Identification and valuation of ecosystem services of the Sundarbans mangrove forest: existing scenario and the way forward towards blue governance in Bangladesh

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Abstract
Characterized by tidal flats, natural levees and the unique Sundarbans mangrove forest, the coastal zone of Bangladesh is regarded as one of the most productive ecosystems of the world due to regular flush of nutrient rich silts and supply of organic matters from the mangroves. Over the last few decades, however, changes in land use pattern including clearing of mangroves for settlement and agriculture, construction of embankments along the coast to boost rice production and conversion of saline water-logged agricultural lands to shrimp farming have redefined the coastal landscape and damaged the ecosystem of the coast and the Sundarbans. The tidal forest provides a wide range of ecosystem services (ES) to millions of coastal people, yet unsustainable extraction of resources and traditional economic development continue further jeopardizing the ES potential of mangroves. Lack of knowledge on the value of mangroves ES are largely responsible for such unsustainable practices. True valuation of mangroves ES is a daunting task because all the services cannot be quantified in tangible monetary terms; consequently, efforts in this regard are lacking. Hence, identification of ES and understanding their interplay are crucial to apprehend the actual value of the Sundarbans and its biosphere-supporting contribution to the dynamic delta. This is also necessary to understand how the mangroves ES are contributing to the wellbeing of the coastal community of Bangladesh whose lives and livelihoods are directly dependent on a healthy ecosystem.

Keywords : Ecosystem Services Sundarbans, Mangrove Forest

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1. Introduction

Being part of the world's largest delta (Gupta, 2017) Bangladesh is blessed with fertile alluvial soils, favorable tropical climate, and readily accessible surface and ground waters that have been supporting diverse agriculture activities for the lives and livelihoods of people living on this soil. Out of the world's 500 million delta-living people, over one fifth live in the Bengal delta (Ayeb-Karlsson, 2016), also known as the Ganges–Brahmaputra delta or the Sundarbans delta (BDP, 2018). The Bengal delta is bounded in the north by the Ganges floodplain and in the south by the Sunderbans mangrove forest, the world's largest single-tract mangrove forest.

In the backdrop of an agrarian economy, the country had to intervene in the coastal area to bring more lands under agricultural activities to ensure food security for an increasing population. Currently, Bangladesh remains one of the most densely populated countries of the world with over 160 million people living on a relatively small land of 147,570 sq. km. Together with high population density, the unique geographic location, low elevation from the sea and overwhelming dependence on nature make it highly vulnerable to climate change. The country is sloping gently from the north to the south, meeting the Bay of Bengal at the southern end to form a 710-km long coastline. According to the Coastal Zone Policy 2005 of Bangladesh, 19 districts out of 64 are in the coastal zone covering an area of 47,201 sq. km., which is 32 percent of total landmass of the country (Fig. 1). Out of these 19 districts, 12 meet the sea or lower estuary directly and are at greater risk of natural calamities and sea level rise (Islam, 2004) that could displace millions living in the coastal districts.

