Earth Systems and Climate Change Hub

National Environmental Science Programme

NCCC National Centre for Coasts and Climate

Climate change and blue carbon in Australia

3D model (rendered from aerial images) for estimating above ground biomass of mangroves at Jack's Beach, Victoria. (Image: Ben Fest)

> Australia has large expanses of mangrove, saltmarsh and seagrass habitats, collectively known as blue carbon ecosystems.

> Blue carbon ecosystems can accumulate and store large amounts of carbon and thus have great potential to help mitigate climate change.

> Blue carbon ecosystems are under threat from climate change, coastal degradation and ecosystem exploitation.

> Protecting blue carbon ecosystems is important as it can take more than 60 years to restore their full carbon storage potential.

Blue carbon ecosystems are vegetated coastal habitats (saltmarshes, mangroves and seagrass meadows) that are found in diverse coastal and estuarine settings around the globe.

The term blue carbon was defined in 2009 when it was recognised that these ecosystems play an important role in the coastal carbon cycle.

Blue carbon ecosystems (BCEs) accumulate and store more carbon per unit area than tropical forests, with most of the carbon stored in below-ground biomass and the sediment.

Carbon can persist in the sediment of BCEs for time frames that are relevant to climate change mitigation (centuries to millennia). The lack of oxygen in these sediments slows down microbial processes which favours the preservation of organic carbon.

However, BCEs are relatively open systems with plant material and sediment being potentially imported into them from large distances and exported from them into the open ocean via a process called tidal pumping. This creates uncertainties about what proportion of the carbon buried in BCE sediments originated from sources within the ecosystem (autochthonous carbon) and outside the ecosystem (allochthonous carbon).

Given that allochthonous carbon might be old in age and originate from terrestrial sources where it has already been accounted for in the terrestrial carbon cycle, only the autochthonous carbon sequestered in BCEs can count towards global climate change mitigation.

Researchers at the National Centre for Coasts and Climate (NCCC) in the Earth Systems and Climate Change (ESCC) Hub are improving methods for measuring carbon stocks and accumulation rates, and developing methods for quantifying allochthonous sources of carbon in BCEs.

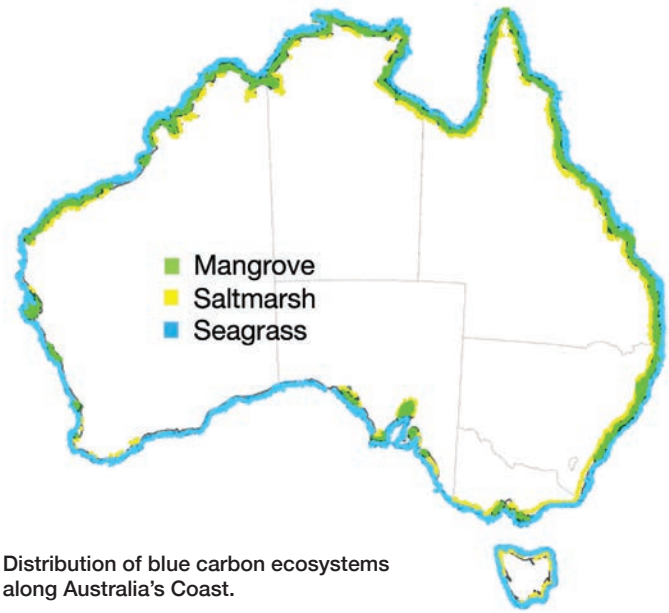
Blue carbon ecosystems in Australia

In Australia, blue carbon ecosystems (BCEs) occur along the coastlines of every state and territory (except for the lack of mangroves in Tasmania). Australia harbours about 12% of the global extent of BCEs, which hold about 7-12% of the global carbon stock.

BCEs can bury carbon in their sediments at rates up to 40 times higher than tropical forests sequester carbon in their soils. BCEs can also store carbon in their sediment for longer periods compared to upland forest soils.

