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Stand structure, biomass and dynamics of naturally regenerated and restored mangroves in Malaysia

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ABSTRACT

Regeneration of mangroves that occurred within Straits of Malacca over the last 35 years offers an excellent model system to examine how stand dynamics change over time. With exact stand age known, assessment of forest structure, biodiversity and biomass along a natural mangrove development chronosequence provides valuable information to define how long it takes mangrove restoration to return to a natural baseline condition. In natural settings, it is hypothesized that forest structure, diversity and biomass increase with stand age and that these are highest and most complex in intact mangroves. Thus, the study analyzed dynamics in species composition, forest structure and biomass across intact as well as naturally regenerated (NR) stands from 3, 6, 12, 18, and 25 years of age. Intact mangrove stands were structurally more complex and more diverse than younger stands. The preponderance of *A. marina* regeneration that appear for succession gives rise to a high importance value in the study area. The mean for above-ground and below-ground biomass was 71.00 ± 2.30 and 36.07 ± 0.52 Mg ha^{-1}, respectively. Mean individual tree mass to tree density relationship resembles the mean tree weight–density trajectory of self-thinning even-aged plant populations where mean individual tree mass increased with decreasing density. Naturally regenerated mangroves supported higher tree diversity with complex in stand structure compared to restored mangroves, which were basically comprised of *Rhizophora* species. Restored mangroves attain higher biomass in a shorter period of time compared to naturally regenerated mangroves. Mangrove restoration should focus on naturally regenerated mangroves in order to increase carbon sequestration and thus provide climate change mitigation. Ecosystem services, biodiversity and climate change mitigation values need to be considered for both mangrove types as restored mangroves lower tree diversity compared to naturally regenerated mangroves of the same age stand. Therefore it is suggested that sustainable management such as silviculture method might be suitable for naturally regenerated mangroves to absorb more carbon from atmosphere and maintain the higher diversity.

1. Introduction

From provisional (e.g., charcoal timber and fuelwood) (Uddin et al., 2013), to regulating (e.g., flood, storm and erosion control; prevention of salt water intrusion) (Barbier, 2016), to cultural (e.g., recreation, aesthetic, non-use) (James et al., 2013; Thiagarajah et al., 2015), to supporting (e.g., wildlife habitat and fisheries) (FAO, 2007), mangrove forests have far-ranging environmental services and critical ecological functions, affecting both upland and oceanic resources. Located in the ecotone of land–sea–estuary, mangrove ecosystems are heterogeneous habitats that are characterized by highly variable environmental factors such as temperature, salinity, rainfall, tidal currents, sedimentation, and nutrients (Ellison et al., 1999; Ashton and Macintosh, 2002). All these factors exhibit temporal and spatial variations that can act as environmental gradients that determine the distribution and density of species and individuals along the gradients (Lugo, 1980). The ability of

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