



Recognizing the complexity of soil organic carbon dynamics in vegetated coastal habitats

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Our understanding about the sequestration and release of atmospheric greenhouse gases from terrestrial ecosystems and its importance for, and feedbacks with, global climate change has matured considerably in the last few decades. The contribution of temperature, precipitation, erosion and sediment redistribution, as well as the composition of the biota, for the ecosystem's organic carbon (OC) turnover has been examined for many different terrestrial ecosystems. Our understanding of OC storage in marine ecosystems is more fragmented. Among marine ecosystems, soil OC storage in vegetated coastal habitats (VCHs) is of particular significance due to their high OC stocks and storage rates, their proximity to human settlements and dependence on human activities on land.

The most important VCHs are mangroves, salt marshes and seagrass meadows. Among these VCHs, OC storage and the decline in mangroves are best documented: Hamilton and Friess (2018) calculated that mangroves store 4.19 Pg C, but also concluded that 2% of this OC has been lost between 2000 and 2012. The rapid evolution of the state of our knowledge is illustrated by the rapidly changing assessments of the global OC storage in mangroves, estimated to be 5.0 Pg C in 2000 (Jardine & Siikamäki, 2014) but only 4.28 Pg C in more recent reviews (Atwood et al., 2017; Hamilton & Friess, 2018). There is even more uncertainty concerning salt marshes. Estimates on the areal extent of salt marshes vary 20-fold and on OC stocks 15-fold (Duarte et al., 2013). The estimated areas of seagrass meadows vary by a factor of 3.4 (McLeod et al., 2011) and their OC content is estimated to range between 4.2 and 8.4 Pg (Fourqurean et al., 2012).

A recent publication by Fu et al. (2020) sheds light on many of these uncertainties. The comprehensive analyses of 50 samples from mangroves, 93 samples from salt marshes and 38 samples from seagrass meadows from sites along the Chinese coastline ranging from the tropics to the cold temperate zone add substantially to the

global assessment of OC storage and dynamics in VCH. This study revealed patterns on several scales such as (a) the significance of off-site effects; (b) the role of sea level rise; (c) the role of species composition within the VCH types, including the effect of neophytes; (d) VCH-specific OC stock patterns depending on climate zones; and (e) the consequences of anthropogenic alterations in the coastline.

Many OC stocks reported by Fu et al. (2020) are lower than the OC stocks given in previous publications. The authors argue that the high rates of sediment discharge from the Chinese mainland have diluted the OC content of VCH soils. Given the 1 m limit of OC stock calculations and sediment accretion rates of up to 90 mm/year, it is likely that the reported OC stocks are higher if applied to the entire sediment column. These findings also add an interesting perspective to the discussion about the fate of OC in catchments with high rates of terrestrial soil erosion. The drastic reduction of sediment delivery by major rivers in China by 85% between 1954 and 2015 reported by Wu et al. (2020) illustrates the alteration in the geomorphic conditions for VCH off the coast of China and elsewhere. Fu et al. (2020) also highlight the importance of OC in VCH derived from terrestrial ecosystems, which contributes between 34% and 47% in the examined VCH. Fu et al. (2020) suggest that low OC stocks in estuarine mangroves or seagrass meadows are due to a decreased supply of OC derived from land. Many other factors, however, such as overall hydrodynamic conditions, the type of dominant tree species and their functioning (e.g. pneumatophores), sediment grain size and nitrogen availability in the sediment control soil OC storage in mangroves. In seagrass meadows, above-ground as well as below-ground production of different seagrass species vary by orders of magnitude, controlling soil OC stocks. Increased light availability, coupled to moderately increased nutrient supply may stimulate seagrass productivity, enhancing their function as sediment trap and increasing soil OC storage. The study by Fu et al. (2020) and other data syntheses should inspire researchers to apply and adapt our recently increased understanding about storage and preservation of soil OC in terrestrial settings to VCH. Future research should focus on the

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fate of terrestrial soil OC in VCH and the mechanisms of soil OC storage. Many studies have reported a dependence of OC stock on the prevailing vegetation. The comprehensive examination by Fu et al. (2020) shows that plant species control OC storage more strongly than climate, which influences production and decomposition and the resulting storage of OC. These factors depend on the interplay of temperature and precipitation and the redox status of the soil. Precipitation exerts an important control on soil OC storage as it influences salinity.

Freshwater availability might impact the stability of wetlands (Osland et al., 2018). However, it is important to consider the geomorphic setting of VCHs. In Swan Lake, a lagoon almost completely cut off from the open ocean, prevailing *Zostera japonica* and *Zostera marina* stands result in high OC storage rates. It is a task of future research to examine the role of plant succession in VCH, and its dependence on the shape of the coastline. The high OC storage rates in habitats dominated by *Spartina alterniflora*, a dominant species in salt marshes, contribute to a stabilization of salt marshes and consequently of the coastline, protecting it from erosion.

Finally, Fu et al. (2020) demonstrate the effect of multiple human interventions on the coastline, which are the subject of many recent studies. Eutrophication of VCHs promotes the degradation of salt marshes to mudflats (Deegan et al., 2012). Increased turbidity of the water column reduces the photosynthetic capacity of seagrass species in VCH. This increased turbidity is caused largely by human activities such as harbour constructions and other severe interventions. However, this detrimental effect is not necessarily universal, as some VCH are nitrogen limited and moderately increased nutrients may support OC storage rates. The rate of VCH loss over the past 70 years documented in the work by Fu et al. (2020) provides a stark example of negligent handling of sensitive ecosystems in a region of rapid economic development.

The article by Fu et al. (2020) shows that understanding OC storage and loss require a comprehensive approach taking into account land–ocean interactions with special consideration of the significance of allochthonous OC and mechanisms of OC storage. Considering geomorphic setting and vegetation dynamics should strengthen the quality of the parameters required for improved modelling of global VCH OC storage and loss, and thereby providing the scientific base required for restoring and remediating damaged and lost VCHs.

DATA AVAILABILITY STATEMENT

Data sharing not applicable – no new data generated.

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