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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 (PA) is a key strategy to conserve the declining forests and biodiversity worldwide. Due to poor infrastructure and a limited capacity of PA managers, most of the PA's 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.

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 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).

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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

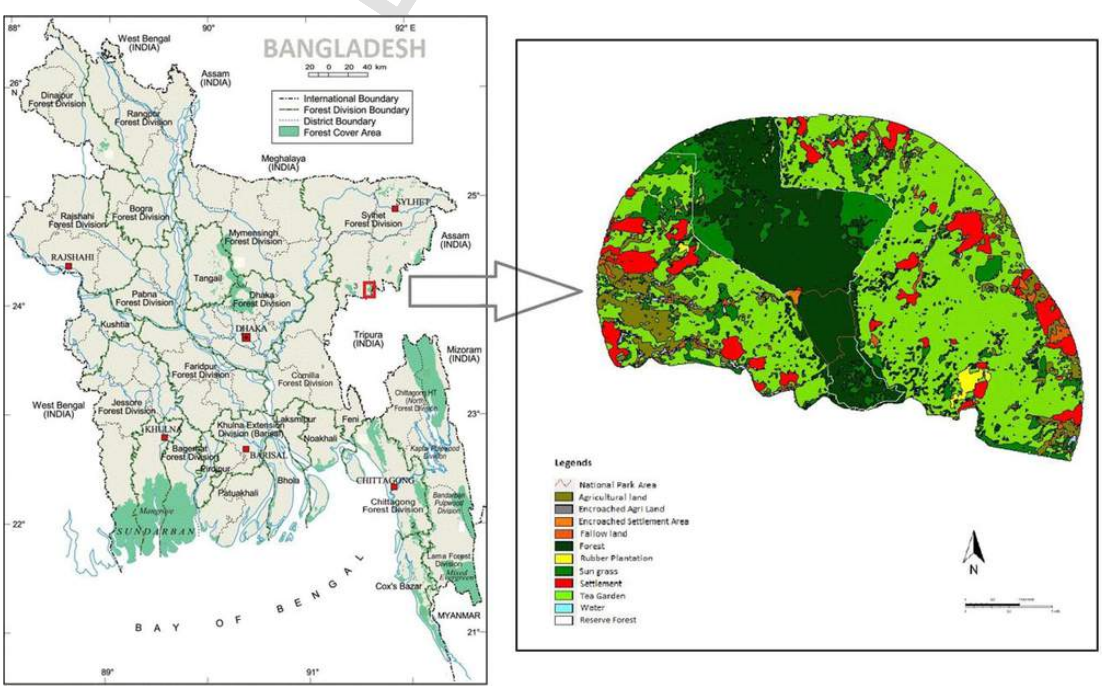

Fig. 1. Location map of the Satchari National Park (SNP) in Bangladesh (left) and the land-use/land cover (LULC) in SNP and its surrounding areas (right). The LULC of SNP and surrounding areas were obtained using a moderate resolution (24 m X 24 m) Indian Remote Sensing satellite image (P6 LISS III) from 2006. A 5 km buffer area around SNP was used.

inside the SNP, the other LULC are some old plantation, secondary forest and 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.

2.4. Participatory assessment, identification and scoring of ES

The Delphi technique which is designed to deal with complex problems within a group of selected individuals was adopted (Scolozzi et al., 2012). A workshop with local stakeholders (n = 20) was organized for the identifica-

Fig. 2. Common LULC in and around SNP, Bangladesh. From top left: (a) primary/old-growth forest, (b) secondary forest, (c) plantation of teak (*Tectona grandis*), (d) tea (*Camellia sinensis*) garden, (e) fallow area, and (f) sungrass (*Imperata cylindrica*). (Photo credits: Sharif A. Mukul).

Table 1
Current land-use/land cover (LULC) in and around Satchari National Park (SNP), Bangladesh.

