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Partitioning the relative contributions of organic matter and mineral sediment to accretion rates in carbonate platform mangrove soils

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ABSTRACT

In coming decades, the global rate of sea-level rise (SLR) is projected to accelerate beyond rates observed over the past several millennia when mangrove wetlands have expanded in tropical, sub-tropical and temperate regions. There is substantial uncertainty about how distinct mangrove ecotypes inhabiting a wide range of geomorphic settings will respond to SLR acceleration, including the thresholds at which they will submerge permanently. In this study, the relative contributions of soil organic and inorganic matter (SOM and SIM) to ^{210}Pb-derived accretion rates were examined at 23 mangrove sites in southwest Florida, USA and the Yucatan Peninsula in Mexico. These sites are situated atop carbonate platforms where there is wide variation in the availability of SIM (generally marine marl). To account for this variability, research sites were classified by SIM presence based on the SOM content (%) estimated using loss-on-ignition: organic sites (SOM > 70%), intermediate sites (SOM = 40–70%) and mineral sites (SOM < 40%).

SOM accumulation rates were largely the same in the three soil classes during the past century ($p < 0.05$); however, SIM accumulation rates in the intermediate and mineral sites were approximately 5 and 20 times greater, respectively, than rates in the organic sites. Despite this substantial difference in total mass accumulation rates, accretion rates were not statistically different between soil classes ($p < 0.05$). Our analysis revealed that the rate of SOM accumulation is the best predictor of accretion rates, while the rate of SIM accumulation primarily predicts soil dry bulk density. These findings indicate that SOM and SIM do not contribute additively to soil volume. This is contrary to findings from North American coastal wetlands broadly, suggesting a unique characteristic of carbonate platform mangrove soils that lack a regular, substantive supply of terrigenous SIM.

Overall, accretion rates in the FL sites and a Yucatan site on the Caribbean Sea are maintaining pace with regional rates of SLR over the past 100-year and 50-year timespans, whereas the sites in Celestun Lagoon, MX (located on the Gulf of Mexico) exhibit an accretion deficit. Estimates of regional SLR rates range from 4.6 to 12.2 mm yr^{-1} by the year 2060. Based on accretion rates observed in the past century, some of these sites may be able to keep pace with the lower SLR estimate, but there is no evidence that any of these sites can match the higher rate.

1. Introduction[2]

Many ecologically and economically valuable ecosystem services provided by coastal wetlands depend on their long-term equilibrium with relative sea-level rise (SLR) (Ellison and Stoddart, 1991; Woodroffe et al., 2016). A net result of SLR is the creation of accommodation space where mineral and organic materials can accumulate, increasing the thickness of the wetland soil (Jervey, 1988; Walsh and

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[1] Present Address: Southeast Environmental Research Center, Florida International University, Miami, FL, 33,199 USA.
[2] Non-standard Abbreviations: soil organic matter (SOM), soil inorganic matter (SIM), loss-on-ignition (LOI), & dry bulk density (DBD).

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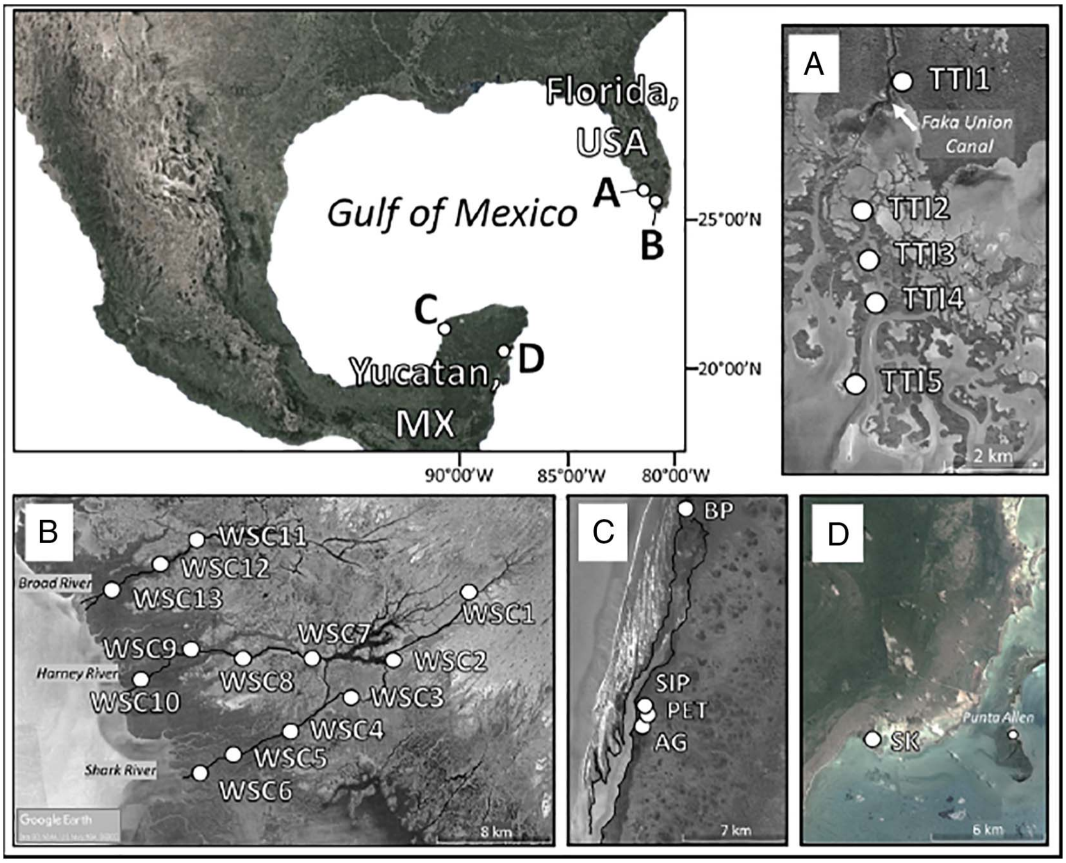

