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The Growth of Mangroves in The Created Wetland at Porong River, East Java, Indonesia

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Abstract

Mangrove plantation projects have been established in the created mangrove wetland in the mouth of the Porong River, East Java, in parallel with the construction of reclamation area for LUSI mud dumping area. This study was aimed to assess the growth of planted mangrove in a created mangrove wetland in relation to the environmental parameters, which are sediment salinity, sediment fraction, pore water salinity, pH/eH, and total organic matter (TOM) in the sediment. Periodical measurement of mangrove growth *Avicennia sp.* and the environmental parameters were undertaken in the created wetland and in the mud flats of intact mangrove forest nearby the created wetland as the natural reference in July to November 2012. We found that sediments in the created wetland had different characteristics of sediment fractions, sediment salinity and TOM compared to sediments in the mud flats of intact forests. Sand dominated sediments with low TOM and higher water salinity in the created wetland as compared to those in the mud flats affected growth rate of mangroves in study sites. We suggest that TOM and salinity are important factors that contribute to the growth of mangroves in the Porong River.

Keywords: mangrove, salinity, Porong River, total organic matter.

Introduction

Mangroves are halophytes, distributed along the interface between land and sea. Mangroves provide a range of goods and services to millions of people living the coasts, including support livelihoods for coastal people, protect the coast from storms, provide habitat for marine live and act as bio filtration and carbon storage. However, mangroves have been degraded due to clear cutting for timber production and land conversion to urban expansion, ports, aquaculture and oil palm plantation, and threatened by natural disaster and climate change (Valiela et al. 2001). In order to compensate for mangrove forest losses, mangrove restoration and rehabilitation efforts are increasingly proposed in Indonesia.

Evaluation of functions in restored mangrove forests is an approach to measure restoration success (Mckee and Falukner 2000; Ruiz-Jaen and Aide 2005). Restored system of mangrove forests may or may not function like a natural system (McKee and Faulkner, 2000; Ruiz-Jaen and Aide, 2005), which can be influenced by hydrological and physiochemical factors including tides, waves, river flows (Alongi and Brinkman, 2011), nutrient availability (Reef et al., 2010) and salinity (Ball, 1988). The understanding of how these parameters influence the growth of mangroves is important, but the management and restoration programs of mangroves are lacking in Indonesia.

In this paper the biogeochemistry of mangrove sediments and mangrove growth were assessed in order to understand successional processes of mangrove forests, which include replanted mangroves in created mangrove wetland and intact mangroves in mud flats as the natural reference. The study was undertaken in the created mangrove wetland that was established since 2010 for mangrove restoration in the Porong River mouth, East Java, Indonesia. We compared the influence of salinity and total organic matter on the growth of replanted mangroves in the created mangrove wetland and the mangroves with natural regeneration in the mud flats near the created wetland. The results would be useful to identify successful practices for the improvement of mangrove restoration and rehabilitation initiatives.

Methodologies and Methods

The study area was located in the Porong River (7° 33' 56" S, 112°52' 14" E) in Sidoarjo, East Java. The study sites were characterised by a tropical climate with average temperature of 28 – 32ºC and mean annual rainfall of 2024.47 mm per year in 2010–2012 (Juanda Station Surabaya, BMKG). During the field study in 2012 the dry season occurred in March to September with a total rainfall of 533.40 mm; the wet season occurred in October to February with a total rainfall of 856.10 mm. Since May 2006, this region has been affected by the eruption of the mud volcano LUSI (Lumpur Sidoarjo) that has destroyed large area of human settlement and displaced >40,000 people (Mazzini et al., 2007). In order to minimize the adverse effects of the LUSI, the Porong River has been undergone hydrological alteration, which led to environmental changes (Jennerjahn et al., 2013).

