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Interactions between freshwater ecosystem services and land cover changes in southern Bangladesh: A perspective from short-term (seasonal) and long-term (1973–2014) scale

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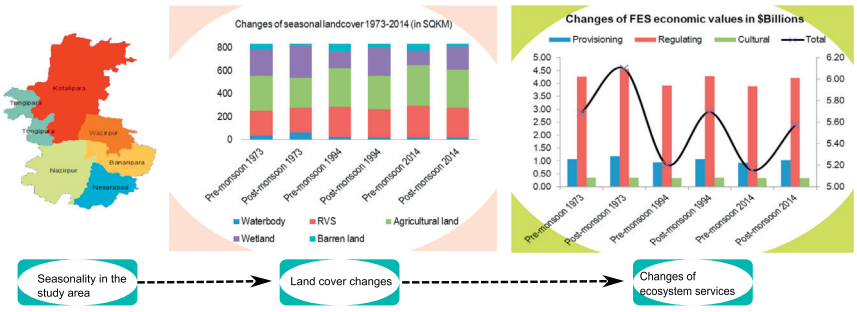
HIGHLIGHTS

- Additional freshwater from monsoon influences the short term land cover change.
- Monsoon and post-monsoon rainfalls increase the supply of regulating FES.
- Low rainfall in the pre-monsoon seasons influences the increase of provisional FES.
- In spite of post-monsoon increase of FES, the long-term supply potential is decreasing.

GRAPHICAL ABSTRACT



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ABSTRACT

We aimed to assess the long-term (1973–2014) and short-term (pre- and post-monsoon) quantities, values and changes of freshwater ecosystem services (FES) in the wetland areas of Southern Bangladesh using land cover change as a proxy indicator. Bangladesh is a sub-tropical country that receives >80% of its annual rainfall during the monsoon and post-monsoon periods, between the months of June and November. Therefore, it could be hypothesized that the monsoon and post-monsoon rainfalls significantly contribute to altering the local land cover, and consequently change the FES. Our multi-stage methodology, among others, included; (i) participatory FES identification (ii) long-term and seasonal land cover analysis using Remote Sensing and GIS, and (iii) assessing FES quantities and values using an expert-developed FES Matrix. The results identified 14 major FES; seven provisioning, six regulating and one cultural service. The results showed that over the last 40 years, significant land cover transformations occurred in the study area e.g. increase of agricultural land, rural vegetation with settlement (RVS) in exchange of wetlands, along with significant seasonal variations include increase of wetland in the post-monsoon seasons and agricultural land in the pre-monsoon seasons. Such changes contributed to the decrease of total long-term FES quantities and economic values including a significant reduction of regulating and provisioning services. Post-monsoon seasons experienced increased quantities of regulating services (e.g. soil fertility, water purification and biodiversity), mainly as a result of additional rainfall, although its overall quantities considerably decreased over the long-term. The results of the study highlighted the importance of prudent land management policies at rural scales for better ecosystem services and conservation.

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1. Introduction

Ecosystem services (ES) can be defined as the benefits that humans obtain from ecosystems to provide human wellbeing in the form of provisioning, such as; consumable and marketable goods; regulating, such as; soil, water, and air management; supporting, such as; nutrient cycling and cultural services, such as recreation. ES are vital to sustain rural livelihoods, particularly in the economically challenged areas of the world (Bhatta et al., 2015). Global environmental changes such as climate change and other anthropogenic stressors such as population growth and urbanization are believed to severely compromise the quantity and quality of ES required to ensure human wellbeing (Huq et al., 2015; Huq and Stubbings, 2015). Therefore, there is a clear demand of assessing the changes of ES, particularly the spatial-temporal extents (Hou et al., 2013; Potschin and Haines-Young, 2013; Wang et al., 2014; Yi et al., 2017), in order to devise sustainable and locally suitable conservation policies to support the billions of rural people around the world through evidence-based decision-making (Huq, 2015; Plieninger et al., 2012).

Despite the importance and recognition, only a handful of ES assessments exist to connect various spatial and temporal scales such as; Cui et al. (2015), Kandziora et al. (2013), Karabulut et al. (2015), Arowolo et al. (2018), and Yi et al. (2018) at the provincial, regional or basin level, Costanza et al. (2014) and Costanza et al. (1997) at global scales, and Burkhard et al. (2015), Burkhard et al. (2010), and Sohel et al. (2015) studied across the local to national levels. Spatial ES assessments include the assessment of ES quantities, economic values and changes over geographical scales. Despite the rich body of ES literature, it rarely includes the valuation of ES, because of the inherent complexities and debates around the valuation methods (Small et al., 2017), which is virtually non-existent in developing country context such as Bangladesh (Rahman et al., 2018). In majority of instances, spatial ES assessment are inherently connected to land cover, which generates supply and production of ES for human benefits and wellbeing (Li et al., 2014; Mukul et al., 2016; Yi et al., 2017).