	Land-use/land cover	Area (ha)	Area (%)	Remark
1	Agricultural land	738.8	7.8	Outside PA
2	Encroached agri land	0.7	0.1	Outside PA
3	Encroached settlement area	10.4	0.1	Outside PA
4	Fallow land	157.1	1.7	Outside PA
5	Old-growth forest	120.3	1.3	Inside PA
6	Secondary forest	89.9	1.0	Inside PA
7	Enrichment forest	1700.0	18.0	Outside PA
8	Old plantation	63.9	0.7	Inside PA
9	Oil palm plantation	24.7	0.3	Inside PA
10	Rubber plantation	54.8	0.6	Outside PA
11	Settlements	637.9	6.7	Outside PA
12	Sungrass	1216.9	12.9	Outside PA
13	Tea garden	4569.9	48.3	Outside PA
14	Water bodies	67.0	0.7	Inside/ outside PA

Source: Nishorgo Support Project (2006).

tion, assessment and scoring of ES from individual LULC in and around SNP. Following a very similar approach to that used by König et al. (2013), the stakeholders were selected based on their familiarity with the SNP and surrounding areas, and their knowledge of the benefits arising from different LULC. Stakeholders included in the participatory identification, assessment, and scoring exercise were: local Forest Department staff, PA managers, tea garden managers, PA co-management committee members, local political elites and local elderly persons (Table 2). During the participatory assessment process, a detailed LULC map of the area was provided to the stakeholders, in the same way this was done during the NSP (2006). Prior to the assessment process, stakeholders were provided with information about the purpose of our study, as well as the nature and types of ES and their components, and the scoring criteria. A photograph of the relevant LULC was provided to the stakeholder(s) when needed to help their recollection of the characteristics of the LULC in the area.

2.5. Scenarios development and ES supply mapping

During the participatory workshop, two alternative LULC scenarios of SNP were developed in conjunction with the local PA stakeholders (Table 3). Scenarios are a useful tool to visualize the development pathways and future options from a defined set of LULC (Beach and Clark, 2015; Alcamo, 2001). Scenario 1 (also referred to as – LAND DEGRADATION: S1 DEG) represent a situation where the fallow land and the current area occupied by sungrass will be converted to human settlement, whilst Scenario 2 (referred to as – LAND RESTORATION: S2 REST) represents an improved land management scenario where the current fallow area and areas occupied by sungrass will be restored to forest using fast-growing species (see Chazdon et al., 2016 for definition) (Fig. 3). The ES supply assessment matrix was integrated with the current LULC map of the area as developed by NSP (2006).

Table 2
Summary of the stakeholders selected for the study.

Stakeholder category	Number (n)	Percentage (%)
FD staff	4	20
PA manager	4	20
Tea garden manager	4	20
PA co-management committee member	4	20
Local political elite	2	10
Local elderly person	2	10
Total	20	100

Table 3
Descrption of the scenarios used in the study.

	Scenario 1	Scenario 2
Scenario name	LAND DEGRADATION	LAND RESTORATION
Abbreviation	S1 DEG	S2 REST
Target year	2025	2025
Main assumption	Loss of forest land and related ES	Gain of forest land and related ES

3. Results

3.1. The current capacity of ES supply in and around SNP

The major LULC in the Satchari area are tea gardens (48.3%), enrichment forest (18.0%), sungrass (12.9%), agricultural land (7.8%), and settlements (6.7%) (Table 1, Figs. 1 and 2). As expected, the capacity of different LULC to provide relevant ES varied considerably across those land-uses. Table 4 shows the assessment matrix that was constructed during the participatory scoring exercise. We found a relatively higher capacity of LULC inside the SNP (e.g. old-growth forest, old plantation) to provide supporting ES in the area. Areas outside the PA and non-forest areas like tea gardens and rubber plantations also provided relevant supporting ES in the area. However, only old-growth and secondary forest maintained the maximum level of biodiversity in the area. Areas occupied for settlements had no biodiversity value while agricultural land, fallow area and rubber plantation had a very low capacity to maintain biodiversity in and around SNP. Natural forests and old plantations had habitat quality highly suitable for biodiversity conservation in the Satchari area. Forest-based LULC performed better when considering the reduction of nutrient loss, storage capacity and water flows in and around SNP. Like supporting ES, provisioning ES was also highest from natural forests followed by secondary forest, old plantations, enrichment forests and tea gardens. However, different ES components under the provisioning ES varied considerably between contrasting LULC in the area and were lower from LULC inside the park mainly due to the restriction imposed by the PA managers to collect forest resources from the area. The supply of biomass, timber and woodfuel were highest from natural and mixed natural forests, whereas only agricultural land had the capacity to provide agricultural crops in the area. The provisions of wildlife were greatest from old-growth forests and old plantations. Old-growth forests also had the highest capacity to supply regulating and cultural ES in and around SNP, followed by old plantations and other forest-based LULC. Certain LULC (e.g. settlements, agricultural land) however had no or very little capacity to supply regulating and cultural ES in the area. The spatial distribution and supply of different ES in and around SNP are illustrated in Fig. 4. It is clear that forest-based LULC always had the highest capacity to supply relevant ES in and around SNP. Tea gardens are prominent among the non-forest LULC that are able to provide comparable ES in the Satchari area.

