Fifth National Climate Assessment

Focus on Blue Carbon

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Focus on Blue Carbon

Blue carbon refers to carbon captured by marine and coastal ecosystems, such as mangroves, coastal wetlands, and seagrasses. Coastal ecosystems sequester carbon at a much faster rate than terrestrial ecosystems, and the carbon stored belowground can remain in place for decades to millennia if undisturbed by humans or extreme events. Conservation and restoration of coastal ecosystems can play a role in reducing carbon dioxide accumulations in the atmosphere by increasing sequestration of blue carbon.

Why So Blue, Carbon?

Blue carbon is the marine analog of green carbon, which refers to carbon captured by terrestrial (i.e., land-based) plants.[1] Marine ecosystems are aquatic environments with high salinity levels, including the open ocean, deep sea ocean, and coastal ecosystems. Marine and terrestrial plants capture and store carbon through photosynthesis and the accumulation of organic matter, such as roots, in the soil.[1,2] Blue carbon ecosystems (BCEs) are coastal ecosystems such as mangroves, wetlands, and seagrasses that store most of their carbon belowground in ocean sediments. Acre for acre, BCEs are estimated to store about twice as much carbon belowground than terrestrial vegetation (Figure F5.1).[3,4]

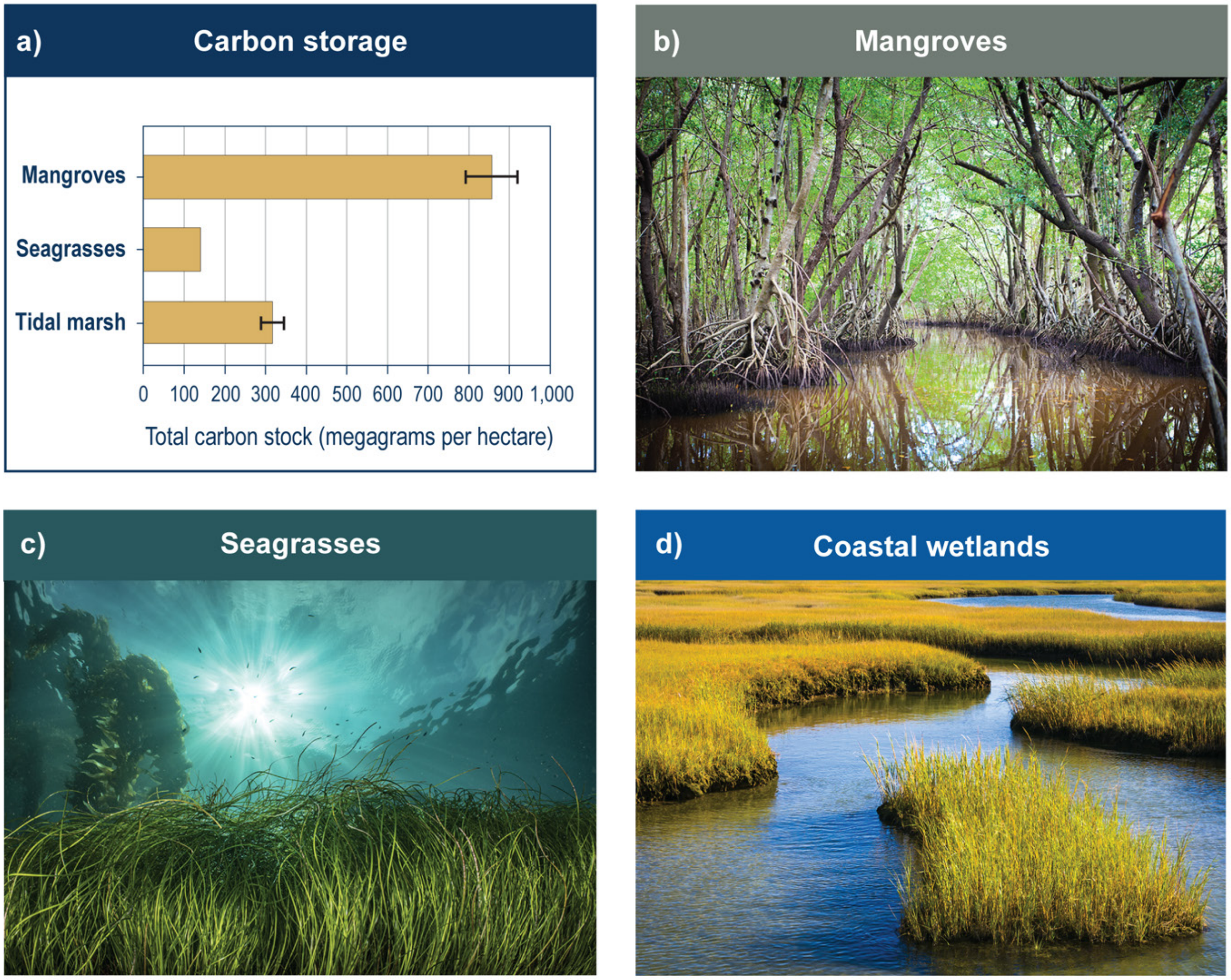
The Carbon Benefits

BCEs' ability to capture and store carbon has spawned numerous international efforts that support blue carbon as a natural climate mitigation option through enhanced stewardship, management, conservation, and restoration of these ecosystems and the ecosystem services and co-benefits they provide (KM 8.3).[2,3,5] This work includes creating and improving financing and policy mechanisms for coastal restoration that increases carbon sequestration,[6,7,8] as well as developing methods to better quantify carbon sequestration.[9,10,11]

