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Effects of different management regimes on mangrove ecosystem services in Java, Indonesia

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ABSTRACT

Over half of the mangroves in Indonesia have been degraded or converted for aquaculture. We assessed the consequences of management decisions by studying the effects of different management regimes on mangrove ecosystem services in Java, Indonesia. A novel typology of management regimes distinguishes five main categories: *natural*, *low intensity use*, *high intensity use*, *mangroves converted for aquaculture* and *abandoned aquaculture*. Eleven specific management regimes were distinguished, based on legal status, management activities and aquaculture indicators. We assessed and verified matching ecological characteristics per regime. We identified key ecosystem properties underpinning service provision and 'state' and 'performance' indicators for seven ecosystem services: food, raw materials, coastal protection, carbon sequestration, water purification, nursery and nature-based recreation. Service provision was estimated and scored for each regime by relating their ecological characteristics with ecosystem service indicators. *Natural mangroves* scored highest for most services, except for food. High food production in *aquaculture* occurs at the expense of other services. Transitions between management regimes were illustrated to show consequences of management decisions. This study shows the merits of quantifying multifunctionality of management regimes in mangrove systems. Our findings contributed to a common vision among Javanese decision makers to include mangrove ecosystem services in their sustainable coastal management plan.

1. Introduction

Indonesia has the largest extent of mangroves in the world (Spalding et al., 2010). Mangroves occur in the intertidal zone and can include both the trees and their ecosystems (Spalding et al., 2010). Mangroves can endure frequent inundation, high wave energy and varied salinity gradients, which makes them highly adaptable to harsh environments (Walters et al., 2008). Since the 1980s, the extent of Indonesian mangroves has declined from 4.5 to under 3 million hectares (Giesen et al., 2006, Spalding et al., 2010). Mangroves are mainly converted into aquaculture, but timber extraction and the expansion of urban areas and agriculture also contribute (Giesen et al., 2006).

Various scientists have used the concept of ecosystem services to emphasise the various consequences of mangrove decline (e.g. Barbier et al., 2011, Rönnbäck, 1999). Ecosystem services are the contributions to human wellbeing (TEEB, 2010) and mangrove ecosystem services include food, fuel wood, coastal protection and nursery for fish and crustaceans. Ignoring mangrove ecosystem services in policy and management decisions is the major reason

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for continued mangrove conversion and degradation (Barbier et al., 2011). Rather than quantifying ecosystem service provision in non-monetary terms (e.g. biophysical, intrinsic values or human dependence), the monetary value of ecosystem services is often emphasised and communicated (c.f. Schröter et al., 2014). Monetary valuation offers interesting insights, but generally ignores differences in underlying environmental and socio-economic properties, and management (Barbier et al., 2011; Rönnbäck, 1999). Therefore, monetary valuation of ecosystem services could be strengthened by quantifying the interactions between as well as the effects of human activities on ecosystem properties and the services they underpin (Barbier et al., 2011).

Land uses in mangrove systems typically relate to the land–water interface and supporting management activities include harvesting wood, replanting mangrove trees but also fishing and aquaculture management. Land use refers to the purpose of management activities (e.g. fish and timber production, biodiversity conservation) and can be influenced by legislation, socio-economic development etc. (Verburg et al., 2013). Management regimes are the bundle of human activities that serve land-use purposes (Van Oudenhoven et al., 2015). Knowing the effects of management regimes on mangrove ecosystem services allows decision makers to assess consequences of decisions and develop management plans accordingly. Empirical evidence on management outcomes is needed to support decision making because many management assumptions have not been tested or verified (Carpenter et al., 2009).

This study assesses the consequences of management decisions in mangrove systems of Java, Indonesia, by analysing the effects of different management regimes on mangrove ecosystem services. Java was chosen because this island is heavily impacted by management activities for different land uses, and many national government decisions are first implemented here. However, data on management, ecological characteristics and ecosystem services is scarce. Based on literature research, we collected key indicators for seven mangrove services, which were selected in agreement with decision makers. We developed a typology of five main and eleven specific management regimes, which was verified by rapid field assessments in Java. The management regime typology and ecosystem services indicators apply to mangrove systems in the context of Indonesian legislation and Javanese management practices and ecological characteristics resulting thereof. The consequences of each management regime for ecosystem service provision were assessed and compared, and we furthermore illustrate transitions between management regimes.

