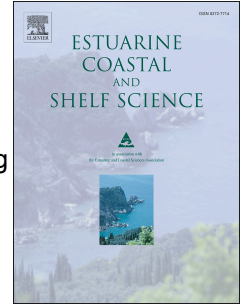


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## Investigating the decline of ecosystem services in a production mangrove forest using Landsat and object-based image analysis

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### Abstract

The Matang Mangrove Forest Reserve is widely recognised as a sustainably managed mangrove forest. However, recently evidence of multiple ecosystem services decline has emerged. The primary objective of this study was to apply remote sensing techniques to assess the impact of the silviculture in the mangrove forest reserve on the provision of ecosystem services. It applied an object-based approach to classify multi-temporal Landsat imagery. The classified images enabled the study to characterise and analyse the spatiotemporal changes in the distribution of stand age composition and structure over a 35 year period. Links were established between the classified images and the ecosystem services assessment based on the assumption that the classification results provided a reliable proxy for an indirect analysis on the temporal and spatial distribution of aboveground biomass of the mangrove forest reserve. The relationship between the potential impacts of the observed changes derived from the classified images with the data obtained from the ecosystem services assessment were analysed. The analysis showed that the fluctuation in greenwood yield was affected by varying rates of regeneration, exposure to excessive thinning and delays in harvesting. The production of blood cockles around the mudflats of the mangrove forest reserve was determined to be influenced by both timber extraction and natural coastal erosion. An undetected ecological change in the late eighties and anthropogenic disturbances were possible key factors behind the decline in the population of the Milky Stork and migratory shorebirds. The study highlights the importance of understanding and managing the trade-offs between wood production and ecosystem services in a managed mangrove forest and provides an important reference for the future management of the Matang Forest Reserve and other multiple-use wetland forests.

Keywords: Ecosystems, man-induced effects, Forest industry, Ecological balance, Satellite sensing

### 1. Introduction

The Matang Mangrove Forest Reserve (MMFR) is the largest tract of contiguous mangrove forest in Peninsular Malaysia. It has been primarily managed for timber production for more than a century (Chong, 2006, FAO, 2007). Apart from being recognised as a well-managed production mangrove forest, it is also one of the best studied mangrove ecosystems in Southeast Asia (Alongi et al., 2004). Over the years, through the integration of new advancements in knowledge and technology, the forest

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