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Integrating ecosystem services supply potential from future land-use scenarios in protected area management: A Bangladesh case study

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ABSTRACT

The establishment of protected areas (PAs) is a key strategy to conserve declining forests and biodiversity worldwide. Due to poor infrastructure and a limited capacity of PA managers, most of the PAs in developing countries fail to achieve their management targets. In this paper, the potential to integrate ecosystem services (ES) into land-use planning was assessed in order to better manage PAs in tropical countries. Firstly, we mapped the relative capacity of different land-use/land cover (LULC) to supply ES in and around the Satchari National Park (SNP) located in northeast Bangladesh. Two alternative scenarios to envisage the likely future supply of ES in the area were then analysed. The study reveals a relatively higher supply of supporting ES from LULC located inside the park compared to the ES supplied from surrounding forests, tea gardens, and oil palm and rubber plantations. Provisioning ES were greater in surrounding forests than from SNP. Both regulating and cultural ES were also higher in LULC within the park. Spatially explicit ES supply assessment and mapping was found to be useful for land use planning and the prioritization of future management actions. Based on our findings, we suggest that PA managers should consider the ES framework as an effective tool for the future-oriented PAs management.

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1. Introduction

Protected areas (PAs) have been rapidly increasing in recent years and now cover more than 15% of earth's surface (Juffe-Bignoli et al., 2014; Geldmann et al., 2013; Jenkins and Joppa, 2009). The establishment of PAs is essential for preserving the last of the world's wild areas (Inostroza et al., 2016). PAs are also central to effectively conserving the declining level of forests and biodiversity worldwide (Mukul et al., 2016a, 2010; Mulongoy and Chape, 2004). The increasing global demand for agricultural and forest commodities, however, creates conflicts and trade-offs between conservation and production, and particularly in the tropical countries (Moilanen et al., 2011; DeFries et al., 2007). Efforts to set aside new lands for biodiversity conservation in this region are compromised by the rising demand for food, timber and other products (Koh and Ghazoul, 2010). In many tropical countries with high population densities, PAs coexist with people in uneasy, tightly coupled and fractious relationships (Mukul et al., 2012; Nagendra, 2008).

In recent years, the ecosystem services (ES) framework has become a focus for many environmental policies and actions (Costanza et al., 2014, 1997; Reyers et al., 2013). Increasingly, efforts are being made to transfer the ES framework to land-use planning and policy-making activities (Fürst et al., 2014). The importance of ES to human well-being is also acknowledged in the Millennium Ecosystem Assessment (MEA) where it was found that globally, the supply and provision of ES is now continuously threatened by human activities including the unsustainable use of biodiversity (Millennium Ecosystem Assessment 2005). The ES framework has much potential to help policy-makers and practitioners to identify, protect and prioritise areas for biodiversity conservation in human-dominated landscapes (Alamgir et al., 2016a; Law et al., 2015; Sohel et al., 2015; Bhagabati et al., 2014; Egoh et al., 2010, 2009), where ecosystem dynamics are driven by anthropogenic factors (Zewdie et. al., 2017). ES are now

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also a significant research topic and there are many modelling and mapping approaches aimed at understanding the stocks, demands and flows of ES at different spatial and temporal scales (Alamgir et al., 2016b; Burkhard et al., 2013, 2012).

Despite the increasing interest in ES in science and policy arenas worldwide (e.g. Helming et al., 2013), it still remains unclear how ES, and particularly changes in ES supply, could be incorporated into the planning and management of PAs (Reyers et al., 2013). Palomo et al., (2014) has suggested that PA managers should incorporate into the decision-making process those stakeholders who value, use or enjoy the ES supplied by a PA. Measuring and managing ES, however, requires a sophisticated systems-based approach that accounts for how these services are generated, how different ES interact with each other, and how changes in the total bundle of services may influence the local ecosystem and/or livelihoods (Nahlik et al., 2012; Raudsepp-Hearne et al., 2010). Mapping and determining the ES supply, their demand, spatiotemporal distribution, and their integration into planning processes and land management is a crucial step for achieving robust and effective outcomes that are widely accepted by diverse stakeholders (Tulloch et al., 2015; Goldstein et al., 2012). Quantification of various ES components, however, is rather expensive and time-consuming (Sohel et al., 2015; Burkhard et al., 2010). Innovative, ready-to-use methods and indicators are required to support the full integration of the ES framework into land-use planning and policy-making (Burkhard et al., 2012).