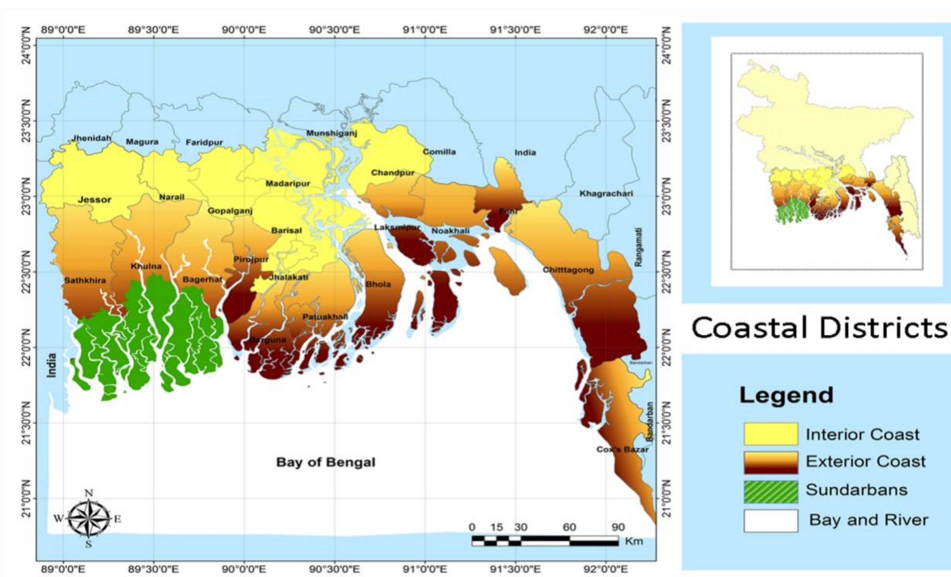

Figure. 1. Map of Bangladesh showing the exterior and interior districts relative to the Bay of Bengal and the Sundarbans mangrove forest

These districts are characterized by a delicately balanced natural morphology of an evolving flat delta, which is subject to very high tides and frequent cyclones from the Bay of Bengal encountering very large sediment inflows from upstream. A large number of rivers, streams, and canals occupying about 7% of the country's surface discharge about 43,000 m3/s alluvial fluids averaged over the year into the Bay of Bengal, constantly forming and shaping a dynamic coastal zone (Chowdhury, 2000; Akter, 2016). Certainly, land and water are the two most precious natural resources in the coastal area of Bangladesh that support economic and livelihood activities of coastal communities. The ecosystem of the coastal area of Bangladesh is quite distinct and tropical in nature supporting various aquatic and terrestrial resources that have been used from time immemorial by the community for their livelihoods. Characterized by tidal flats, natural levees and vast mangrove swamps, the coastal zone of the country is regarded as one of the most productive ecosystems of the world due to regular flush of nutrient rich silts and supply of organic matters from the mangroves.

2. The Sundarbans Mangrove Forest

In Bangladesh, mangroves are locally known as 'Sundarbans', a national pride literally meaning beautiful forest, which in the past, was distributed along much of the coastal belt, but is now mostly confined to three southwest coastal districts: Khulna, Bagerhat and Satkhira (see Fig. 1). Notwithstanding this decline, the Sundarbans is regarded as the largest continuous natural mangrove forest in the world, ten times larger than the second largest (Agarwala, 2003)! The Sundarbans covers an area of 5970 sq. km, which represents about half of the country's total forest cover (Akhter, 2012) with a peripheral buffer zone of an additional 3640 sq. km (IUCN, 2014a). As a unique aquatic ecosystem, about one third of the forest area comprises canals and tributaries while most of the forest remains under water in synchronization with daily and lunar tidal cycles. Owing to its ecological significance, the Sundarbans was declared as the world's 560th Ramsar site wetlands in 1992 and subsequently in 1997 the southern part of the forest was declared by the UNESCO as a natural world heritage site.

The Sundarbans mangrove forest is one of the world's richest biodiversity hotspots and harbors several irreplaceable biomes. Over 500 species of plants, 448 vertebrates including the mighty Bengal Tiger and Ganges Dolphin, about 300 hundred fish and shrimp species and about as many as 240 insect species are found in the biome (IUCN, 2014a). Being blessed with such unique and rich biodiversity, the tidal forest provides a wide range of ecosystem goods and services to millions of people living around the forest. The majority of these people derive their principal income from fishing and related activities while a great many rely on the forest to meet their subsistence needs for fuel and construction materials.

3. Vulnerability Context of the Coast and the Sundarbans

Given the foregoing, it is not surprising to witness anthropogenic pressures on the Sundarbans mangrove forest since ancient times but the major changes that shaped the forest to its current state include clearing of mangroves for human settlement during the past centuries and construction of embankments along the coast to boost rice production during the second half of the 19th century. Anthropogenic changes of the past centuries resulted in confinement of the Sundarbans to three southwest coastal districts while construction of embankments changed the water management paradigm of the entire coast. Large-scale earthen embankments, popularly known by its Ducth term ‘polder’, were constructed during 1960s to protect the coastal lands from tidal inundation and flooding, and to increase rice production. By 1980s, polders became part of the natural setting of coastal Bangladesh with a network of nearly 5,700 km long embankments in 139 polders (Islam, 2004), of which 41 were constructed along the rivers in the upper catchment area of the Sundarbans (IUCN, 2014b).