Consequently, BCEs show potential to accumulate and store large amounts of carbon over timeframes relevant to climate change mitigation. Some BCEs (mostly mangroves) are already included in voluntary carbon markets globally, and their inclusion into the Australian Government's Climate Solutions Fund has been proposed.

Research by the CSIRO Marine and Coastal Carbon Biogeochemistry Cluster has found that Australian BCEs continue to be lost and degraded at a rate of ~ 2% annually, as a result of coastal development, declining ecosystem health, coastal squeeze and climate change. As habitat loss and degradation result in emissions of stored carbon and other greenhouse gases, strategies to avoid or mitigate these impacts to BCEs are potential methods for offsetting emissions in Australia.



Distribution of blue carbon ecosystems along Australia's Coast.

Blue carbon cycle in a mangrove ecosystem

Carbon Uptake / Photosynthesis

Carbon dioxide (CO_2) from the atmosphere is taken up by trees and plants during the process of photosynthesis. Some of this is released back as CO_2 to the atmosphere via plant and soil respiration.

Carbon Release

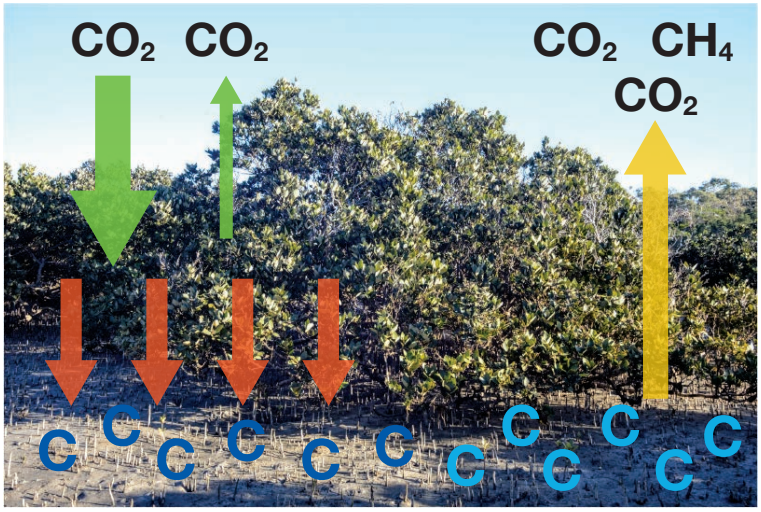
Disturbance that exposes buried carbon to the atmosphere (excavation, dredging, cyclones, tsunami etc.) leads to accelerated release of the stored carbon back to the atmosphere in the form of carbon dioxide and methane (CH_4).

Carbon Storage / Sequestration

Dead leaves, branches, bark and roots containing carbon get buried in the sediment, which is frequently inundated by salt water.

The breakdown and decomposition of plant material is slowed down by the very low oxygen availability in the sediment.

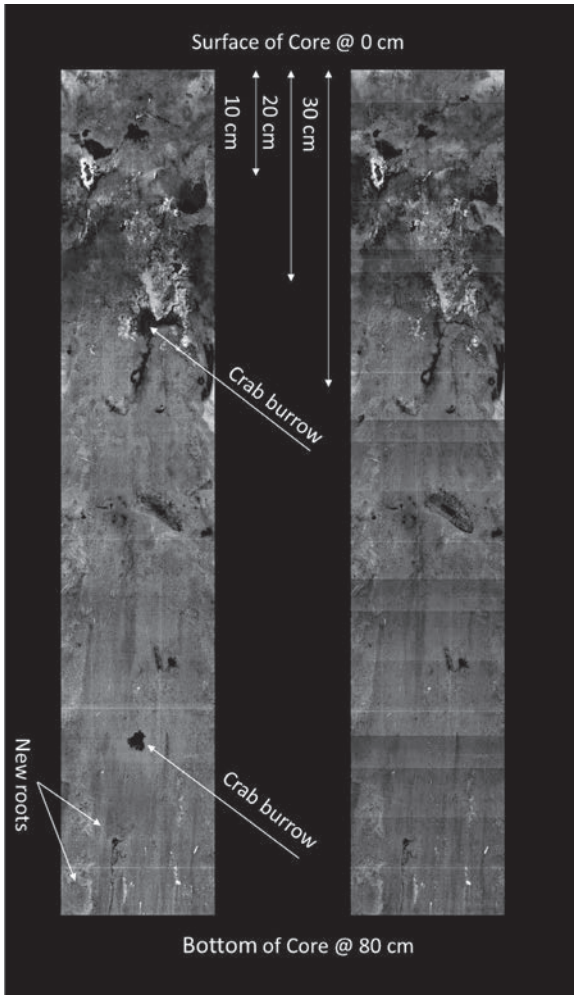
The carbon buried in the plant material can remain stored (sequestered) in the sediment for decades to centuries, resulting in significant carbon dioxide removal from the atmosphere, therefore mitigating climate change.