3.2. ES supply potentials from future LULC in and around SNP

In our study, we used two alternative scenarios where scenario 1 (S1 DEG) involved reduction in land designated for conservation in the area and scenario 2 (S2 REST) portrays a relatively better future with additional land allocated for conservation in the Satchari area. The spatial distribution and ES supply potential from the future possible LULC in and around SNP are illustrated in Figs. 5 and 6. In scenario 1 (S1 DEG), fallow lands and sungrass will be subject to use for human settlements causing losses of relevant supporting, provisioning, regulating and cultural ES in and around SNP (Supplementary Table 2). In scenario 2 (S2 REST), the allocation of lands (that area currently being used for sungrass or fallow land) to be restored as enrichment forest with the long-term aim of developing into old-growth forest will result in superior ES supply potential (Supplementary Table 3).

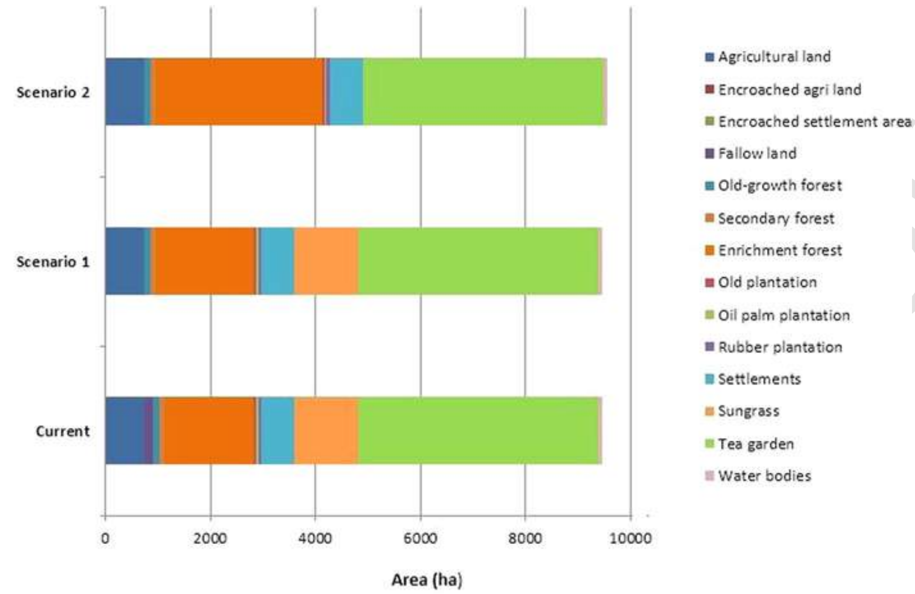

Fig. 3. LULC under different scenarios in SNP and surrounding areas. Where scenario 1 and scenario 2 represent two contrasting situations, respectively LAND DEGRADATION and LAND RESTORATION.

Table 4
Scoring matrix showing the ES supply for specific LULC in and around SNP, Bangladesh.