Sediment and water sample collection was conducted during the wet and dry season at five sites, defined as Station I, II, III, IV, and V (Figure 1). Station I and II were located before and at the mud flow outfall, respectively, in the Porong River. Station III was at the mud flats of intact mangrove forest nearby the created wetland in the mouth of the Porong River, which was approximately five meters from the created wetland. Station IV and V were located in the ponds in the created mangrove wetland, which was constructed for LUSI mud dumping and planted by mangroves in July 2011. In addition with sediment and water characteristics, the growth of mangroves was assessed in Station III, IV, and V (Figure 1).

Sediments were collected for the identification of sediment characteristics, which included sediment particle size (sand, silt, and clay content), salinity (sediment and surface water), pH/eH, and total organic matter (TOM). Sediments were sampled using Ekman grab, prepared and stored cool for TOM, salinity, and sediment particle size analysis at the Environmental Quality Laboratory, the Institute of 10th November (ITS), Surabaya. Sediment pH/eH was measured by using handheld soil pH and humidity tester (model DM-5, Japan) and water surface salinity was measured by using multi-parameters water quality checker (DKK – TOA, Model WQC-24, Japan).

The growth of mangroves was assessed by measuring the diameter at breast height (DBH) of mangroves in Station IV and V and the intact mangroves that naturally encroach the mud flats near the created wetland (Station III) in the mouth of the Porong River. The DBH was measured by using Vernier caliper 0.01 mm. Mangroves in the created wetland were replanted in June 2011 (one year before the first measurement), which were dominated by *Avicennia marina*. Mangrove growth monitoring and sediment sample collection were conducted simultaneously on the 12th of July 2012, 4th of October 2012, and 3rd of November 2012.

Mangrove growth was determined based on trunk diameter increment over 12 weeks of observation period and was converted to basal area in $m^2.ha^{-1}$. Mean ± standard deviation was calculated for mangrove growth for each site (N=3 per site). We used ANOVA to determine the effect of site on pH/eH, salinity (water surface and sediment), and total organic matter. Simple linear regression was used to quantify mangrove growth and the relationship between mangrove growth and water surface salinity, sediment salinity, total organic matter (TOM) and pH/eH.

Figure 1. Study sites at the Porong River, which are located before the mud outfall (Station I), at the mud flow outfall (Station II), mud flats in mangrove forest (Station III), and in the created mangrove wetland in the river mouth (Station IV and V). ST = station.

Results

Sediment Characteristics

The sediment particle size of Station I, Station IV, and Station V was dominated by sand, which comprised 77.7%, 88.2% and 88.9% of total sediment contents at those stations, respectively. The composition changed to the mud dominated sediment in Station II and III (at LUSI outfall and the mud flats located after the outfall), with the proportion of 59.9 % (Station II) and 41.7 % (Station III). The sand dominated sediments in Station I, IV and V were consistent with previous study by Nurdiansyah (2011) that showed the major proportion of sand in sediment contents in the mouth of the Porong River.

Sediment TOM, pH/eH, sediment salinity, surface water salinity of mud flats (Station III) and of the created mangrove wetlands (Station IV and V) were measured to assess the relevance of those parameters to mangrove growth. The concentration of TOM was higher in the mud flats (Station III: 4.6% - 6.9%) than in the created wetland (Station IV = 1.1% - 2.1%; Station V = 0.8% - 1.8%) (Table 1), but the values were not significantly varied among the sites (P-value = 0.24). Low TOM in the created wetland (Station IV and V) was concurrent with high proportion of sand in sediment of this area (Figure 2). Sediment pH/eH was not significantly varied among the sites (P-value = 0.33) with the pH ranged from 4 to 6 (Table 1). Sediment salinity was also not varied among the sites (P-value = 0.35) with the highest value of 15.9 to 20.6 ppt at Station V in the created wetland and it was low in the mud flats (Station III = 4.8 to 7.6 ppt). Station I and III had low sediment salinity with values ranged from 2.1 to 4.5 ppt and 0.1 to 3.5 ppt, respectively. Surface water salinity was not significantly varied among study sites (P-value = 0.41). Surface water salinity in the created wetland (Station IV = 31.8 ppt – 36.0 ppt and Station V = 30.0 to 33.4 ppt) was high compared to the salinity in the mud flats in the intact mangrove forest (Station III = 20.5 ppt - 29.2 ppt) (Table 1). Station I and II which are located upstream of the Porong River had lower salinity than Station III, IV, and V. Salinity in Station I and Station II ranged from 0.4 to 4 ppt and 4.3 to10.7 ppt, respectively.

