Carbon burial and land building in low-laying tropical coastal wetlands

A new way to integrate climate change mitigation and adaptation strategies

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Background

Coastal wetlands ecosystems, including mangrove forests are known to sequester large amounts of carbon (C), typically around 1,000 Mg C ha^{-1} (Donato et al. 2011, Murdiyarso et al. 2015) – more than three times as large as terrestrial forests. Most of these are stored in sediments below the ground with a burial rate more than 20 times than any terrestrial ecosystem (McLeod et al. 2011).

The burial rates depend on net primary production of the mangrove forests and the quality and quantity of sediments transported laterally. These include litter production, fine root turnover and decomposition, and deposition from upstream of the catchment and ocean (Twilley et al. 1992). Globally, the average rate is around 163 g-C m^{-2} yr^{-1} (Breithaupt et al. 2013). Table 1 shows variation of carbon burial rates in fringe and interior zones in some regions.

Table 1. Carbon burial rates in fringe and interior zones of mangroves in different climate regimes

Location	Hydrogeomorphic setting	Carbon burial rate (g-C m^{-2} year^{-1})	References
Rookery bay. Southwest Florida	fringe	69	Lynch et al 1989
Rookery bay. Southwest Florida	interior	99	Lynch et al 1989
Susan's creek, Florida	fringe	127	Marchio et al 2016
Susan's creek, Florida	interior	50	Marchio et al 2016
Hamilton avenue creek, Florida	fringe	73	Marchio et al 2016
Hamilton avenue creek, Florida	interior	47	Marchio et al 2016
Babeldaob, Palau	fringe	231.1 ± 55.7	MacKenzie et al 2016
Babeldaob, Palau	interior	187.4 ± 46.1	MacKenzie et al 2016
Mekong, Vietnam	fringe	323.8 ± 109.2	MacKenzie et al 2016
Mekong, Vietnam	interior	235.6 ± 14.2	MacKenzie et al 2016

This study was designed to assess a contrasting mangrove forests in Indonesia in their capacity in coping with sea level rise. Their sedimentation rates were evaluated in terms of carbon burial as well. These are the West Papuan mangroves, which were well managed and the degraded North Sumatran mangroves due to aquaculture development.

Methods

Following Webb et al (2013), the contemporary sediment accretion rate was monitored using a combination of the Rod Surface Elevation Table and Marker Horizon (RSET-MH) in various hydro-geomorphic settings, namely interior, fringe, and mudflat (see Figures 1a and 1b). The carbon content was analyzed using LECO^{TM} elemental analyzer.

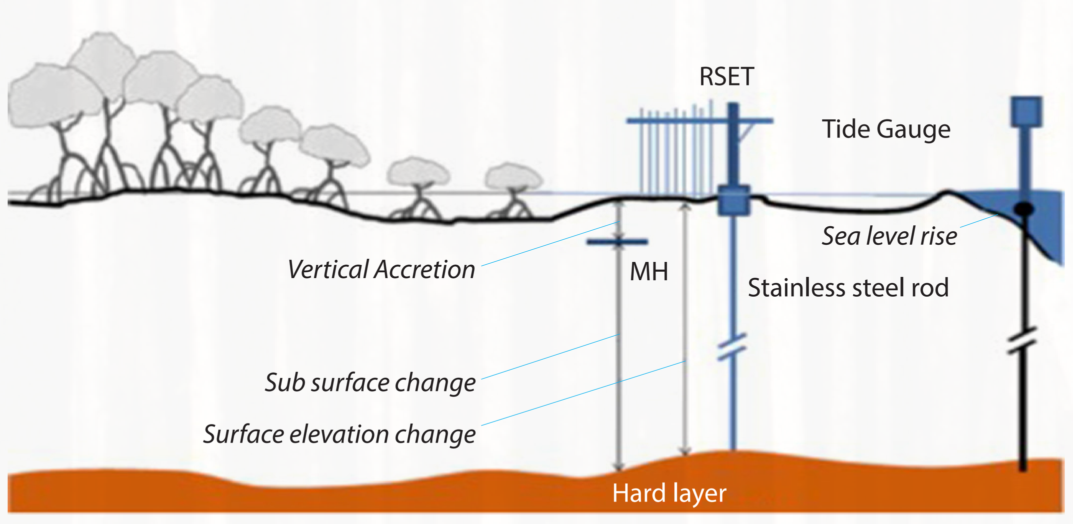

Figure1a. Installation of RSET-MH in mudflat zone, where colonization of mangrove takes place