Land-use/cover	Supporting services	Biodiversity	Habitat quality	Reduction of nutrient loss	Storage capacity	Water flows	Provisioning services	Biomass	Agricultural crops	Freshwater supply	Timber	Fodder	Medicinal plants	Wild fruits	Wood fuel	Wildlife	Regulating services	Erosion control	Flood protection	Groundwater recharge	Climate regulation	Nutrient regulation	Pollination	Cultural services	Intrinsic value of biodiversity	Recreationand aesthetic values
Agricultural land	1.80	1	2	2	2	2	1.00	1	5	0	0	2	1	0	0	0	0.67	1	0	1	1	0	1	1.00	1	1
Encroached agri land	0.80	1	1	0	1	1	0.78	0	5	0	0	2	0	0	0	0	0.33	0	0	1	1	0	0	0.00	0	0
Encroached settlement area	0.00	0	0	0	0	0	0.11	1	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0.00	0	0
Fallow land	1.60	1	2	1	2	2	1.44	2	0	1	1	2	2	2	2	1	1.50	2	2	0	2	1	2	1.00	1	1
Secondary forest	4.60	4	4	5	5	5	4.11	5	1	2	5	5	5	5	5	4	4.33	5	5	3	5	4	4	4.00	4	4
Enrichment forest	4.80	5	4	5	5	5	1.78	1	1	2	0	1	3	5	1	2	4.67	5	5	4	5	5	4	4.50	4	5
Old-growth forest	5.00	5	5	5	5	5	1.67	1	1	3	0	1	3	3	1	2	4.83	5	5	4	5	5	5	5.00	5	5
Oil palm plantation	2.60	2	3	3	2	3	1.33	2	1	0	0	1	1	2	2	3	1.83	2	1	2	3	2	1	3.00	2	4
Old plantation	4.60	3	5	5	5	5	2.67	4	1	2	0	4	4	5	2	2	4.67	5	4	4	5	5	5	5.00	5	5
Rubber plantation	2.60	2	2	3	3	3	1.11	3	0	0	3	0	0	0	3	1	2.33	3	3	2	3	2	1	3.00	3	3
Settlements	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0.50	0	1
Sungrass	1.60	1	2	2	2	1	1.11	2	0	0	1	3	1	1	1	1	1.00	1	1	0	2	1	1	0.50	1	0
Tea garden	3.80	4	3	4	4	4	3.44	5	4	2	4	2	3	3	5	3	3.33	4	3	2	4	3	4	4.50	5	4
Water bodies	1.00	1	1	1	0	2	0.56	0	0	5	0	0	0	0	0	0	1.00	0	2	2	1	1	0	1.50	1	2

4. Discussion

4.1. Current flow of ES supply from contrasting LULC in Satchari National Park and surrounding areas

We found LULC to be key determinants of ES supply in and around SNP. The composition and complex structure of a particular LULC determine its ability to provide multiple ES components in the area. As expected, forest and/or tree based LULC had the greatest ability to provide higher ES and multiple ES components in the Satchari area (Fig. 7). In contrast, LULC that is extensively modified by human activity and/or subjected to human use (e.g. agricultural land, fallow land, settlements) had relatively lower capacity to provide relevant ES and ES components (see also Supplementary Table 2). In a previous study in Bangladesh with comparable LULC, Sohel et al. (2015) also documented the higher capacity of more natural, less disturbed LULC to supply provisioning, regulating and cultural ES, as well as greater ecological integrity. LULC with only single species (e.g. sungrass, rubber, oil-palm plantation) also provided limited ES and ES components in the Satchari area. A similar observation is evident in other tropical multifunctional landscapes where human interests have modified the formerly pristine landscapes to meet diverse goods and objectives (see Burkhard et al., 2015; Law et al., 2015; Sohel et al., 2015). The capacity of forest and other forest-based LULC in and around SNP to provide key ES components such as biodiversity, biomass, timber, fodder, medicinal plants, wild fruits, wood fuel, wildlife, and recreational and aesthetic values are also reported in Mukul et al. (2016a, 2010, 2007, 2006), Uddin et al. (2013), Akhter et al. (2009) and Uddin and Mukul (2007). We also observed a synergistic relationship between different types of ES and/or components in the Satchari area where the supply of one ES type and/or components were compromised by a particular LULC's ability to provide another ES type and/or components. Mukul et al. (2016b), Koh and Ghazoul (2010) and Nelson et al. (2009) have found a very similar situation in the Philippines, Indonesia and

