



Sediment geochemistry of organic carbon, trace metals, and total nitrogen across replanted *Rhizophora apiculata* stands of contrasting ages in Singkawang, West Kalimantan, Indonesian Borneo: A baseline assessment

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ABSTRACT

Mangrove sediments store a disproportionate share of blue carbon, yet trace metal behaviour during restoration remains poorly constrained in peat-influenced systems. This study provides a baseline geochemical assessment of five replanted *Rhizophora apiculata* stands (S1-S5, 2015–2019) in Singkawang, West Kalimantan, Indonesian Borneo. Sediment cores (0–60 cm) were analysed for total organic matter (TOM), total organic carbon (TOC), total nitrogen (TN), TOC/TN ratio, eleven metals (Fe, Al, Mn, Pb, Cd, As, Cu, Cr, Co, Ni, Zn), particle size, and biomass carbon. TOC (40–65%) and TOM (43–68%) were exceptionally high reflecting a peat-influenced, allochthonous organic matter source rather than exclusively autochthonous mangrove production. TN was highest at the surface and declined with depth, most markedly at the oldest stand (S1); TOC/TN ratios (50–90) indicated organic matter dominated by vascular plant material. Sediment carbon was the largest ecosystem carbon pool at every station, and total ecosystem carbon stock declined from S1 (~283 Mg C ha⁻¹) to the youngest stand, S5. Fe (~51,900–98,100 mg/kg; 5.2–9.8 wt%) and Al (~99,400–198,700 mg/kg; 9.9–19.9 wt%) reflected the lithogenic, laterite-forming geology of West Kalimantan. All metals with established sediment-quality guidelines remained below CCME thresholds, and low contamination risk (CF, PLI<1; RI<150). Pb showed relative surface enrichment at younger stations against local deep layer backgrounds. Station level multivariate analyses linked geochemical structure to station identity, of which restoration age is one of the correlated factors. These findings establish an associational, space for time baseline for blue carbon accounting and contamination risk assessment in replanted Bornean mangroves.

1. Introduction

Mangrove forests hold a disproportionately large amount of organic carbon compared to their small global area, sequestering about 174 Tg C per year in sediments. This accounts for roughly 10% of total organic carbon (TOC) burial in coastal marine environments, even though they cover less than 0.5% of the ocean surface (Bouillon et al., 2008; Alongi, 2020). This sequestration capacity is primarily determined by the sediment carbon pool, which represents the largest portion of total ecosystem carbon stocks in mature stands. It is maintained through slow

anaerobic decomposition, substantial allochthonous inputs, and the trapping of fine particles beneath dense root systems (Kauffman et al., 2020; Macreadie et al., 2021). The world's largest mangrove forest is in Indonesia, covering about 3.1 million hectares, and has undergone some of the most significant mangrove losses in Southeast Asia in recent decades for commodities (Murdiaso et al., 2015; Goldberg et al., 2020).

Community-based and government-led initiatives have been implemented to combat coastal erosion and restore ecosystem services (Friess et al., 2020; Astiani et al., 2024). In peat-rich coastal systems like those along Borneo's western coast, sediment organic carbon (SOC) processes

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