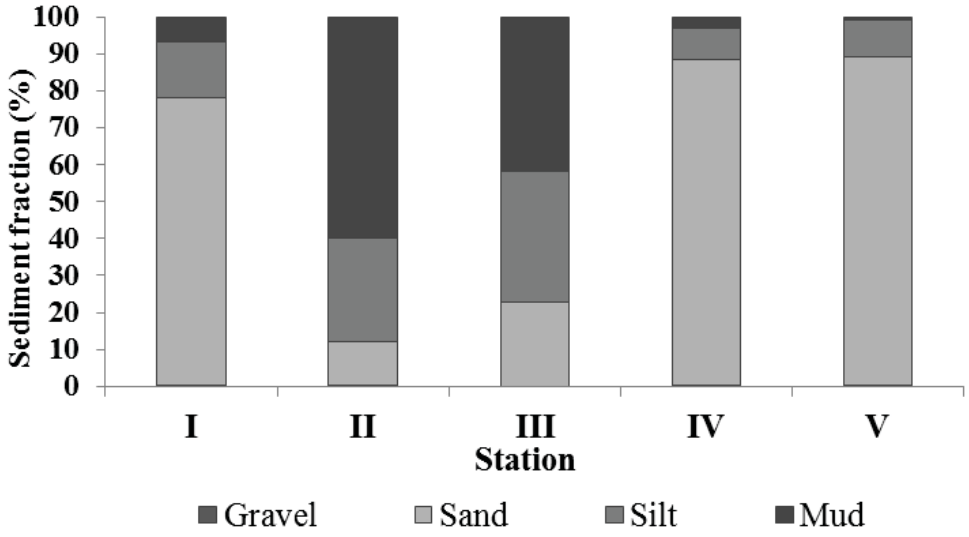

Figure 2. Sediment content at five study sites in the Porong River, East Java.

Table 1. Sediment characteristics, surface water salinity and growth rates of mangroves at the study sites in the Porong River.

Parameters	July	October	November	Mean (± SE)
Sediment pH/eH				
Station I	6.60	3.70	6.50	5.60±0.95
Station II	6.20	4.70	5.80	5.57±0.45
Station III	5.80	6.10	5.70	5.87±0.12
Station IV	6.40	6.00	6.00	6.13±0.13
Station V	6.20	6.40	4.00	5.50±0.77
Total Organic Matter (%)				
Station I	3.51	9.18	5.51	6.07±1.66
Station II	5.05	13.40	8.93	9.13±2.41
Station III	6.13	3.61	7.21	5.65±2.41
Station IV	1.63	1.10	1.84	1.52±0.22
Station V	1.33	1.33	1.06	1.24±0.09
Sediment salinity (ppt)				
Station I	2.25	3.75	3.53	3.18±0.47
Station II	1.13	1.69	1.99	1.60±0.25
Station III	6.99	3.49	8.22	6.23±1.42
Station IV	9.04	5.42	10.20	8.22 ±1.44
Station V	17.94	22.43	14.30	18.22±2.35
Surface water salinity (ppt)				
Station I	5.80	0.30	0.50	2.20±1.80
Station II	13.90	4.00	4.50	7.47±3.22
Station III	17.50	24.50	32.50	24.83±4.33
Station IV	30.00	37.30	34.40	33.90±2.12
Station V	28.40	32.80	33.90	32.00±1.68
Growth rates (cm^2 per year ± standard deviation)				
Station III		515.20 ± 182.60	404.40 ± 128.40	
Station IV		16.80 ± 4.80	13.20 ± 3.60	
Station V		29.40 ± 7.60	23.10 ± 5.90	