As mentioned, embankments were built to protect the coastal lands from tidal inundation and flooding, and to increase rice production. Owing to the reality that it was no longer financially viable to cultivate rice because the polders had eventually become waterlogged farmers were compelled to convert crop lands into shrimp farms. Equally important was the fact that during this period, a number of fiscal, financial and institutional supports created an environment that stimulated public and private investments in shrimp industry (Bhattacharya et al., 2005). Shrimp culture is often wrongly associated with mangroves destruction in Bangladesh but this cannot be supported by empirical data although it has had other socioeconomic and environmental consequences. Globally, almost 60 million ha of mangroves have been lost since the early 1980s, of which shrimp culture alone contributed to 38% (Valiela et al., 2001). During this period, Bangladesh also witnessed an unprecedented expansion of export-oriented shrimp farming in mangrove areas that had been cleared during pre-colonial and colonial eras for settlement and agriculture (Hunters, 1875). Thus, unlike other Southeast Asian countries loss of mangroves attributable to shrimp farming in Bangladesh was estimated to be less than 10% of the country’s total mangrove acreage of 640,000 ha (Lindén and Jernelöv, 1980). Nevertheless, the clearing off of an entire 7,500 ha mangrove forest in the southeastern Chakaria coast of Bangladesh for shrimp culture (Hossain et al., 2001) signifies the fact that similar destruction of mangroves would have happened for the Sundarbans mangrove forest had it not been done earlier. The extinction of entire mangroves in Chakaria during the early years of shrimp industry is a vivid example of productionist paradigm rather than integrated coastal planning of the government and the donors. Considering dominance of outsiders at the beginning as an exception, it is reasonable to ascertain that commercial shrimp culture was not a deliberate choice by the traditional crop farmers; rather it was a livelihood transition by the farmers in response to changed landscape and paradigm shift in coastal water management.

In addition to these historical and recent man-made changes, the Sundarbans is vulnerable to extreme weather events in the recent years and anticipated sea level rise in the years to come. Acting as a natural barrier for the coast, the Sundarbans absorb major forces of cyclones and storm surges but the increased frequency and intensity of these extreme weather events are causing extensive damage to the forest as has been witnessed during Sidr in 2007 and Aila in 2009. For example, with a wind velocity of 220-240 km/h the category 5 cyclone Sidr severely damaged 36% of the mangrove forest (CEGIS, 2007). The most recent cyclone, Amphan, hit the southwest region in May 2020 causing extensive damage to the coastal area including the Sundarbans (FD, 2020). The anticipated sea level rise is predicted to alter erosion rates, causing saline waters to flood the forest, shrinking its protective barriers together with the ecosystem goods and services it provides to the coastal community (Hossain et al., 2018).

In spite of its local and global significance the vulnerability of the Sundarbans to climate change and other anthropogenic pressures is increasing while dominance of policies for traditional economic development that impact mangroves continue. Many stakeholders are not aware of the real value of mangroves as valuing the mangrove ecosystem services is a daunting task because all the services cannot be quantified in tangible monetary terms. This makes the contribution of mangroves less visible in markets; consequently, mangroves are generally undervalued in decision-making relating to their use, conservation, and restoration (Brander et., 2012). Hence, identification of ecosystem services and understanding their interplay are crucial to apprehend the actual value of the forest and its significance to the development of the dynamic delta as well as to understand how the ecosystem goods and services are contributing to the wellbeing of the coastal community of Bangladesh whose lives and livelihoods are directly dependent on a healthy and functioning ecosystem.

In this article, we examine the ecosystem services (ES) provided by the Sundarbans mangrove forest, distill available literatures to provide a brief description on past efforts for quantification of ecosystem goods and services into tangible economic terms. We then delve into methodological choices with key uncertainties and assumptions and finally we provide insights into critical knowledge gaps for ES assessment of the Sundarbans mangrove forest.

