CARBON CYCLE

Storage beneath mangroves

Empirical data on mangrove carbon pools and fluxes are scarce. A field survey in the Indo-Pacific region suggests that the sediments below these remarkable trees hold exceptionally high quantities of carbon.

Steven Bouillon

Mangrove forests are diverse, highly productive ecosystems that stretch along the intertidal zone of tropical and subtropical coastlines. These forests provide a wealth of ecosystem services. They are often associated with highly productive fisheries — although the causal mechanisms are a matter of debate — and are thought to export to the coastal zone a significant amount of the carbon they fix, either as organic or inorganic carbon. Despite their impact on carbon cycling and ecology, however, large uncertainties exist regarding the productivity and areal extent of mangrove forests, and the amount of carbon stored in their sediments¹. Writing in *Nature Geoscience*, Donato and colleagues report that mangrove forests surrounding the Indian and Pacific oceans are among the most carbon-rich forests in the tropics².

Mangrove forests consist of a consortium of tree and shrub species adapted to cope with the saline conditions and fluctuating water levels that characterize their environment. One such adaptation is the development of different aerial root systems such as stilt or prop roots (Fig. 1) that anchor the plants in the sediment and allow oxygen to penetrate the submerged roots. These complex root structures also slow down incoming waters during tidal inundation, causing much of the suspended material in the water column to settle onto the sediment surface. This highly efficient particle-trapping mechanism³ leads to the sequestration of carbon not only from the mangroves — for example, from leaf and root litter — but also from outside the ecosystem, including from rivers and adjacent seagrass meadows. These coastal carbon sinks are thought to bury carbon at rates up to 50 times higher than those in tropical rainforests⁴, where local vegetation is the predominant carbon source.

Mangrove forests are rapidly disappearing owing to human interference, with up to 50% being lost over the past 50 yr, primarily because of harvesting and land conversion⁵. The impact of such losses goes beyond a decrease in carbon sequestration. As forests

are removed, the organic carbon built up over decades to millennia is subject to increased remineralization and erosion, and therefore to release — *in situ* or elsewhere — to the atmosphere as carbon dioxide. However, the climatic impact of mangrove loss is difficult to gauge. It is known that mangroves can develop very deep organic sediments — deposits of ten metres have been reported in the Caribbean⁶. But there are insufficient data to quantify mangrove carbon stocks on a global scale, because the combination of data required is rarely measured.

Donato and colleagues² help to fill the gaps by quantifying above- and below-ground carbon pools in 25 mangrove systems across the Indo-Pacific. Above-ground pools, inferred from standing tree and dead-wood biomass, were significant, averaging 159 Mg C ha⁻¹. But below-ground pools — assessed by measuring carbon content, density and depth in an impressive number of sediment cores — proved to be exceptionally high, and the dominant carbon store, compared with above-ground biomass. Mangrove-sediment carbon stores were on average five times larger than those typically observed in temperate, boreal and tropical terrestrial forests, on a per-unit-area basis.

Donato *et al.* extrapolate their findings to a global scale, taking into account possible bias owing to the selection of sampling sites. According to their calculations, the total amount of carbon stored in mangrove sediments ranges from 4 to 20 Pg. Constraining this estimate further will require quantification of carbon stocks in a range of other mangrove systems and the development of a typology for these ecosystems based on their carbon stocks and relative distribution globally. They also provisionally estimate that 0.02–0.12 Pg C could be released as a result of mangrove clearance each year. The upper estimate amounts to around 10% of current global carbon dioxide emissions associated with land-use change, which is a major contributor to the present rise in atmospheric levels⁷.

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Figure 1 | Mangrove forest in Gazi Bay, Kenya. Mangrove trees possess highly developed and complex root structures that slow down the flow of water during tidal inundation, promoting carbon-containing particles suspended in the water column to settle on the sediment. Donato and colleagues² measured whole-ecosystem carbon storage in 25 mangrove forests in the Indo-Pacific region. They show that mangroves are among the most carbon-rich ecosystems in the tropics, and suggest that clearance of these forests could lead to large emissions of carbon dioxide.

In the face of continued deforestation, the high carbon stocks in mangrove forests unveiled by Donato *et al.*² provide a strong incentive to consider mangrove ecosystems as priority areas for conservation. Furthermore, these results highlight the need for scientists and funding agencies to address uncertainties regarding the fate of the carbon after land clearance. Only a handful of studies have quantified the loss of sediment carbon after mangrove clear-cutting — but all suggest that these losses are very significant (for example, up to 50% loss in the upper 15 cm of sediment after

8 yr)⁸. Furthermore, studies monitoring carbon losses over longer time periods, or the emission of other greenhouse gases, are lacking.

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