Mangrove Growth

Station III was an intact mangrove forest that had existed before the establishment of created mangrove wetland. The average of tree height in this area was 196 cm and dominated by *Avicennia marina*. The ponds in the created wetland are occupied by one-year-old mangroves with the average of trees height of 56 cm (Station IV) and 49 cm (Station V). Over 13 weeks of observation period, the growth of mangroves varied among the sites. Mangroves in the mud flats in intact mangrove forest (Station III) had higher growth rate compared to the mangroves in the ponds in the created wetland (Station IV and V). The growth rate of mangrove in Station III was 404 cm^2 per year, while in Station IV and V of 13 cm^2 per year and 23 cm^2 per year, respectively. The growth of *Avicennia* showed the optimal growth of 24 cm per year at the salinity of 18 ppt.

Surface water salinity and TOM had effect on the growth of mangroves at all sites (surface water salinity: P-value = 0.04; TOM: P-value = 0.05), but sediment salinity and pH/eH had no influence to the growth of mangrove at all study sites (sediment salinity: P-value =0.58 and pH/eH: P-value = 0.99).

Discussion

Sediments in the Porong River varied along the river from sand dominated to mud dominated due to the input of the LUSI mud. Sediments in mud flats consisted of large proportion clay and mud and had higher TOM compared to sediments in the created

wetland. Sediment fraction of the created wetland is similar to Station I located in the upstream of the Porong River, which is dominated by sand. Sandy sediment (large substrate particles) can bind higher amount of oxygen than clay (smaller substrate particles), but had a lower capacity to bind nutrients (Hutchings and Saenger, 1987) which are transported through tides and come into the mangrove system (Davis et al., 2003; Reef et al., 2010), and it commonly consists of low organic matter (Hograt, 1994). Large proportion of mud in the mud flats of the mangrove forest may contribute to higher TOM, which in turn provides suitable environmental condition for mangrove to grow. *Avicennia marina* and *Avicennia alba*, which are predominant in this study sites, are well developed in sandy-mud sediments that have high organic matter. The mangroves in mud flats had higher growth rate in comparison to same species *Avicennia alba* (142.35±6.57 cm per year) in Pak Phanang estuary, Si Thammarat, SE Thailand (Duarte et al., 1999).

The measurement of pH/eH sediments in Station III, IV, and V indicated that the mangroves can grow in acidic condition and the pH/eH values were similar accross all stations. Study of Reef et al. (2010) showed that mangrove sediments are influenced by anoxic, acidic condition and salinity. High anoxic can be caused by low litter decomposition rate (Nedwell et al., 1994). Below ground decomposition of organic matter is an important contributor of nutrients for mangrove growth, particularly during the high tide (Alongi et al., 2005; Lee, 1995). Water salinity in the created wetland was more saline than in mud flats, and this variation has resulted in different growth rates of mangroves in the study sites. Higher sediment and surface water salinity in the created wetland may be resulted from the construction of the ponds that limits the hydrology regime within the mangrove area for water exchange. The influenced of the hydrology on mangrove plantings behind the created mangrove wetland in Porong River mouth provide more appropriate condition for mangrove recruitment and growth (Sidik et al., 2013).

Conclusion

The Porong River was characterised by variation of sediment composition that may contribute to different TOM content of mangrove soil at the study sites. Our assessment showed that TOM and surface water salinity had effect on the growth of mangroves in Porong River mouth. This study demonstrated that combination of higher TOM and water salinity provided suitable condition for mangroves in the mud flats to grow at higher rates than in the created wetland.

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