4. Ecosystem Functions and Services

The Millennium Ecosystem Assessment (MA) conceptualized ecosystem services as contributions from nature to human wellbeing. According to MA, ES is ‘a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit’ (MA, 2005). The Economics of Ecosystems and Biodiversity (TEEB)[1] has played a global role in popularizing ES paradigm and in ‘making nature’s values visible’ (Tinch et al., 2019). De Groot et al. (2002) classified ES into provisioning, regulating, supporting and cultural services. Provisioning services are the natural products that are directly derived from the mangroves (such as timber, fish) whereas regulatory ecosystem services are the benefits obtained from the regulation of various ecosystem processes, for instance, carbon sequestration. On the other hand, cultural services are nonmaterial benefits, e.g. aesthetic beauty, national pride and heritage etc. Table 1 provides a list of goods and services under these four categories that can be obtained from the Sundarbans.

[1] http://www.teebweb.org/

Table 1. Ecosystem services of the Sundarbans

Types of services	Goods and services
Provisioning	Timber, Fish, Building materials, Honey and wax, Fuel wood, Medicinal plants, Fruits
Regulatory	Storm protection, Tidal surge protection, Erosion control, Pollination, Water quality control, Carbon sequestration, Land accretion
Supporting	Soil formation, Nutrient cycling, Primary production, Nursery habitats Biodiversity, Genetic resource pool
Cultural	Tourism and recreation, Spiritual sacred sites, Educational, Cultural heritage

The list provided Table 1 is not exhaustive rather a general one to have an idea of the wide range of ES that Sundarbnas could provide. Articulating all potential indirect but crucial services of the world's largest single-tract mangrove forest in simple qualitative term is not possible without explaining and comprehending the interplay among various services. The Sundarbans act as the important breeding and nursing grounds for a variety of fish, shrimp crab and other aquatic organisms but the aquatic ecosystem also indirectly support other fish that never enter mangrove environments. It is well known that as a tidal forest, rivers, canals and creeks form an integral part of the forest ecosystem, which serve as an important ecological niche for aquatic organisms but waterbodies far from the mangroves do also form integrated ecosystems of high productivity (Ogden, 1997). For example, Ku¨hlmann (1988) found that coral reef functioning and fisheries production depend on the ability of mangroves to control water quality in terms of trapping and assimilating sediments. Similarly, about 80% of all marine species of commercial value in Florida, USA, have been estimated to depend upon mangrove estuarine areas (Hamilton and Snedaker, 1984). While empirical data in this regard are lacking for Bangladesh, conventional wisdom suggests that the fisheries resources of the entire coastal rivers, estuaries and marine waters depend on many supporting and regulatory services of the Sundarbans.

5. Economic Valuation of ES

The concept of economic valuation of resources is enshrined in the foundation of welfare economics and the concept of externality introduced by Pigou (1920), which refers to the sustainable well-being of people due to use and/or existence of a resource (see Pearce (2002) for the conceptual background and history to the development of environmental economics and economic valuation). Following the seminal work by Costanza et al. (1997) and, as mentioned previously, the subsequent global campaigns by MA and TEEB, valuation of ES has received unprecedented attention in the last two decades (Bateman, 2013; Kareiva, 2008; Tinch et al., 2019). Economic valuation of ES is a complex process because apart from the provisioning services which have traditional commodity markets, valuation of services belonging to other three categories remain subjective. This is because many of these ES have the characteristics of 'public goods' such that the people who benefit cannot be excluded from receiving the service provided (e.g., habitat and nursery service supporting fisheries); and that the level of consumption by one beneficiary does not reduce the level of service received by another (e.g., barrier to storm surges and coastal protection) (Luke et al., 2012).

Due to these characteristics, incentives to sustainably manage mangrove ES is limited and markets for such services do not exist. As a result, these ES are generally overlooked or undervalued in both private and public decision-making relating to their use, conservation and restoration (Luke et al., 2012; Tinch et al., 2019). Even for the provisioning services where market prices do exist, the complexities of market structure often do not reflect the true opportunity cost of the resources undermining their actual prices. This type of neglect toward the assessment of ES can be best represented by the water-diamond paradox. Water is essential for life, still little value is attached to it, diamond is not important to maintain our quality of life at all; however, it has a great monetary value (Heal, 1999).