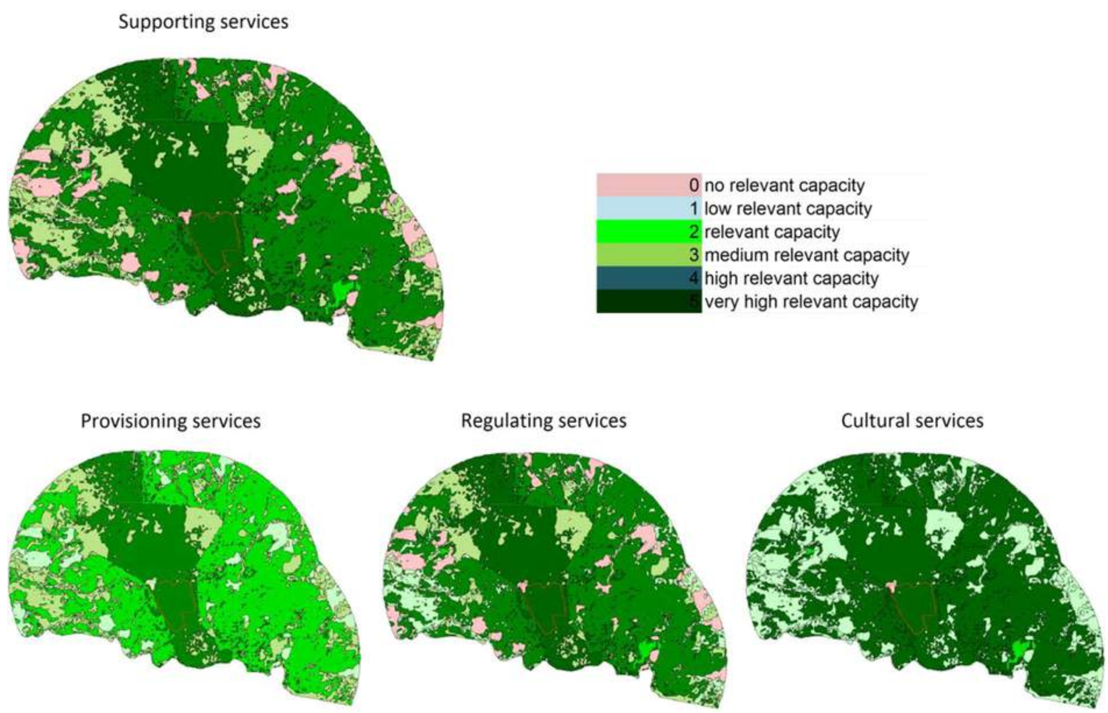

Fig. 4. Spatial distribution of ES supply from contrasting LULC in and around SNP, Bangladesh.