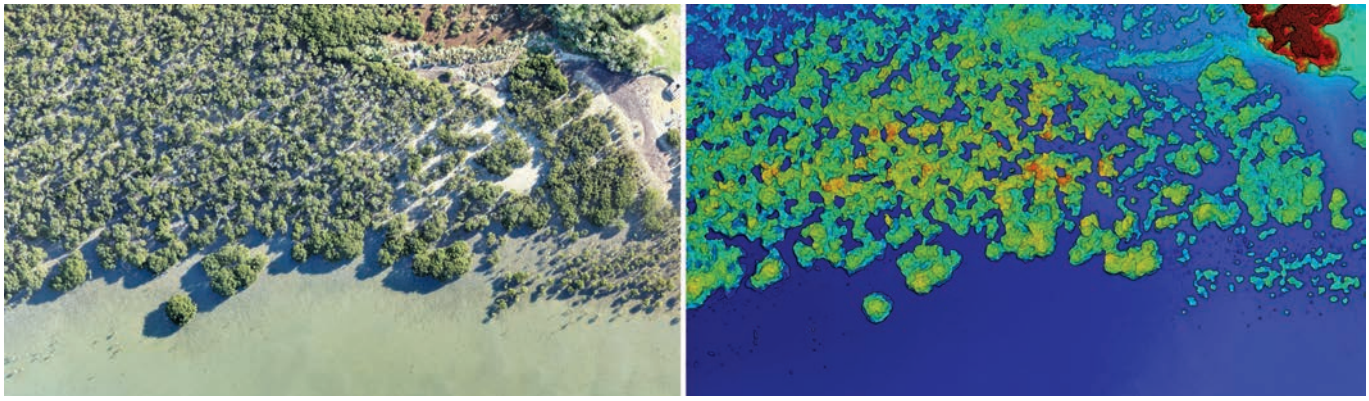
Developing methods to reduce uncertainty in BCE carbon stocks and accumulation rates

There are complexities in the cycling of carbon within these ecosystems and some methodological challenges still need to be resolved before BCEs can be included in any emission trading scheme. To tackle some of these methodological challenges, our researchers have:

- Applied a new approach to monitor root distribution and root turnover (the rate of growth and dieback) in BCEs with the help of a 'minirhizotron', a root imaging system commonly used in agriculture. This tool is being used to estimate allochthonous carbon sequestration by tracking how quickly mangrove fine roots turnover, and where in the sediment profiles this is occurring. It is also being used to estimate how much carbon may be lost and where due to aeration of sediment from the burrowing activity of crabs.
- Investigated the above ground carbon stocks of BCEs, such as mangrove forests, using 3D mapping systems, enabling researchers to track temporal changes in above-ground carbon over large areas.
- Developed guidelines outlining how to achieve accurate estimates of sediment carbon stock at lower analytical cost[1].



A window into the mud – Minirhizotron pictures taken from a mangrove ecosystem two months apart showing crab sediment disturbances.

