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Bottom sediments affect *Sonneratia* mangrove forests in the prograding Mekong delta, Vietnam

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ABSTRACT

Mangrove forests exert a strong influence on tropical deltas by trapping sediments discharged by rivers and by stabilizing the substrate with roots. Understanding the dynamics of sediments and morphology in and around mangrove forests is critical in order to assess the resilience of coastlines in a period of accelerated sea level rise. In this research, sediment samples, mangrove forest characteristics, and remote sensing data are used to investigate the relationship between mangroves and sediment substrate in the Mekong Delta, Vietnam. Our data show a significant correlation between percent of sand in bottom sediments and density of *Sonneratia caseolaris* forest. We ascribe this result to higher sediment disturbance in muddy areas that prevents seedling establishment. This correlation potentially allows the determination of substrate characteristics from vegetation attributes detected by remote sensing, despite the impenetrability of the forest canopy. The results presented herein suggest that a supply of sand from the river and hydrodynamic processes moving the sand ashore control the density of the *Sonneratia* mangrove forests at this location, promoting tidal flat colonization and canopy expansion.

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1. Introduction

Mangroves are commonly defined as an association of trees and shrubs forming the dominant vegetation in tidal, saline wetlands, along tropical and subtropical coasts. The ecological, social, cultural, and economic values associated with mangroves have been demonstrated in many studies (e.g. Kuenzer et al., 2011). Mangroves are also among the most threatened and vulnerable ecosystems: the habitat area loss during the last two decades is estimated to be about 36% of the total global mangrove area (Aschbacher et al., 1995; Spalding et al., 2010). As a result, there is an urgent need for conservation and restoration of these delicate environments.

Mangroves interact with sediment deposits through a complex and diversified roots system that varies for different mangrove species. Aerial roots are a common adaptation of mangrove trees to their saline environment, allowing root respiration despite the anaerobic substrate. Because mangroves colonize the shorelines where large rivers discharge, excess input of sediment to mangroves can affect forest health. Field observations show that mangrove trees die when a large portion of their roots are buried under a thick sediment layer (Ellison, 1998), although there is also evidence that some mangrove species can adjust to higher elevations resulting from sediment deposition (Rogers et al., 2005). Other studies show that mangrove propagules are sensitive to burial. Therefore high sediment deposition increases seedling mortality of mangrove species (Thampanya et al., 2002; Duke and Jackes, 1987). As a result, mangrove species and vegetation dynamics are different along prograding shorelines with respect to areas with limited sediment deposition, because sedimentation patterns control elevation and therefore vegetation zonation (Thampanya et al., 2002; Duke and Jackes, 1987). Thampanya et al. (2002) indicate that mangroves from the genus *Sonneratia* are suited for colonizing areas at lower intertidal elevations in Southeast Asia, even in locations potentially subject to abrupt high sedimentation rates.

Retrieving information with regard to the extent and condition of mangrove ecosystems is essential to support the management of these sensitive areas. Typical mangrove habitats are temporarily inundated and sometimes located in inaccessible regions; consequently, traditional field-based survey methods are time-consuming and cost-intensive. Remote sensing provides a cost-effective means to undertake large-scale, long-term monitoring and mapping. Remote sensing has been proven to be highly

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valuable in monitoring and mapping highly threatened mangrove ecosystems (Blasco et al., 2001; Simard et al., 2008; Kuenzer et al., 2011). For example, remote sensing data, often integrated with GIS, has been used to: assess structural and physiognomic parameters in mangroves (Blasco et al., 2001), measure mangrove height and above-ground biomass using SRTM (Simard et al., 2008), establish the impact of shrimp aquaculture on mangrove using SPOT imagery (Tong et al., 2004), and monitor change in extent of mangrove forests (Thu and Populus, 2007).

In this study, the relationships between a mangrove fringe forest and bottom sediments are investigated in the Mekong Delta, Vietnam, by means of a detailed field survey and the Normalized Difference Vegetation Index (NDVI) derived from Landsat images. NDVI is used worldwide to monitor vegetation dynamics, assess both abundance and richness of target species, evaluate the response of vegetation to either land use or climate change, and assess damage after severe storms (e.g. Sims and Thoms, 2002).