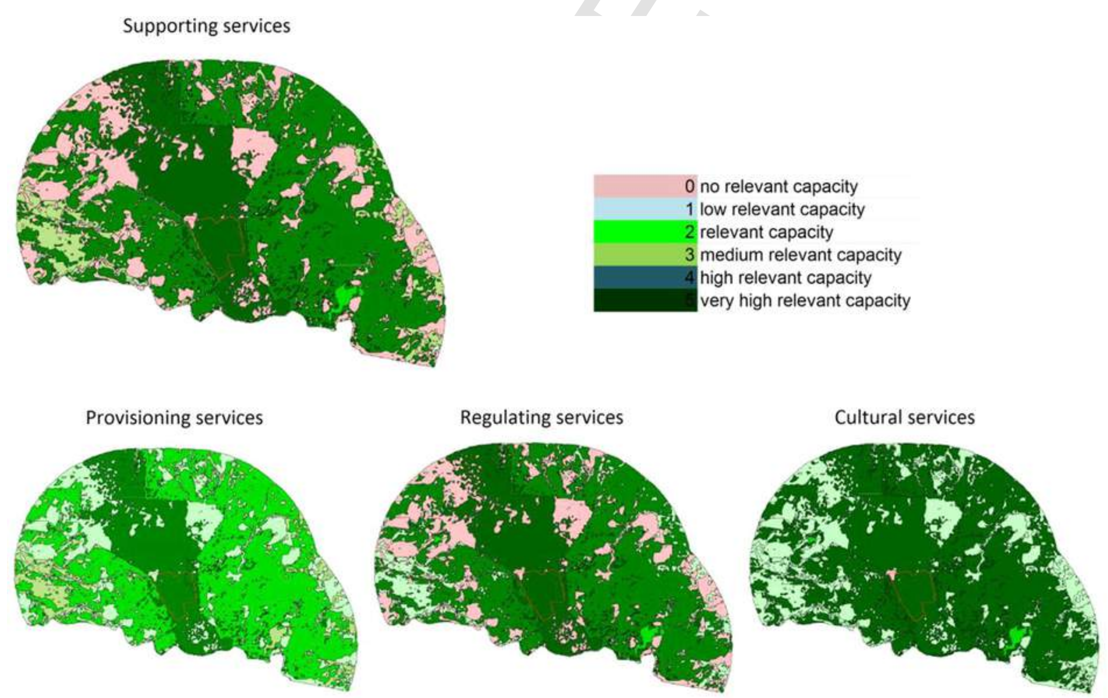

Fig. 5. ES supply potential with scenario 1 (S1 DEG) from in and around SNP, Bangladesh.

the USA, respectively. Similar phenomenon has also been reported by Alamgir et al. (2016a) and Bennett et al. (2009).

4.2. Integrating ES supply potentials from future LULC and PA management

Ideally, PA networks are designed to reduce anthropogenic pressures in areas of high conservation importance (Mukul et al., 2017, 2012, 2010; Palomo et al., 2014, 2013). In human-dominated tropical landscapes, the capacity of LULC to supply ES is, however, continuously shaped by human activity and anthropogenic pressures (Burkhard et al., 2015; Fang et al., 2014; Palomo et al., 2013). Expectedly, we observed a reduction in ES supply potential in scenario 1 and an increase in ES supply potential in scenario 2. However, the changes in ES supply potential were limited to only two major LULC (i.e. fallow areas and sungrass) and not markedly different in other LULC (Fig. 8; Supplementary Table 4). In the cases of fallow areas and sungrass, the transformation from the current scenario to scenario 2 (S2 REST) yielded better ES supply outcomes than the transformation to scenario 1 (S1 DEG). This is largely due to the main focus and assumption we followed during the development of our scenarios.