Figure 1b. Monitoring of surface elevation change using RSET-MH

Natural ^{210}Pb radio nuclide were also employed to measure the unsupported radionuclides ^{210}Pb from each sediment interval by using Constant Rate Supply technique (Lubis, 2013).

$$A = Ao e^{-kt}$$

Where,
- *A*: unsupported ^{210}Pb activity below the individual segment being dated (Bq m^{-2}),
- *Ao*: total unsupported ^{210}Pb activity in the soil column (Bq m^{-2}),
- *k*: decay constant of radioactive ^{210}Pb = 0.03114 yr^{-1},
- t: age of the sediment (yr) was derived from

$$t = \frac{1}{k} \ln \frac{Ao}{A}$$

The sedimentation rate (kg m^{-2}yr^{-1}), was calculated using:

$$r = \frac{kA}{C}$$

The accretion rate (cm yr-1), was calculated using:

$$Ar = \frac{r}{C}$$

Where,
- *C*: unsupported ^{210}Pb concentration at a certain depth (Bq kg^{-1})

$$C\text{-}burial = Ar * BD * C\text{-}conc$$

Where,
- *BD*: average soil bulk density along a certain interval within a profile (g cm^{-3})
- *C-conc*: average of soil carbon concentrations with the same interval (%)

Results

Figures 2 and 3 show that the averaged sedimentation rates in West Papuan mangroves range between between 0.4 – 6.1 mm yr^{-1}, while in North Sumatra they range between 3.7 – 5.6 mm yr^{-1}.

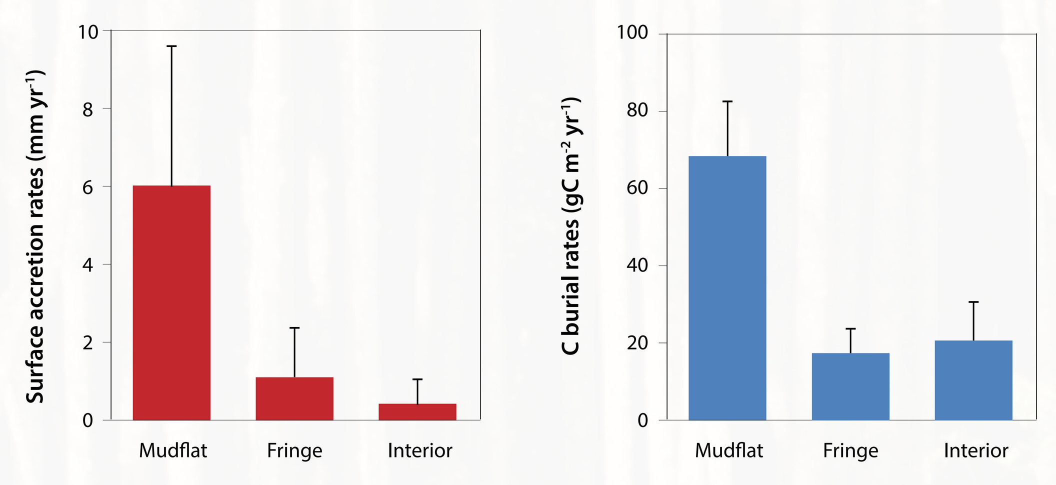

Figure 2. Accretion rate and carbon burial rates in mudflat, fringe, and interior zones of highly productive and protected mangroves in West Papua, Indonesia, estimated using combined RSET-MH approach