The lack of understanding of the values of all ES of mangroves may lead to their omission in public decision making. Without information on the economic value of mangrove ES that can be compared directly against the economic value of alternative public investments, the importance of mangroves as natural capital tends to be ignored (Brander et al., 2012). The objective of finding values of ES is to objectively determine the ultimate price the human being will have to pay or sacrifice without their services. A number of studies have developed and applied different methods to calculate the monetary value of ES of mangroves and other natural resources (Tinch et. al, 2019). Values for goods and services traded in markets are generally estimated through observed prices. Where market values cannot be used or adjusted, there are two main approaches to valuation: revealed preference (actual market scenario) and stated preference (hypothetical scenario).

Revealed preference methods analyze relationships between demand for some market goods and preferences for related non-market goods/services. These methods only work if changes in provision of the non-market good have an observable impact on the demand for a market good (Tinch et al., 2019). Examples include production function method (value of pollination can be estimated based on the value and quality of the timbers, honey), cost-based (damage avoided, replacement and substitution costs; value of improved water quality, water purification, erosion protection, storm protection, and habitat and nursery services), hedonic pricing methods (value of aesthetic beauty) and travel cost method (recreational value). Stated preference methods include contingent valuation and choice experiments and based on surveys which create hypothetical markets for respondents to express their preferences. In contingent valuation method, respondents are asked how much they are willing to pay (WTP) to maintain pristine quality of mangroves or willing to accept (WTA) compensation for its deterioration. In choice experiments, respondents are asked to express their preferences among alternatives comprising different combinations of the goods and services of an ecosystem.

Revealed preference methods are based on actual market behavior of users of ecosystem goods and services. However, their applicability is limited only to a few ecosystem goods and services. On the other hand, stated preference methods can be applied to all types of ecosystem goods and services but their application is complex and resource consuming. Nevertheless, these are the only methods to obtain non-use values of an ecosystem such as biodiversity of the Sundarbans. Besides, the main advantage of stated preference methods is that they can elicit scenarios that are yet to occur, therefore providing *ex ante* information on expected WTP to inform the design of future policies (Tinch et al., 2019). However, WTP method is highly controversial due to its propensity towards biased response. Critics argue that hypothetical questions generate hypothetical, invalid responses. The fact that valuation based on WTP do not vary with the scope or quantity of the goods and services of ecosystem (Veisten et al. 2004) makes the outcome, according to Hausman (2012), as 'dubious to hopeless.'

Choice experiment method has been developed to address the above limitations of WTP. In choice experiment method, potential goods and services are described in terms of their environmental as well as cost attributes, each taking different levels in each scenario. Information on the values that people assign to improvements in the different goods and services are indirectly inferred from the trade-offs that people are willing to make when choosing their preferred alternatives (Tinch et al., 2019). Several authors have successfully applied this approach to estimate WTP for valuation of natural resources including mangroves (Iqbal, 2020 and references cited therein). The benefit transfer or, more appropriately, value transfer method is an alternative to stated preference and revealed preference methods, as it typically requires less resources and time (Brouwer, 2000). However, it is not a valuation method *per se* as it only uses values estimated in other similar valuation studies to estimate the value of goods or services by using correction factors or meta-data analysis. Nevertheless, from a practical point of view the use of value transfer to provide information for decision making is advantageous over conducting primary research to estimate ES values.

A detailed description of each of these methods is beyond the scope of this article. For a comprehensive overview and summary of studies undertaken so far to investigate the ES of mangroves readers are referred to Vo et al. (2012) where the authors provide a detail description of different valuation techniques and illustrates applications with examples drawn from empirical studies. Employing one or the other method will depend on the objectives of the study and of the degree of familiarity with the different methods. The final selection of the method depends on many factors, like: (i) type and number of objects to be valued; (ii) relevant population (e.g. users or non-users or both; geographical scope (local, regional, national, international); (iii) data availability (e.g. restricted data access – data on house values); (iv) available time and financial resources; (v) team (e.g. experience).

