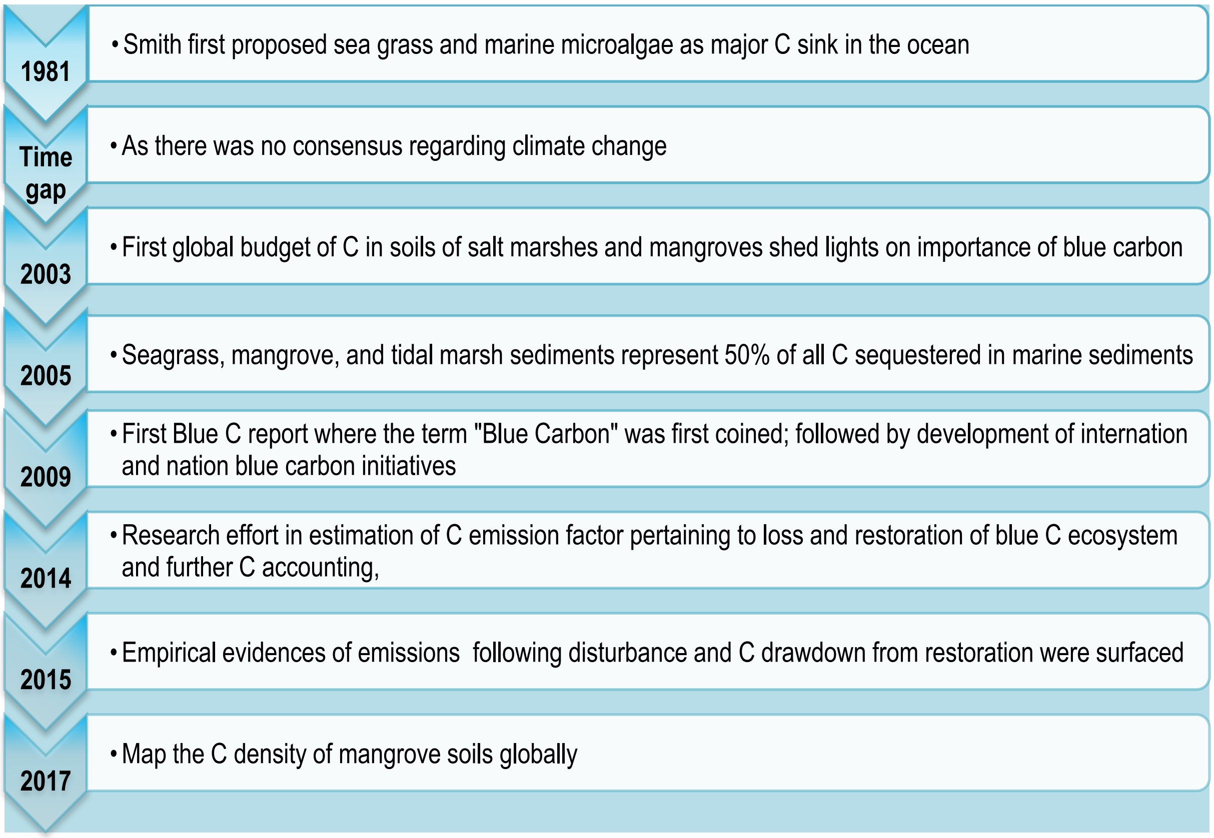

Figure 1. Timeline of advancement in blue carbon science

EVOLUTION OF BLUE-CARBON ECOSYSTEMS

Estuaries, lagoons and deltas are characterized by BC ecosystems which are predominantly found in subtidal and intertidal zones of temperate and tropical regions. BC ecosystems, developed over the period of 2,000-6,500 years, as a result of slowing down of sea level rise rate (below 0.5 mm yr^{-1}) and subsequent infilling of coastal waters with soils, has rich diversity of plant species. These coastal areas are dominated by mangroves and efficient in trapping finer soil particles and accumulating un-decomposed roots and rhizomes. Thus, can sequester 276–822 Tg CO_2 yr^{-1} which is reported to be quicker than oceanic or terrestrial ecosystems (Sanderman et al., 2018). However, anthropogenic pressure and climatic irregularities have caused area losses of 0.17% yr^{-1} (Hamilton and Casey 2016). Hence, conservation of BC ecosystems is possible only by increasing awareness among people regarding the role of these ecosystems along with necessary initiatives to preserve newly deposited and ancient organic matter.