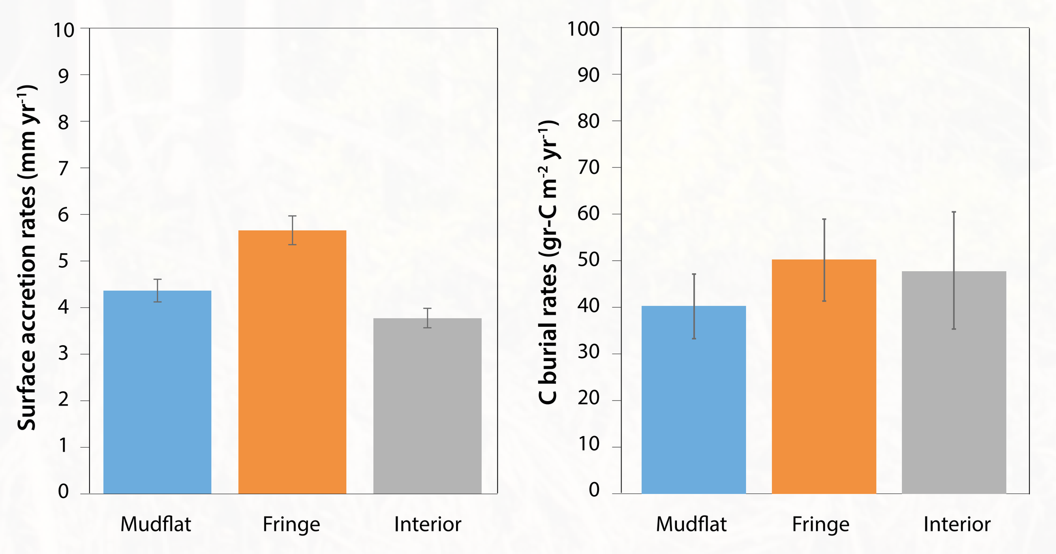

Figure 3. Accretion rate and carbon burial rates in mudflat, fringe, and interior zones of degraded and intensively used mangroves in North Sumatra, Indonesia, estimated using ^{210}Pb approach

Figure 4. Colonization of mudflat by *Avicennia* sp. Showing gradual growth and developement of the stands

Although RSET-MH shows contemporary sedimentation and 210Pb approach shows historical sedimentation, their results in two contrasting sites are different. The maximum rate of carbon burial in West Papua (36 ± 16 g C m^{-2}yr^{-1}) was quite contrast with that of North Sumatra (59 ± 15 g C m^{-2}yr^{-1}). These differences are shown specifically in fringe and interior geomorphic settings. These suggest that the sources of carbon from both floral and edaphic factors are crucial.

West Papuan mangroves with relatively maintained soil environment following logging sufficient amounts of decomposed litter and roots. Whereas in heavily degraded mangroves due to past excavation for shrimp ponds, although they are revegetated, the supply of biomass and organic materials are limited.

Concluding remarks

- Contemporary sediment accretion and C burial are maintained around 3 mm yr^{-1} and 0.36 Mg C ha^{-1} yr^{-1} respectively. If the entire catchment is managed properly, coastal wetlands, including mangroves show potential for climate change mitigation.
- Depending on the hydro-geomorphic settings the range of sedimentation rate between 2.3 – 11.6 mm yr^{-1} is sufficient to cope with the IPCC high scenario (RCP 8.5) of sea level rise of 0.7 m in less than 100 years. This is an adaptation capacity of coastal ecosystem that has been underestimated.
- Bundling mitigation and adaptation strategies in the context of global mechanisms stipulated in the Paris Agreement, such as Nationally Determined Contributions (NDC), Reduced Emissions from Deforestation and forest Degradation (REDD+) and Joint Mitigation and Adaptation (JMA) should be encouraged to attract the new funding mechanism, Green Climate Fund (GCF).

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