2. Materials and methods

2.1. Study site

The study area is a fringe mangrove forest located between the two branches of the Song Hau River, which is one of the main distributaries of the Mekong River Delta in Vietnam. The study area, approximately 170 km southwest of Ho Chi Minh City and centered on 9°30′N, 106°16′E, is located in the northeast part of the Soc Trang province, bordering the Tra Vinh province in the Mekong Delta region (Fig. 1). The Mekong river delta is among the world's largest deltas, encompassing about 39,000 km^2 and supporting tens of millions of people in southwestern Vietnam. The delta is divided in nine distributaries separated by shore-perpendicular delta plains (Tamura et al., 2010).

The sedimentary dynamics of the delta and its coastal evolution have been studied by several researchers (e.g., Nguyen et al., 2000; Ta et al., 2002, 2005; Tanabe et al., 2003; Tamura et al., 2010; Nardin et al., 2016). The Quaternary evolution of the deltaic plain has been driven by spatially variable depositional and erosional events, with some shorelines prograding and some eroding because of the complex tidal regime and wave action around the delta. These events produced a series of sandy ridges, separated by depressions where clay and organic matter accumulated.

The study area is located in an almost flat region, densely populated and intensively farmed: paddy fields, along with shrimp ponds, salt pans and mangroves are the most conspicuous land-use unit in the landscape (Tong et al., 2004). The climatic conditions are moist tropical: the rainy season begins in late May to early July and ends during October to November (Tamura et al., 2010). The fringe forest faces the Southeast Asia Sea and it is influenced by its moderate wave energy and semidiurnal tide with amplitude ranging from 2.2 to 3 m at the coast. In theory, the Mekong River Delta's broad ecological, geomorphological and hydrological conditions are extremely favorable for the development of dense mangrove forests, but human legacies of war, collection of firewood, clearing for agriculture, and, more recently, shrimp farming has heavily reduced the total mangrove area in the delta.

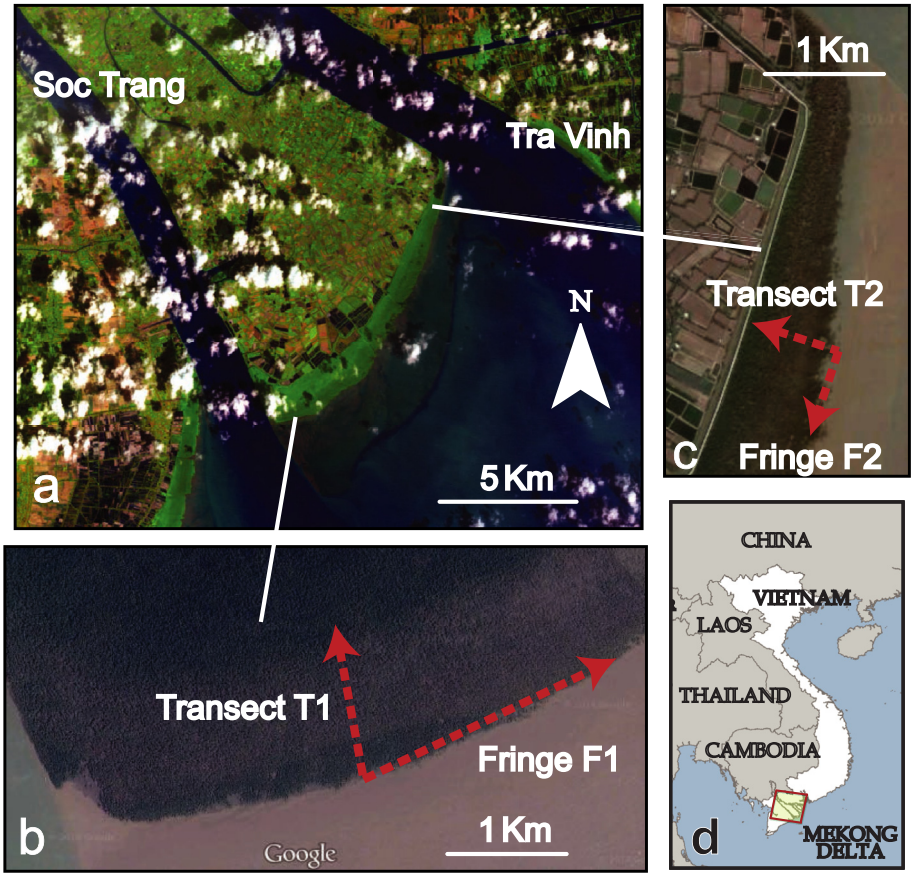

Fig. 1. Study area in the Mekong river delta, a) Landsat 5 ETM image taken on February 11, 2010. The two aerial photographs b) and c) represent the study site with transects location (courtesy of Google Earth, Image 2006 GeoEye). d) Our study site is indicated with a red box. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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