How Worthy is the Sundarbans Mangrove Forest? An Exploratory Study

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ABSTRACT

Sundarbans mangrove forest carries an enormous value to local and global context. It provides various ecosystem services primarily to local communities and broadly to global communities. For instance, the Sundarbans offers livelihood, recreational facilities within local territory and carbon sequestration at the global scale. Based on previous studies, the paper discusses different ecosystem services of Bangladesh Sundarbans from the socioeconomic viewpoint and compares the total economic value of Sundarbans mangrove forest with that of other mangroves in the world. Among others, this paper recommends for sustainable management of forest to attain full benefits of the Sundarbans mangrove with least ecological damage.

Keywords: Sundarbans mangrove forest/ Ecosystem services/ Biodiversity loss/ Socioeconomic valuation
Received: 29 January 2015 Accepted: 1 March 2016
DOI:10.14456/ennrj.2016.3

1. INTRODUCTION

The Sundarbans mangrove forest (SMF) is one of largest mangrove forests in the world. It covers 10,000 km^2 of land and water within the Ganges Delta, with some 62 percent located in Bangladesh and the remainder in the Indian state of West Bengal. SMF is famous for its biodiversity having variation in both floral and faunal species. Among floral species, a total of 334 plant species under 245 genera were recorded in the Sundarbans in 1903 (Prain, 1903).Later, Chaffey and Sandom (1985) recorded 66 species in the Bangladesh Sundarbans from 37 families. The Sundarbans flora is abundant with sundari (*Heritiera fomes*), gewa (*Excoecaria agallocha*), goran (*Ceriops decandra*) and keora (*Sonneratia apetala*) all of which occur prominently throughout the area (Table 1).

Table 1. Biodiversity in the Sundarbans mangrove forest (Hendrichs, 1975; Blower, 1985; Chaffey and Sandom, 1985; Acharya and Kamal, 1994)

Type of species	Local name/ english name (scientific name)
Major plant species	Kankra (*Bruguiera gymnorrhiza*), Goran (*Ceriops decandra*), Gewa (*Excoecaria agallocha*), Sundari (*Heritiera fomes*), Spear grass (*Imperata cylindrica*), Dhanshi (*Myriostachya wightiana*), Golpata (*Nypa fruticans*), Nol kagra (*Phragmites karka*), Keora (*Sonneratia apetala*), Dhundul (*Xylocarpus granatum*), Passur (*Xylocarpus mekongensis*).
Major animal species	Mammals: Royal Bengal tiger (*Panthera tigris tigris*), Spotted deer (*Axis axis*), Rhesus macaque (*Macaca mulatta*), Wild boar (*Sus scrofa*), Otter (*Lutra perspicillata*). Birds: Herons, egrets, storks, sandpipers, curlew, woodpeckers, barbets, shrikes, drongos, mynas, minivets, babblers. Reptiles: Estuarine crocodile (*Crocodylus porosus*), cobra, the green pit viper, the rock python, sea snakes. Fishes: Pangas catfish (*Pangasius panagasius),* Hilsa shad *(Hilsa ilisha),* Bhetki/ barramundi *(Lates calcarifer),* Giant river prawn/ fresh water prawn *(Macrobrachium rosenbergii).*

The name of the Sundarbans probably derived from the tree species sundari (*Heritiera fomes*). New forest accretions are often conspicuously dominated by keora (*Sonneratia apetala*) and tidal forests. It is an indicator species for newly accreted mud banks and is an important species for wildlife, especially spotted deer (*Axis axis*). There is an abundance of dhundul (*Xylocarpus granatum*) and kankra (*Bruguiera gymnorrhiza*) though distribution is discontinuous. Among palms, dhanshi (*Myriostachya wightiana*) and golpata (*Nypa fruticans*), among grasses spear grass (*Imperata cylindrical*) and nol khagra (*Phragmites karka*) are well distributed.

Variations in faunal species of the Sundarbans are also distinctive as it forms a uniquely rich ecosystem, famous for its tiger (*Panthera tigris tigris*) population of 350 found from the survey conducted in 1975. Major animal species as reported in reconnaissance survey are shown in Table 1 and there has seldom been carried out the detailed survey on population. About 50 species of mammals (*Mammalia*), 300 species of birds (*Avifauna*), 50 species of reptiles (*reptilia*), 8 species of amphibians (*amphibia*) were reported from the Sundarbans (Hendrichs, 1975; Blower, 1985; Rashid et al., 1994).

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The Sundarbans water also supports 53 species of pelagic fish, 124 species of demersal fish, 24 species of shrimps, 7 species of crabs, 2 species of gastropods, 6 species of pelecypods, 8 species of locust lobster and 3 species of turtles (Acharya and Kamal, 1994). In the Sundarbans, insects including local honeybee (*Apis dorsata*) are also available, a few of them are economically important. The Sundarbans reserved forest lies in between the latitudes 21°30'N and 22°30'N, and longitudes 89°00'E and 89°55'E. It has a buffer zone comprising of major tree species in the study area (Figure 1).