TYPES OF BLUE CARBON

There are two major groups of blue carbon viz. autochthonous and allochthonous. Autochthonous carbon is produced and deposited in the same location. Here, plants fix carbon form the atmosphere and/or ocean through photosynthesis and convert them in plant biomass. In due course, major parts of plant biomass get allocated to roots where it undergoes very slow decomposition in anaerobic conditions, resulting in storage of the carbon within the sediments. On the contrary, allochthonous carbon is produced in one location and deposited in another. It exists in very hydrodynamically active settings as being continuously disturbed due to waves, tides and coastal currents which transport and deposit sediments and organic matter from adjacent ecosystems. The plants of these systems are very efficient in trapping the sediments and organic matter by their complex root structures and canopies, eventually adding to the local carbon stock.

THE MAJOR ROLE PLAYERS OF BLUE CARBON

Major components of blue carbon ecosystems include seagrass and weeds, micro algae, mangroves and tidal marshes. Globally, BC ecosystems has been estimated to store >30000 Tg C in approximately 185 million ha area, with the benefit of potentially avoiding emissions of 304 (141-466) Tg CO_2 equivalent per year (Table 1). In addition, restoration effort of BC ecosystems in the range of 0.2-3.2 million ha for tidal marshes, 8.3-25.4 million ha for seagrasses and 9-13 million ha for mangroves, could also fix a supplementary 841 (621–1,064) Tg CO_2 equivalent per year, by 2030, together contributing to almost 3 percent of global emissions (based on 2019 and 2020 global annual fossil fuel emissions; Macreadie et al., 2021). Global averaged estimates of blue carbon stock in different blue carbon ecosystem have been reported to be ranged from 108-386 Mg ha^{-1}. With increasing knowledge regarding the significance of BC ecosystem in mitigating climate change, there has been a growing trend of putting value in to the ecosystem services provided BC ecosystem.

Figure 2 shows the value (US $) of ecosystem services provided by various BC ecosystems. Depending upon the capacity of the ecosystem to sequester carbon and the potential for emission voidance through conservation and restoration measures, the valuation of the ecosystems differs. Besides, valuation of BC ecosystem will also highlight its tangible benefit, thus will enable its inclusion in national and international greenhouse gas inventories, in mitigation and adaptation interventions, and in policy and management narratives. Furthermore, tangible gains in C sequestration and avoided emissions by conservation and restoration of BC ecosystem could be utilized either through voluntary C markets or through the Clean Development Mechanism of the UNFCCC (Emmer et al., 2015).

Table 1. Distribution and variation of carbon among the different blue carbon ecosystems

Ecosystem	CARBON STOCK(Mg ha^{-1})	RANGE (Mg ha^{-1})	CO_2 (Meq ha^{-1})
Mangroves	386	55 – 1376	1415
Tidal salt marsh	255	16 – 623	935
Sea Grass	108	10 – 829	396

(Source: IPCC 2013)

