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An integrated approach to coastal rehabilitation: Mangrove restoration in Sungai Haji Dorani, Malaysia

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ABSTRACT

To achieve an efficient method of coastal rehabilitation, a coastal structure was applied in combination with the mangrove restoration scheme in Sungai Haji Dorani where coastal forest over-cutting associated with erosion has resulted in severe coastline retreat. Such an attempt provides the opportunity to mitigate erosion as well as improve ecological and socio-economic aspects of coastal areas, both of which are of great importance to local communities and authorities. Beach morphological changes were monitored for an eight-month period of time. The results indicate that the attempt has been successful in retaining sediment on the beach and consequently raising the elevation of the site. While the monitoring schedule is required to continue for several years to evaluate long-term performance of the rehabilitation effort, approximately 30% of the transplanted mangrove saplings' survival after eight months shows that the project was moderately successful. Since the general conditions of the selected site represent the majority of the eroded shorelines on the west coast of Peninsular Malaysia, the method applied in this study can be replicated as an appropriate cost-effective alternative for the same cases.

1. Introduction

One of the most important problems in the coastal areas all over the world is erosion which has threatened human activities in the areas exposed to such hazard. Coastline retreat could result in very serious economic, environmental, and social impacts depending on the eroded area.

Over the past decades, as development has taken place in Malaysian coastal states, overlogging and clear-cutting of mangroves along coastlines has made coastal areas exposed to natural phenomena such as tidal inundation, storm surges, currents, and wave action. These pressures have resulted in severe coastline retreat. It has been generally proved that mangroves can decrease the wave energy (Kathiresan and Rajendran, 2005). Although mangroves may not completely halt the coastal erosion, the presence of mangroves reduces the erosion rate (Thampanya et al., 2006). Department of Irrigation and Drainage (DID) of Malaysia (2006) reported that 1414.5 km, 29%, of Malaysian shorelines face erosion impacts. The area of mangrove forests continues to decline at a rate of 1% per year (Gong and Ong, 1990) which means natural rehabilitation process is not capable of effectively recovering mangroves from degradation.

Rehabilitation efforts may be more successful at sites where mangroves previously existed, but the topography of a degraded site may be changed due to erosion/accretion and consequently the hydrologic regime could be altered. Therefore, normal hydrology assessment (depth, duration, and frequency of inundation) of target mangrove species is the most important factor in a mangrove restoration project (Lewis, 2005). In designing a successful restoration project, special attention must be paid to environmental conditions (e.g. hydrology, wave energy, salinity regime, soil and water pH, soil texture, nutrient concentration, elevation, and slope) required by existing natural mangrove species in an adjacent reference site (Elster, 2000; Gilman and Ellison, 2007).

The primary objective of mangrove rehabilitation projects is often to restore structure and functionality of degraded mangroves to a "least disturbed condition" (Lewis, 2005; Gilman and Ellison, 2007). The term "functionality" is taken to mean the ability of restored mangroves to stabilise shoreline, trap sediments, improve shoreline protection, offer suitable habitat for animals, provide timber and firewood, and promote aesthetic value of coastal areas, in a similar way to natural mangroves (Bosire et al., 2008). The current study is aimed to present an integrated approach to mangrove restoration, and its key objectives are: (1) to improve sediment deposition on the restoration site in order to raise the sea floor (datum recovery) to the elevation that provides the correct hydrologic regime; and (2) to restore mangroves to create a sustainable ecosystem that functions at an equivalent level to the adjoining natural mangrove ecosystem. To

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achieve this purpose, the Sungai Haji Dorani (Sg Hj Dorani) beach was selected on which irreversible land use, over-exploitation of mangrove forests, and mismanagement over the past decades have deteriorated the beach to the point that it has been classified in the critical category by DID (2006).

2. Description of the study area

2.1. Environmental conditions

Sg Hj Dorani is located 90 km to the north of Kuala Lumpur, near Sabak Bernam, on the west coast of Peninsular Malaysia (Fig. 1). It is nearly 2.6 km long and has a 1:100 foreshore slope. Bernam River and Perak River both carry huge amount of sediments to the Malacca Strait (Cleary and Goh, 2000), meet the coastline some 40 km away from Sg Hj Dorani. Littoral currents distribute this fluvial discharge over the shoreline to the Sg Hj Dorani beach where destruction of the coastal forest decreases the chance of sediment deposition. Therefore, it was anticipated that mangrove replanting in this area could help with trapping the sediment.