The importance of estimating carbon emissions and sequestration in BCEs is recognized in international policies such as the Intergovernmental Panel on Climate Change (IPCC) guidelines for greenhouse gas inventories.[12] The United States has included coastal wetlands within its annual national inventory of greenhouse gas emissions and sinks,[13,14] and the government monitors sites across the US with the most blue carbon storage potential, such as the Florida Everglades, San Francisco Bay, and Chesapeake Bay. Globally, the US has one of the highest rates of BCE losses, largely due to hurricanes and coastal erosion.[15]

With conservation and restoration, BCEs could sequester enough carbon each year to offset about 3 percent of global emissions (based on 2019 and 2020 emissions).[3] Other coastal and marine ecosystems or species, such as kelp forests, freshwater wetlands, phytoplankton, and the deep sea may also capture carbon; however, the carbon sequestration potential of these ecosystems and species is likely lower than BCEs (Figure 8.19).[16,17]

Blue Carbon Ecosystem Sequestration Potential



Coastal blue carbon ecosystems play an important role in carbon sequestration but are vulnerable to climate change.

Figure F5.1. Blue carbon coastal ecosystems—mangroves (**b**), seagrasses (**c**), and coastal wetlands (**d**)—store more carbon belowground in soils and root systems (per hectare) than terrestrial vegetation, with mangroves storing the most carbon per hectare (**a**). They also provide other benefits such as reducing flood risk, supporting subsistence livelihoods, and providing recreational opportunities. However, blue carbon ecosystems are vulnerable to sea level rise, hurricanes, and other extreme events. In (a), black bars indicate the 95% confidence interval (which was unavailable for seagrasses). Figure credit: (a) Pathways Climate Institute. Photo credits: (b) YinYang, iStock/Getty Images Plus via Getty Images; (c) tswinner, iStock/Getty Images Plus via Getty Images; (d) Ken Wiedemann, iStock/Getty Images Plus via Getty Images.