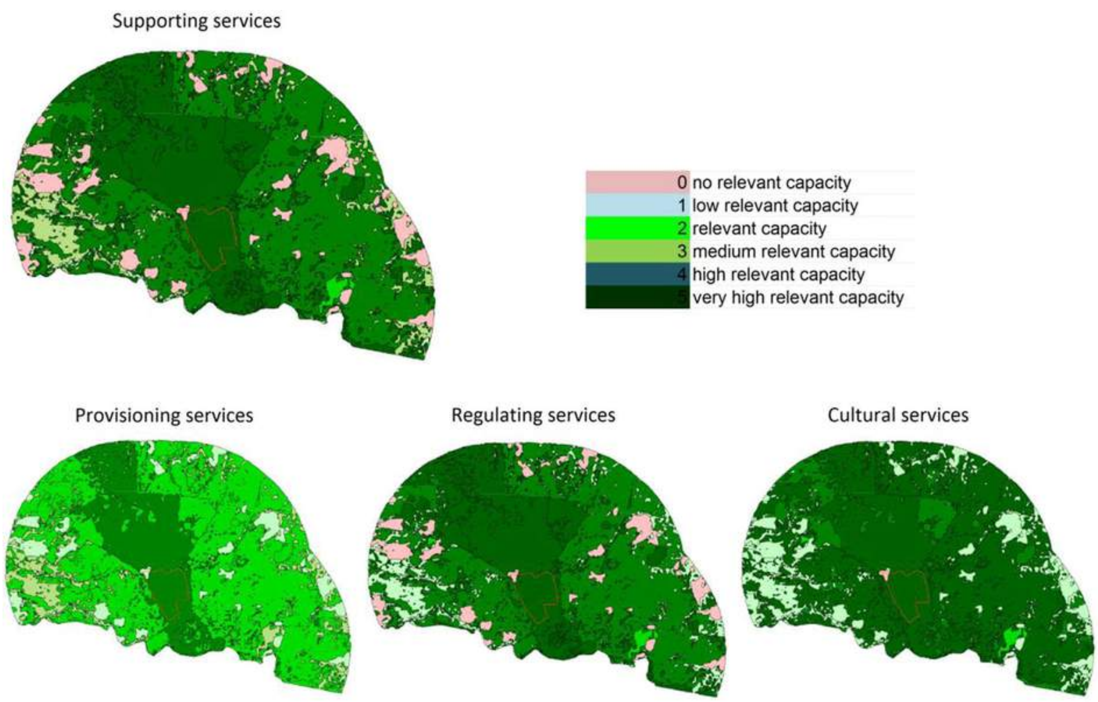

Fig. 6. ES supply potential with scenario 2 (S2 REST) from in and around SNP, Bangladesh.

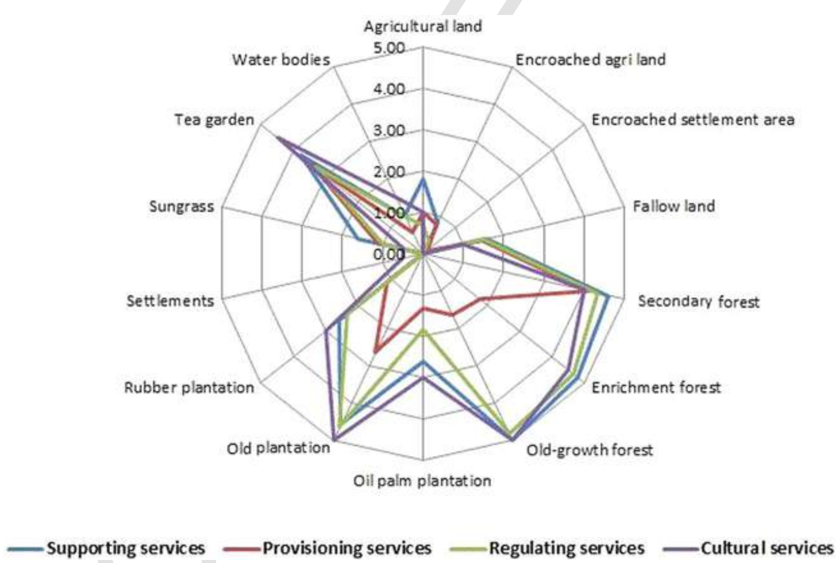

Fig. 7. ES supply from contrasting LULC in and around SNP, Bangladesh.

4.3. Putting ES into practice in PA management

Visualization and integration of social and ecological data using maps and other relevant matrices are increasingly recognised as highly useful for the management and conservation of declining habitat and biodiversity values in the tropics (see Tulloch et al., 2015; Stephanson and Mascia, 2014; Palomo et al., 2013; Reyers et al., 2013; Pressey et al., 2007). Our findings have highlighted that under possible future anthropogenic pressure and use, there is a need to strengthen monitoring and LULC planning and implementation in order to maintain and improve ES supply from in and around SNP. ES assessments and mapping based on consultation with local stakeholders are straightforward, relatively quick and efficient (Burkhard et al., 2015, 2013, 2010, 2009; Sohel et al., 2015; Jacobs et al., 2015). The limitations are mainly due to the landscape complexities that exist in the tropical region and methodological uncertainties, both of which can be overcome by improving and standardizing assessment methods and protocols, and optimizing spatial, geographic and biophysical datasets (see Jacobs et al., 2015; Hou et al., 2013; Estoque and Murayama, 2012).