Fig. 1. Map of soil core locations in Florida, USA and the Yucatan Peninsula in Mexico: Ten Thousand Islands (A), Everglades National Park (B), Celestun Lagoon (C), Sian Ka'an (D). Site coordinates are provided in Table 1.

Nittrouer, 2004; Fitzgerald et al., 2008). Additionally, SLR is a key regulator of mangrove productivity, controlling the addition of organic matter at the soil surface and within the active root zone, and by facilitating its preservation through flooding (McKee et al., 2007). The interaction of long-timescale SLR and short-timescale hydroperiod contribute to the depth, frequency, and duration of inundation that control sub/anoxic conditions that are favorable for long-term preservation of SOM. Conversely, if the rate of soil accumulation fails to keep pace with SLR, the wetland surface will gradually become submerged, permanently altering the soil biogeochemistry and structure and functioning of the local vegetation community (Cahoon et al., 2003; Lewis et al., 2015; McCloskey and Liu, 2013).

Soil accretion in coastal wetlands occurs by the net addition of organic and mineral materials resulting from numerous biophysical processes (Furukawa and Wolanski, 1996; Lynch et al., 1989; Nyman et al., 2006), including the following: Mineral sediments are delivered via riverine and/or longshore-tidal transport and storm-surge events (Castañeda-Moya et al., 2010; Smith et al., 2009; Smoak et al., 2013; Whelan et al., 2009). Sources of SOM include the *in situ* production of above- and belowground (root) biomass (Castañeda-Moya et al., 2013, 2011; McKee et al., 2007), benthic algae (McKee et al., 2007; Sanders et al., 2014) as well as contributions of allochthonous material including marine vegetation such as seagrass and macro algae or terrestrial vegetation and upland forest litter (Gonneea et al., 2004). The contribution of organic and mineral materials to accretion is dependent on the quantity, quality, and timing of their delivery or in situ production. Additionally, the size fractions and relative volumes, as well as relative rates of decomposition or dissolution, also influence the accretion contribution of each component.

The relative accretion contributions made by SOM and SIM have been well documented in freshwater, brackish and salt-marsh dominated environments (DeLaune et al., 1983; Turner et al., 2006; Neubauer, 2008; Nyman et al., 1990). Overall, these studies have found that organic matter is the dominant driver of accretion. Similar research is lacking in mangrove wetlands (Callaway et al., 1997). Some exceptions include work that has focused on mangroves trapping and collecting sediments (Furukawa and Wolanski, 1996; Kumara et al., 2010) and the contribution of different types of organic matter production and degradation to accretion and elevation change (Krauss et al., 2014).

Mangroves are distributed along temperate, subtropical and tropical coastlines in a range of distinct geomorphological settings (Woodroffe, 1992; Morrisey et al., 2010), and therefore exhibit highly variable productivity (Bouillon et al., 2008) and availability of mineral sediments. Because of these environmental differences, it is critical to evaluate not only overall accretion rates, but also the relative contribution made by different sources of material in each region. The objectives of this research were to evaluate the spatial variability of accretion rates in mangroves of southwest Florida and the Yucatan Peninsula of Mexico, and subsequently to quantify the relative contributions of SOM and SIM to accretion. Mangroves in south Florida and the Yucatan Peninsula are located in karstic, carbonate platform environments where the direct contribution of mineral sediment by rivers is limited or absent. This contribution contrasts with other geomorphic settings inhabited by mangroves such as river deltas where riverine inputs are the dominant driver of mineral sediment delivery and nutrient loading (Woodroffe, 1992). Specifically, the following hypotheses were evaluated: 1) organic matter is the dominant driver of accretion rates in both regions, and 2) the soil volume contributions made by organic and mineral sediments are additive such that accretion rates will be highest where the combined mass of organic and mineral matter is greatest.