Additional Benefits

BCEs are located at the interfaces among terrestrial, freshwater, and marine environments. They provide habitat for species, filter fresh water, recycle nutrients and other materials (KM 8.3), and help sustain human communities by providing other benefits, such as dissipating waves, reducing flood risk, and supporting coastal livelihoods, food security, cultural activities, and tourism (KMs 23.2, 30.4; Box 30.5).[18,19] Coastal seagrasses and wetlands provide nursery habitat for young crustaceans and fishes of economic and cultural value[20] and support the status and function of adjacent ecosystems. In addition, seagrasses may mitigate ocean acidification locally, thereby reducing some climate-driven stressors to shellfish and crustaceans.[21,22]

Effects of Climate Change on Blue Carbon

Sea level rise (SLR) and extreme events are the greatest climate change threats to BCEs.[23] In the past, many BCEs adapted to SLR through belowground root growth, sedimentation, and inland migration, which collectively increased the elevation of BCEs. As SLR accelerates, the ability of BCEs to continue to adapt is uncertain.[24,25] If BCEs cannot adapt to accelerating SLR, their geographical extent will decrease, and their species composition will change.[26] Currently, 43%–48% of wetlands along the Atlantic and Gulf Coasts are vulnerable to SLR, with northern wetlands limited by inland migration capacity and southern wetlands limited by local subsidence, which increases the relative rate of local sea level rise (KM 9.2).[27]

Growth of some plant species may increase in response to a warming climate and increased atmospheric carbon dioxide concentrations. This increased plant growth could locally offset accelerating SLR and allow some BCE species to continue to adapt. However, a 33-year coastal wetland experiment suggests that when SLR reaches a certain rate, plant growth will be hindered, thereby limiting these benefits.[28] This suggests that enhanced plant growth alone may not enable all coastal wetland species to adapt to accelerating SLR.

Human disturbance, SLR, and extreme events can erode and degrade BCEs, reducing carbon storage and potentially releasing previously stored carbon and methane.[29,30,31] If conservation efforts are not undertaken, this release of stored carbon could result in harmful climate change feedbacks.[32,33] For example, accelerating sea level rise would further degrade blue carbon ecosystems, reducing carbon sequestration and releasing stored carbon, which would further increase the rate of ecosystem degradation. Protecting and minimizing degradation of coastal areas to support carbon sequestration can have cascading ecological and societal benefits.[3]

Emerging Research

Although BCE conservation and restoration have wide-ranging benefits, uncertainties remain regarding carbon sequestration rates across different ecosystems and regions.[34] Research efforts are ongoing to improve methods, measurements, and modeling to fill knowledge gaps related to coastal carbon budgets.[35,36,37]

Seagrasses may mitigate local and/or regional ocean acidification rates by absorbing carbon dioxide and increasing the pH of seawater.[22] However, oceanic conditions are changing rapidly, and additional research is needed to assess this mitigation potential under high ocean acidification rates and warming ocean temperatures (KM 10.1).[38] The effect of ocean acidification on marine ecosystems is expected to vary depending on the combined influence of multiple climate drivers and other factors.[39]

The most effective means of enhancing BCEs and carbon sequestration are increasing local sediment supplies; enabling wetland expansion, including inland migration capacity; and restoring natural tidal conditions.[40] Mechanisms to support these enhancements are location-, ecosystem-, and stressor-dependent, and their success will be affected by past actions such as damming rivers, deforestation, building seawalls and other structures, and encroaching development.[41]

Traceable Accounts

Description of Evidence Base and Research Gaps

Although much is known about carbon cycling in coastal ecosystems, there are substantial challenges and uncertainties to quantifying carbon storage, carbon storage potential, and carbon sequestration rates across different ecosystems, vegetation types, and locations. Coastal systems are also stressed by natural coastal and climate variability (e.g., erosion, extreme storm events, sea level rise) and other historical and contemporary land uses that affect carbon cycling.[3,26] The extent to which these stressors may impact carbon storage or emissions is uncertain but is important to quantify for improved sequestration assessments.

Finding consistent and comparable data to compare belowground and aboveground carbon storage across coastal and terrestrial ecosystems is challenging. Cooley et al. (2022)[18] presented the most recent data compilation across several research efforts; however, these comparisons among ecosystems used different depths belowground for carbon stock measurements, and some measurements did not separate aboveground and belowground carbon storage or separate biomass carbon storage from soil carbon storage. Soil carbon storage, and the ratio of soil carbon to biomass storage, may indicate the potential of BCEs for carbon storage.

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