Overall, using SNP as a case study site we found that the ESPA approach (i.e. ecosystem services in protected area management) is useful for understanding the importance of different LULC and their capacity to supply ES in and around the PA. Our ES assessment and maps clearly depict where in the landscape different ES are generated along with their relative extent and the interactions among them. Integration of ES supply potential with two alternative scenarios in our study has provided insights about future pathways that could generate superior ES and components suitable for the conservation of habitats and biodiversity in and around SNP. The scenarios were also useful to decide management actions that are compatible with the objectives for biodiversity conservation and PAs in the area.

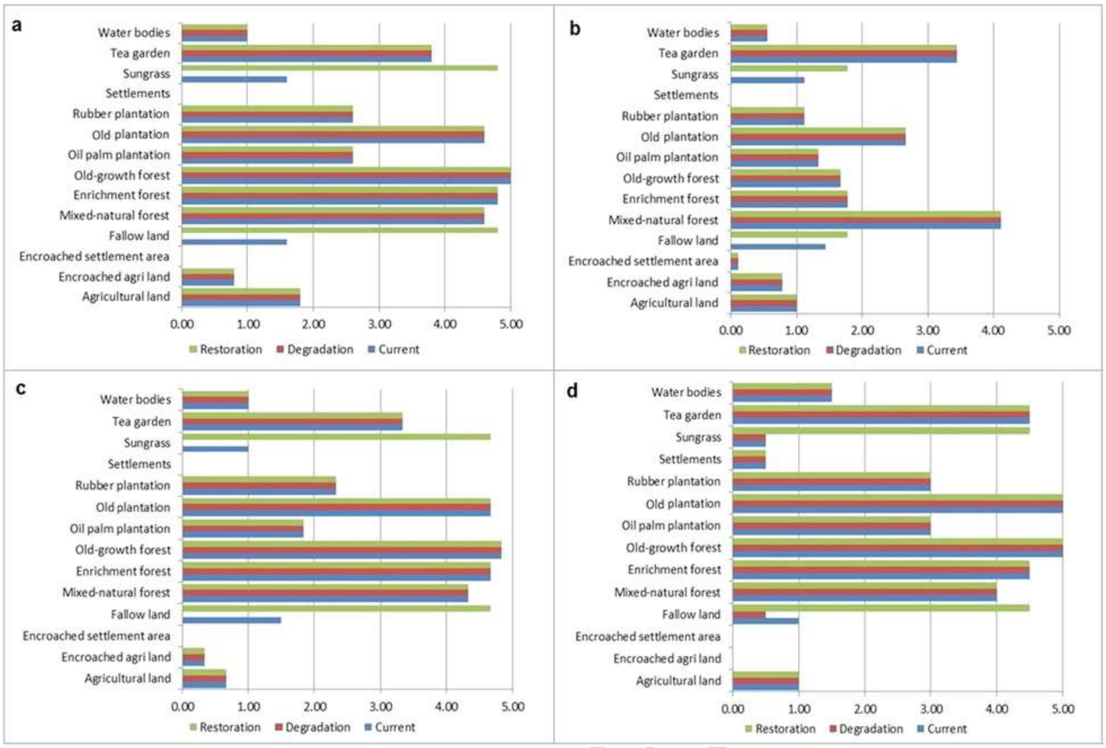

Fig. 8. Changes in ES supply from different LULC in and around Satchari area with contrasting scenarios; where: a) supporting ES, b) provisioning ES, c) regulating ES and d) cultural ES.

5. Concluding remarks

Understanding the relationship between LULC and ES supply is important for improving the ecosystem health and sustainability (Naidoo et al., 2008). To achieve better PA governance and management, stakeholders must reach a consensus about the current ES supply from relevant LULC within and surrounding the PA, and the future goals and expectations of ES supply from the area after considering the local LULC dynamics. As the supply of ES increasingly takes centre stage in the global conservation and development arena, we conclude that ES assessments should be integrated into terrestrial PA planning and management. It is, however, critical to ensure that this integration includes programs that build the capacity of PA managers to effectively assess and map the local and/or regional ES supply. Continuous development, learning, and expanding the diversity and numbers of stakeholders to secure representativeness and greater access to geospatial data in data poor regions of the world are also important for improving PA planning and management (Hou et al., 2013).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecoser.2017.04.001.

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