In this paper, a participatory ES supply and planning approach for PA management (hereafter referred as to ESPA, or ecosystem services in protected area management) was applied using a case study site (i.e. Satchari National Park) in north-eastern Bangladesh. In Bangladesh, like elsewhere in the developing world, sustainable land management and conservation within PAs can only be achieved with the strong involvement of local communities (Mukul et al., 2014, 2012). The proposed ESPA approach involved local stakeholders in the creation of two alternative scenarios to forecast the impact of local decision-making on the supply of ES from one of the most biologically rich PAs in the country. This study is a crucial initial step to formally recognize the potential of ES in the land-use planning and management of PAs in complex human-dominated tropical landscapes where conflicts between management, conservation and livelihoods are common (Mukul and Saha, 2017; Mukul et al., 2012). The objectives of this paper are twofold: 1) to forecast the impact of local decision-making on the supply of ES from Satchari National Park, and 2) to identify the crucial potential of the ES framework for the sustainable land-use planning and management of Satchari National Park. In the following sections we first describe the case study area, followed by an outline of the ES components and how they are mapped and quantified. We then present our main findings and discuss these in context of the current flow of ES supply from contrasting land-use and land-cover (LULC) classes in Satchari National Park and surrounding areas, and how the ES supply potential can be integrated into practice in future PA management. Finally, we discuss the opportunities and challenges for the ES framework to support the planning and management of PAs in other geographical locations.

2. Materials and methods

2.1. The study area

Satchari National Park (SNP) is part of the greater Raghunandan Hills Reserve (RF) within the Satchari Range in Habiganj district, Bangladesh (Mukul et al., 2012, 2010). SNP was declared as a PA in 2005 and is one of the four forest PAs located in the north-eastern part of Bangladesh (Chowdhury et al., 2014; Mukul et al., 2010). It is also one of the five pilot PAs in the country where a co-management initiative has been introduced under the Nishorgo Support Project (NSP) of the Bangladesh Forest Department with the aim of improving the PA management and governance (Rashid et al., 2013; Mukul et al., 2012). SNP is bordered by India on its southern side (Uddin et al., 2013). Within a total reserve area of 1760 ha, the park encompasses an area of about 243 ha (Mukul et al., 2010). The park and its surrounding area has an undulating topography with small hillocks ranging between 10–140 m asl (Choudhury et al., 2004). The annual average rainfall in the area is about 4200 mm, with average minimum and maximum temperatures of 12 °C and 32 °C respectively.

The forests of the area support a rich diversity of flora and fauna, and one of the last strongholds for critically endangered primate the Hoolock Gibbon (*Hoolock hoolock*) and a rare bird the Hooded Pitta (*Pitta sordida*) in Bangladesh (Uddin et al., 2013; Choudhury et al., 2004). The native vegetation of the area is tropical mixed evergreen (Uddin and Mukul, 2007). Other adjoining vegetation types include sungrass (*Saccharum spontaneum*), tea (*Camellia sinensis*) gardens, rubber (*Hevea brasiliensis*) plantations, and agricultural fields dominated by rice paddy (*Oryza sativa*) (Fig. 1). Apart from a relatively undisturbed forest patch of approximately 120 ha located inside the SNP, the other LULC are some old plantations, secondary forest and a combination of both long and short rotation enrichment plantations of teak (*Tectona grandis*), *Acacia* spp., *Eucalyptus camaldulensis*, *Alabizzia falactaria, Aquilaria agallocha,* and *Bambusa* spp., a small oil palm (*Elaeis guineesis*) plantation, and water bodies (Choudhury et al., 2004; Fig. 2). Table 1 shows the extent of different LULC in and around SNP.

2.2. Ecosystem services (ES) components and types

We considered 22 individual ES components modified after Burkhard et al. (2009) under four main ES categories for our study (Supplementary Table 1). We considered only those ES components that were highly relevant to the studied LULC classes available in and around SNP. The four main ES categories used were: a) supporting services, those necessary for the production of other remaining ES; b) provisioning services, the products (e.g. biomass, timber, wildlife, fodder) obtained from a particular LULC; c) regulating services, derived from a particular LULC (e.g. erosion control, flood protection, climate regulation); and d) cultural services, the non-material services (e.g. recreation and aesthetic value) obtained from an LULC as described in the Millennium Ecosystem Assessment (MEA, 2005).

2.3. ES quantification and mapping

Burkhard et al. (2012, 2009) have provided a framework for the mapping and assessment of individual LULC's capacities to provide different ES. For this assessment, we adopted a modified version of this framework. In the original framework, each of the ES were given a relative score of between 0 to 5, with 0 being the lowest indicating no relevant capacity of a particular LULC to provide the corresponding ES, and 5 being the highest and indicating a very high relevant capacity of the LULC to provide the corresponding ES (Burkhard et al., 2012). To quantify a particular LULC's capacity to provide a specific ES (i.e. supporting, provisioning, regulating, cultural ES) the averaged value of the corresponding ES components (e.g. biodiversity, habitat quality, reduction of nutrient loss, storage capacity, and water flows etc.) under that ES category was used (Sohel et al., 2015). With this approach we ensured that the estimation of the ES provision is properly weighted with limited bias.

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