Recently, the muddy beach of Sg Hj Dorani has become subject to engineering and ecological projects on account of the beach critical situation caused by human induced alterations. In 1977, to protect the coastal area against tidal inundation a dyke was constructed along the shoreline by DID. The dyke faced severe erosion during the 1980s. Hence, in 1991, during maintenance, a length of 1.5 km of the seaward slope of the dyke was covered with concrete armour units along the Northern and the Central beaches where the dyke was exposed to the wave action. In order to protect the concrete armour layer from the toe scour, a 5-m-wide rock mat was constructed in front of the toe along the Central beach. Today, the dyke has a crest elevation of 3.20 m above MSL (mean sea level), and the toe elevation is averaged at about +0.75 m MSL. Although the embankment has strongly prevented the shoreline from retreating and protected the agricultural land against flooding, its construction process accelerated mangrove degradation. Moreover, this barrier broke the link between the mangrove and backshore and prevents mangroves from migrating landward. Consequently, the mangrove area has been sandwiched between the dyke from the landward side, and the wave action from the seaward side. In 2006, D'Muara Marine Park's construction activity along the Southern beach destructed the existing mangrove forest in the recreational area. Currently, the mangrove forest is limited to an

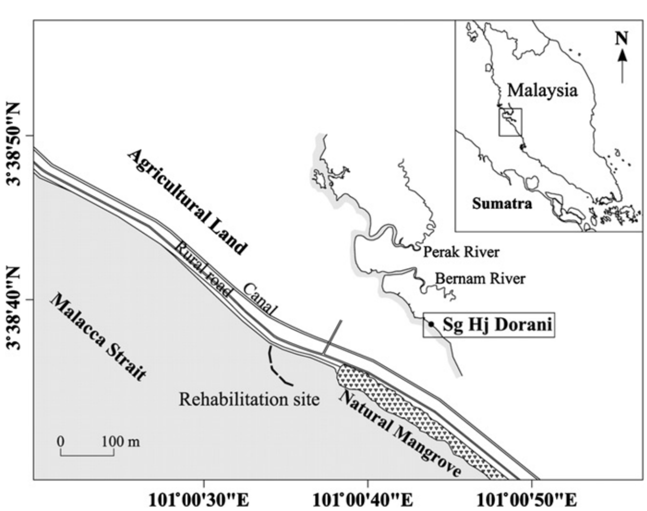

Fig. 1. Study area on the west coast of Peninsular Malaysia.

area between Southern and Central beaches that only covers 800 m of the Sg Hj Dorani beach.

The Sg Hj Dorani beach is predominantly covered by mud deposits. Based on a hydrometer analysis with samples taken from the restoration area at depths of 5–100 cm, the mud contains a mixture of 22% clay (<2 μm), 56% silt, 17% fine sand (coarser than 60 μm), and 5% organic matter on average.

The climate data were obtained from the Malaysian Meteorological Department for a period from 1992 to 2006. The climate of Peninsular Malaysia is mainly influenced by two monsoons during the year; the Southwest monsoon from May to September and the Northeast monsoon from November to March. The period of change between the two monsoons is a transitional period which occurs in April and October. Heavy rainfall often occurs during these two transitional periods (Desa et al., 2001; Suhaila and Jemain, 2007). Tropical climate is experienced year-round with an average annual precipitation of 1790 mm. The relative humidity ranges from 80 to 90% and the temperature averages from 22 to 33 °C throughout the year.

The waves are generally wind-generated waves. The most frequent waves are those from the SW (during the southwest monsoon) and WNW (during the northeast monsoon). The strongest winds occur during the northeast monsoon from WNW with a speed between 10 and 20 knots; winds from the SW, on the other hand, seldom exceed 15 knots. The significant wave height is lower than 1 m around 89% of the time. The significant offshore wave height with a return period of 10 years is 1.50 m. The tidal regime is semi-diurnal with a maximum tidal range of 3.2 m.

2.2. Existing mangrove stands

The existing fringe mangroves consist of a total of 10 species of mangroves or mangrove associates, namely *Avicennia marina*, *Avicennia marina var. acutissima*, *Avicennia alba*, *Bruguiera cylindrica*, *Aegiceras corniculatum*, *Xylocarpus moluccensis*, *Nypa fruticans*, *Excoecaria agallocha*, *Sesuvium portulacastrum* and the fern *Achrosticum aureum*.

Avicennia marina is the dominant species in the study area. Occurrence of *A. marina* trees with heights up to 11 m is common. *Avicennia marina var. acutissima* is not common and occurs in limited numbers. The occurrence of one sapling of *Nypa fruticans* and four small trees of *Xylocarpus moluccensis* in the study area is also noteworthy.

The zonation pattern of mangrove vegetation is distinct in the Sg Hj Dorani study area. *Avicennia marina* occurs in the waterfront for a distance of 5–20 m landward, *Avicennia alba* and *Bruiguiera cylindrica* occupy the second zone for a distance of 4–15 m landward and *Excoecaria agallocha* occurs in the third zone along with *Nypa fruticans* and associate species such as *Thespesia populnea* and *Leucaena leucocephala*. *Sesuvium portulacastrum* is often the ground cover vegetation below *Avicennia* and *Bruiguera* stands. As the area is getting elevated due to sand settlement, wave washed coconut (*Cocus nucifera*) has started germinating and are about 1.5 m in height.

The major reason observed for the degradation of mangroves is the hydrological disruption. The canal behind the mangroves is blocked and the landward area has become elevated due to regular deposition of beach materials such as sand and calcareous material. The substratum below the trees, are becoming more sandy or contain calcareous materials dispersed ashore by waves. The waterways are chocked with rotting wood, plastics and litter. At present in many locations of the mangrove area, the seed/propagule that falls from the mother tree has to fall in the dry to semi-dry land with litter where there is limited chance for germination and establishment.

The mudflats near the mangroves sustain a fair diversity of marine organisms including mudskippers, crabs, barnacles,