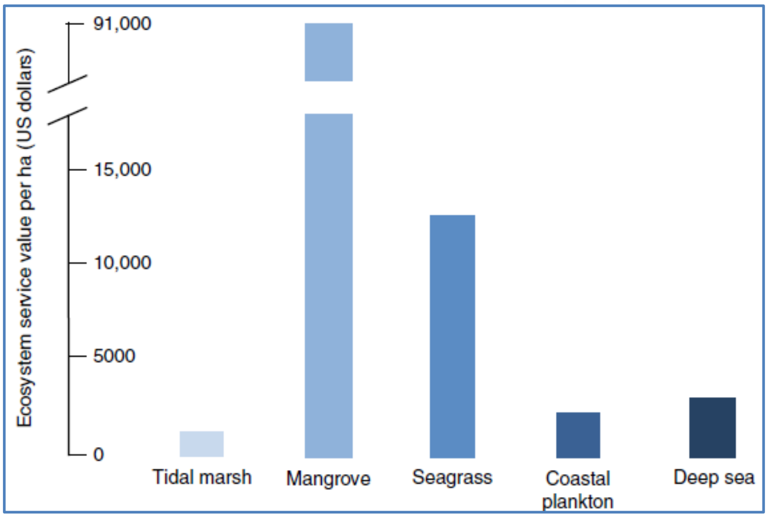

Figure 2. Value of ecosystem services provided by various BC ecosystems

(Source: Macreadie*et al.* 2019)

THREAT TO BLUE CARBON ECOSYSTEM

In spite of their benefits and ecosystem services, BC ecosystems are constantly being threatened with an annual loss of 340000-980000 ha (Murray et al. 2011). It has been estimated that till now 67 percent of the historical global mangrove, 35 percent of tidal salt marshes, and 29 percent of seagrasses were lost due to anthropogenic activities and climate change. At this rate, nearly 30-40 percent more tidal marshes and seagrasses and almost entire unprotected mangroves could be lost in next 100 years (Pendleton et al. 2012). Furthermore, climate irregularities, sea level rise, global warming, eutrophication and anthropogenic pressure on land and water resources, could result in further degradation of BC ecosystem and release 0.15-1.02 Pg $CO_2 yr^{-1}$ (Pendleton et al. 2012).

PRESERVING AND RESTORING BC ECOSYSTEMS

Once identified, BC ecosystems need to be the focal point of both conservation and mitigation endeavour. But, anthropogenic exploitation has to be minimized through firm international policy to withstand the pressure of commercial industry interests. The management approaches can be categorized into three groups: preservation, restoration and creation. Preservation involves approaches like sedimentation and water supply, to sustain the biogeochemical functions of the ecosystem (Macreadie et al., 2017). Restoration approaches involve reforestation of degraded mangrove forest, restitution of hydrology of drained coastal floodplains and restitution of aquaculture ecosystem within mangrove forest to improve the bio-geo-chemical processes of the ecosystem (Murdiyarso et al., 2015). However, all the restoration measures will not compensate what has been lost. Thus, to prevent further future loss, USA and EU are following “No net loss” policies to wetland ecosystems and creating new BC ecosystems replace those lost due to all developmental activities. Moreover, recently carbon credit and voluntary C market have also included the contribution from BC ecosystem through creation, conservation and restoration efforts.

INCLUSION OF BC ECOSYSTEM IN EARTH SYSTEM MODEL

The earth system models predicting C dynamics is constantly being upgraded. Prediction on spatial and temporal dynamics of soil organic carbon improved with the inclusion of role of microbial and functional diversity, carbon-use efficiency and contribution of exoenzymes (Wang et al., 2016). Likewise, including BC ecosystem and their dynamic redox system, plant-microbes interaction will further improve the prediction regarding potential of soil organic carbon sequestration in mitigation of climate change through earth ecosystem models.

CONCLUSION

BC science is a vibrant field; however, it is still far away from reaching maturity. This ecosystem has been perceived to have tremendous economic value. In one hand it provides environmental protection to the communities from coastal storm, and provides habitat for commercial and recreational fisheries, on the other hand it serves as a major sink to sequester atmospheric CO_2 in soils. With the advancement of knowledge regarding the significance of BC ecosystem, communities as well as Govt. has started investing billions to conserve, restore and create these ecosystems. Thus, it is crucial to identify high-value BC ecosystems and strive to increase their sustainability for sustenance of human race, other living animals and the environment, in long run.

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