Arguably, one of the important ES is freshwater ecosystem services (FES), particularly important for the rural livelihoods of the developing world (Bhatta et al., 2015; Coates et al., 2013). Despite such importance, scholarly works on FES, particularly its contribution to livelihoods, changes of FES and challenges are considerably limited than the other ecosystems such as coastal, marine, mountain and urban ecosystems (Boelee, 2013; authors' own assessment and personal communication). The possibility of a freshwater scarce world by 2050 is becoming a reality because of climate change impacts, increasing demand and extraction for human consumption (e.g. agriculture, industry, and energy), may invoke a wave of diminishing freshwater dependent ecosystems, ecosystem services and consequently dependent livelihoods around the world (IPCC, 2014; MEA, 2005; Karabulut et al., 2015). Therefore, particular attention is due to uncover the crucial dimensions such as, spatial and temporal changes of FES to identify short and long-term interactions, trade-offs, quantification and valuation. Particularly, the contribution of freshwater to generate FES, impacts of seasonality on FES generation, and the role of land cover on short- and long-term FES generation are some of the bourgeoning research agendas to efficient management of water resources, ecosystems, and land use.

Bangladesh is one of the deltaic countries which is rapidly undergoing geo-spatial and economic transformations affecting its ecosystems' integrity, especially freshwater and wetland areas of southern Bangladesh (Hossain et al., 2015; Mukul et al., 2016; Huq et al., 2017). Being a deltaic country, Bangladesh is endowed with a vast amount of freshwater resources, which entirely support its agriculture based livelihoods, which is 64.5% total employment and 60 million people are dependent on aquatic resources every day (Faruk, 2015). Bangladesh's aspiration to achieve its sustainable development goals is inseparably linked to prudent planning and use of its freshwater resources and sources (GED, 2011; GED, 2013). Therefore, Bangladesh is an ideal case to investigate some of the aforementioned challenges of FES. One particular concern in this regard is to assess the role of seasonality in FES generation. Bangladesh receives over 75% of yearly rainfall during the monsoon months, from May to October (Loo et al., 2015). Such amounts of rainfall are inevitably connected to the changes of local land cover, agricultural production and livelihood strategies. Consequential relationship exists between land cover and ES, therefore, land cover changes influenced by the seasonal changes and variations such as monsoon may have profound impacts on the supply side of FES, which are rarely studied in the context of Bangladesh. The assessment of seasonality of FES, therefore, needs to be closely studied for evidence-base ecosystem-based decision making, conservation and sustainable land use planning. Using the ES concepts, frameworks and methods in this research, we will identify how seasonality dynamics of FES interact with the local land cover changes whilst identifying the role of water in this process.

Since the publication of Millennium Ecosystem Assessment in 2005 (MEA, 2005), the bulk of ES research are predominantly comprised of delineation and temporal changes of ES quantities, defining qualities of services, mapping of changes and economic value assessments; although without considerable agreement between different methodologies and approaches (Paudyal et al., 2015). Land cover is the primary source of ES generation, therefore, is a widely used indicator to assess the changes of ES on spatial and temporal scales (Tolessa et al., 2017). However, economic assessment always remains at the centre of debate, because of the inherently complex structure of ecosystems and its services e.g. non-marketable characters of ES, contextual values and utility of ES (de Groot et al., 2010; Small et al., 2017). Nonetheless, economic quantification of ES can be an important tool for the policy makers to improve management and governance of ecosystems (Paudyal et al., 2015) which can be equally applied for the freshwater and freshwater related ecosystem services. In case of Bangladesh, there is an even more pressing need for informed environmental policy making, given the background of rapid environmental degradation and rarity of studies on ecosystem services and valuations (Rahman et al., 2018).

Against these backdrops, we conceived three main research objectives;

(i) Assessment of short-term (seasonal) and long-term land cover changes,
(ii) Assessment of short-term (seasonal) and long-term FES changes, and
(iii) Identification of the role of freshwater for producing FES in the wetland context of Bangladesh.

In order to attain our research objectives, firstly, we developed a methodology for linking FES with long-term (1973–2014) and short-term (pre-monsoon and post-monsoon) land cover changes and, secondly, tested the methodology in the wetland area of the middle-south region of Bangladesh to investigate how such changes influence FES potentials, quantities, and values.

2. Study area and methods

2.1. Study area

Wetlands are one of the most significant categories of Bangladesh's landscape and are spread all over the country in various extents. The wetlands of Bangladesh are mainly divided into (a) the *haor* basin of the northeast region and (b) the lowlands of the Ganges–Brahmaputra-Meghna (GBM) flood basin often locally known as "*beel*" (Parvin et al., 2017; Byomkesh et al., 2009). The *Haor* basin is the subject of rich volume of scientific researches, highlighting different aspects of biodiversity, fisheries and livelihoods, whereas the *beels* of the GBM basins received arguably less academic interests. As a consequence, we