6. Valuation of the Sundarbans ES

Until now, most of the economic valuations were conducted for terrestrial ecosystems while coastal ecosystems have received comparatively less attention and, in most cases, mangroves were considered as a subset of the coastal ecosystem (Liquete et al., 2013; Barbier et al., 2011). As critiqued by Mukherjee et al. (2014), 'mangroves are either combined with tidal marshes (wetlands) in Costanza et al. (2014) or divided into 'tropical forests', 'coastal systems' and 'coastal wetlands' in de Groot et al. (2012).' Certainly, literature on economic valuations of Sundarbans is further limited. To date, there are only three studies that dealt with valuation of ES specifically targeting the Sundarbnas mangrove forest of Bangladesh (Uddin et al., 2013; Haque and Aich, 2014 and Rahman et al., 2018).

Using official records of revenue collected by the Forest Department during 2001-2010, Uddin et al. (2003) estimated the value of major provisioning services (timber, fuel wood, thatching materials, fish and honey) and cultural service (tourism) of the Sundarbans amounting US$ 1.39/ha/year. While this estimate captures only a small fraction of the whole range of ES, Haque and Aich (2014) considered the figure as being grossly undervalued since the timber and tourism prices are regulated. In fact, revenues collected by the Forest Department are license/permit fees and therefore do not reflect the market price of the products at all. Rahman et al. (2008) interviewed 100 households inhabiting three villages near the Sundarbans who identified energy, storm protection, fish habitat and aesthetic beauty enjoyment as the most important ES of the forest. Based on market price and WTP methods involving four provisioning services including capture fishery, fuel energy, fodder and honey, two regulating services (storm protection and erosion control) and one supporting service of habitat for fish breeding and nursery service the authors estimated that an economic value of US$ 1159/ha/year could be derived from these services.

Haque and Aich (2014) reported that the Sundarbans generate ES worth about US$ 450-1000/ha/year. However, the authors did not employ any economic valuation method. Instead they relied on a Delphi panel to assign weights to perceived ES based on several development projects being implemented in the Sundarbans as well as on triangulation with data derived from three global meta-analysis of mangroves ES (Costanza, 1997, Groot et al., 2012; and particularly, Brander et al., 2012). Quite recently, Iqbal (2020) adopted choice experiment method to elicit stated preference data and measure WTP to provide further insight into the ES value of the Sundarbans as perceived by the villagers.

Although these studies provide some insights in the range of values that may be assigned to the ES provided by the Sundarbans, they are all context specific and do not provide a more generic insight in the values of mangroves. This calls for collaborative research that combines mangrove ecologists/biologists and environmental economists to jointly model the provision and value of ecosystem services from mangroves. Multidisciplinary efforts are also necessary to determine the optimum limits of sustainable yield of the services under different socio-economic condition and climate change scenarios. Likewise, there is need for economic valuation studies that explicitly focus on mangrove resources that are not marketed, but rather harvested and consumed directly by coastal households. Equally important is to understand ecosystem functioning and its responses to environmental and anthropogenic pressures within the purview of changing climate and anticipated sea level rise. Research that incorporates multi-year time frames and historical perspectives are particularly relevant given the rapid socio-economic and environmental changes surrounding the Sundarbans and along the entire coast. This is particularly the case given the renewed interest in the blue economy implementation in Bangladesh is considered as a new horizon for development, which got momentum after the resolution of maritime boundary disputes over neighboring countries.

7. Conclusion

This article provides a contextual overview on the anthropogenic and natural factors driving land use and land cover changes in the coastal areas of Bangladesh, in general, and in the Sundarbans mangrove forest, in particular, with an inevitable consequence on the lives and livelihoods of the climatically stressed southwest coastal community. Maintaining the pristine quality of the Sundarbans mangroves is central to the livelihood and wellbeing of the coastal communities who depend on and benefit from the wide services provided by the unique aquatic wetland forest. While past anthropological activities and unsustainable use contributed directly to the degradation of the Sundarbans, the current lack of understanding of the services in quantitative terms and their monetary value is considered crucial towards informed decision-making regarding the sustainable use.

A growing body of literatures suggest the numerous goods and services provided by coastal ecosystem in general and by the Sundarbans mangrove ecosystems in particular. Qualitative narratives of these resources are often less persuasive in decision making than quantitative valuation. Yet efforts towards valuing these resources are limited. Translating the value of ES into more explicit monetary terms requires methodology that is able to measure and value not only the substantive provisioning goods that can be obtained from the ecosystem, but also the importance of those supporting, regulating and cultural services that are less amenable to direct economic valuation.

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