2. Methods

2.1. Research framework

Many factors influence management activities, but policy and decision making are the most important factors (Fig. 1), for instance through issuing fishery licences, allowing mangrove conversion or demanding protection. Management is considered the key driving force that affects ecosystem properties underpinning ecosystem service provision. Driving forces other than management (e.g. climate, seasonality) are also considered for some services. The typology of management regimes helps to systematically select and study ecosystem properties underpinning, and 'state' and 'performance' indicators of ecosystem service provision (Fig. 1).

2.2. Developing a management regime typology

We aimed to develop a typology that could be applied to mangrove systems in Java and, when modified, the whole of Indonesia. The typology was based on scientific literature and Indonesian legislation, which ensured consistency with the Indonesian policy context and international scientific knowledge. The typology's main categories were inspired by Van Oudenhoven et al. (2015) and furthermore based on classifications of global land-use studies by Verburg et al. (2013), Van Asselen and Verburg (2012) and Alkemade et al. (2009), and other studies (see references in Table 1 and footnote in Table 3). The five main categories reflect increasing land-use intensity and overuse (i.e. abandonment): *natural*, *low intensity use*, *high intensity use*, *converted for aquaculture* and *abandoned aquaculture*.

We then developed eleven specific management regimes based on a combination of policy status (legislation), management activities and aquaculture indicators (Table 1). Matching ecological characteristics per management regime were then established for the Javanese context, based on the literature (Table 4). To further confirm that the management regimes would apply broadly to the Javanese context, we conducted a rapid field assessment between December 2012 and January 2013 in three study sites in Java of one to two weeks per location: Banten, Pemalang and Pangpang Bay, Banyuwangi (see Fig. 2). We first conducted informal, semi-structured interviews with mangrove ecology and aquaculture experts, pond owners, fishermen and other local stakeholders, and district government representatives to verify management

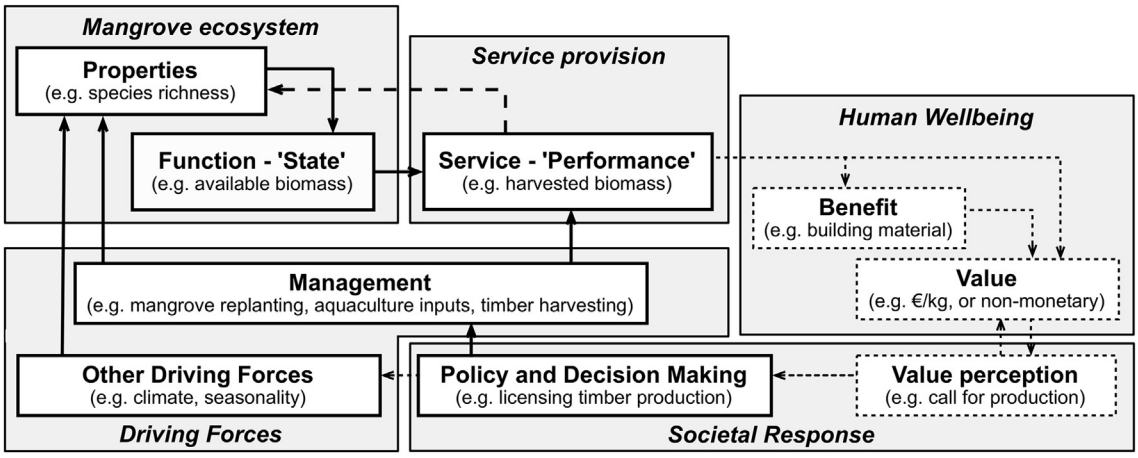

Fig. 1. Research framework, adapted from Van Oudenhoven et al. (2012). Examples between parentheses refer to raw materials provision. Solid arrows indicate direct linkages; dashed arrows indicate potential feedbacks. Boxes and arrows with dotted (out)lines were not considered in our study.