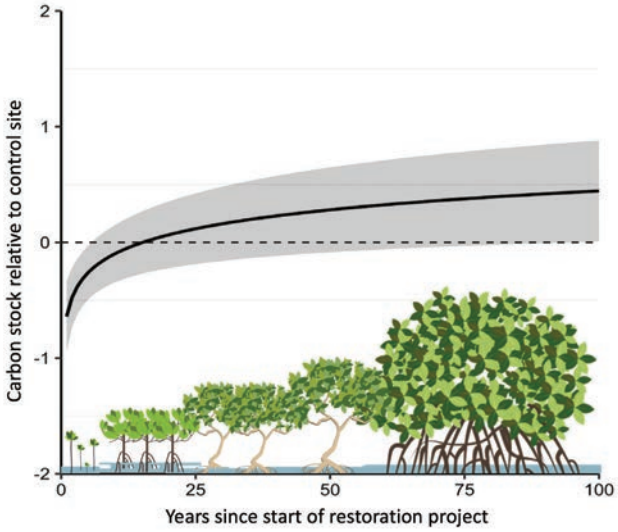


Above-ground carbon stocks can be estimated using 3D maps of canopy structures in blue carbon ecosystems. Mangrove forest stand at Jacks Beach, Victoria.

Reducing uncertainty in the impacts of management actions in Australia's BCEs

As 'blue carbon' science is a relatively new research discipline, BCEs have long been overlooked in the development of carbon offset methods. This has resulted in a lack of on-ground experimental studies explicitly testing the effect of different management interventions on BCE carbon stocks, sequestration rates or greenhouse gas fluxes; and no long-term studies.

To help close this research gap NCCC researchers in the ESCC Hub conducted a literature review to determine the empirical evidence base to support the inclusion of BCE management into emission trading schemes for climate change mitigation. The results of the review2 will help us manage blue carbon ecosystems for climate change mitigation with greater confidence.



Response of BCE carbon stocks to restoration. Carbon stocks increase in BCEs in response to restoration and reach reference levels in between 7 and 95 years.

Evaluating impacts of land management on BCE carbon stocks

NCCC researchers in the ESCC Hub are currently evaluating the potential blue carbon benefits of nature-based coastal defence management strategies such as the use of mangrove planters (pods) to re-establish mangroves in high energy environments. This research involves an interdisciplinary team of ecologists, industrial designers, coastal managers and policy makers.

Deployment of mangrove pods for coastal defence and blue carbon benefits at Grantville, VIC.

Further information

- [1]Fest B, Swearer SE, Arndt S. 2019. Sediment carbon stocks in blue carbon ecosystems – do we have the sampling right? Earth Systems and Climate Change Hub Report, NESP Earth Systems and Climate Change Hub, Australia.
- Maher DT, Eyre B, 2010. Benthic fluxes of dissolved organic carbon in three temperate Australian estuaries: Implications for global estimates of benthic DOC fluxes. Journal of Geophysical Research: Biogeosciences 115 (G4).
- Nellemann C, Corcoran E, Duarte CM, Valdés L, De Young C, Fonseca L, Grimsditch G, 2009. Blue carbon: the role of healthy oceans in binding carbon, A Rapid Response Assessment. United Nations Environment Programme, GRID-Arednal.
- 2O'Connor J, Fest B, Sievers M, Swearer SE. 2019. Impacts of land management practices on carbon stocks and greenhouse gas fluxes in blue carbon ecosystems – a meta-analysis. Global Change Biology.
- Kelleway J, Serrano O, Baldock J, Cannard T, Lavery P, Lovelock C et al. 2017. Technical review of opportunities for including blue carbon in the Australian Government's Emissions Reduction Fund, Canberra, ACT: CSIRO.

For more information please contact: **Professor Stefan Arndt**
sarndt@unimelb.edu.au
nccc.edu.au

The Earth Systems and Climate Change Hub is funded by the Australian Government's National Environmental Science Program.