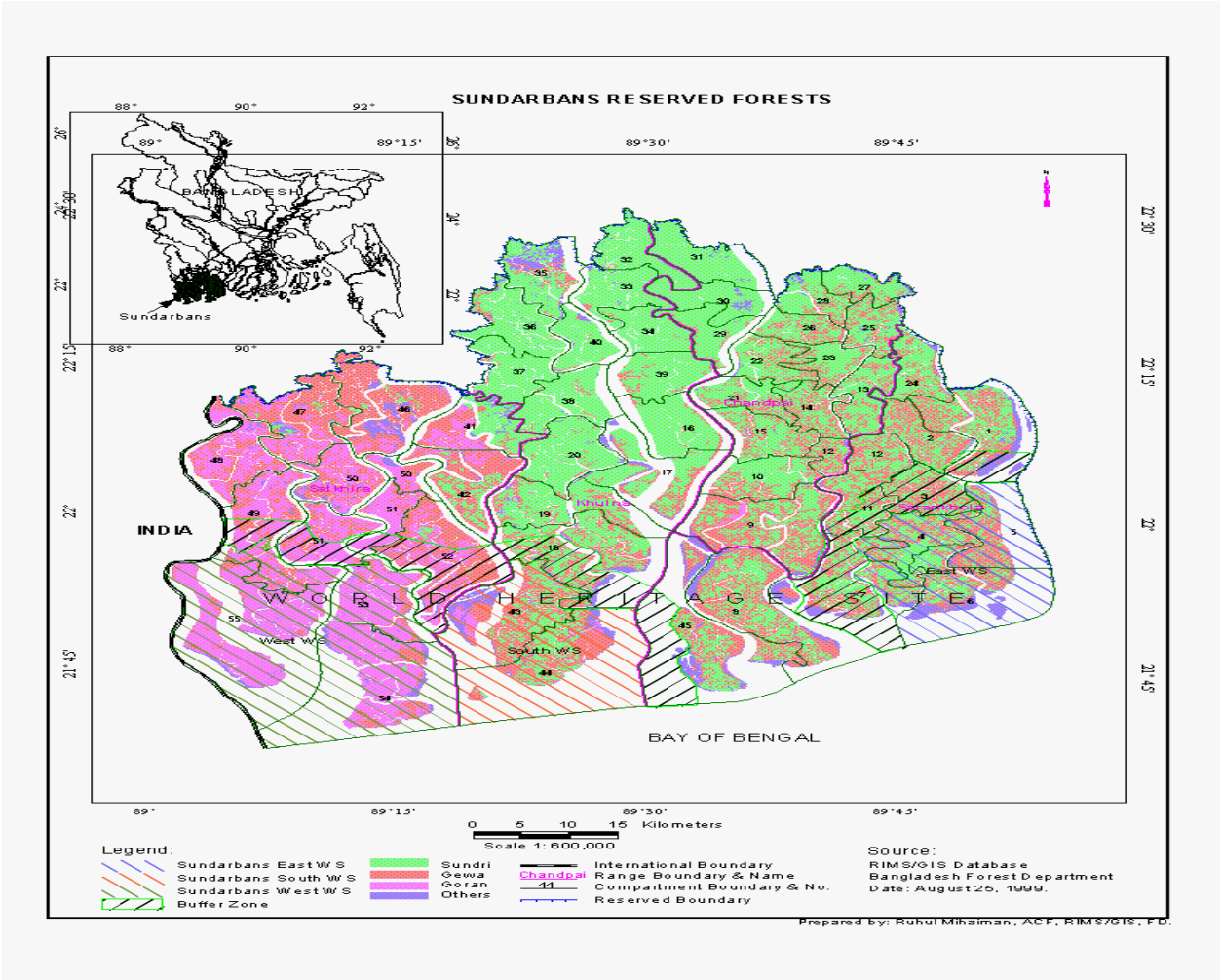

Figure 1. The Sundarbans mangrove forest (Bangladesh) including buffer zone (BFD, 1999).

In Bangladesh Sundarbans, (i) *H. fomes*, (ii) *H. fomes-E. agallocha*, (iii) *E. agallocha-H. fomes* and (iv) *Ceriops decandra-E. agallocha* forest type are distributed as 21%, 29.7%, 14.8% and 14.46%, respectively (Siddiqi, 2001). This Sundarbans covered most of the coastal areas between the Hoogly and the Meghna rivers. In recent decades, the hydrological regime has been affected by the Farakka Barrage (commissioned in 1975) that diverts up to 40 percent of the dry season flow from the Ganges to Hoogly river. There is an influence from other human intervention, as well as natural, long term, large scale plan from developments of the Ganges (moving eastward) and its delta. The area is inundated twice a day, during high tide. The salinity decreases along the coast from west towards east (and of course from the sea towards inland). The weather has a high seasonality, with around 80 percent of the annual rainfall occurring during the monsoon (June-October). Cyclones hit the area occasionally, with storm surges of up to 7.5 m. The Sundarbans was declared a reserved forest as early as 1878 under the 1865 Forest Act. In 1987, parts of the Indian Sundarbans - the Sundarbans west wild life sanctuary (1,33,000 hectare)- became a UNESCO World Heritage Site, and parts of the Bangladeshi Sundarbans- the Sundarbans wild life sanctuaries (1,40,000 hectare) received the same status in 1997 (UNESCO, 2014).

The SMF supplies ecosystem services to both local and global scale. Ecosystem services of the forest range from community livelihoods, nature-based recreation facilities, community protection from natural threats, to carbon sequestration. It is a natural habitat for many plants and animal species. Sundarbans mangrove is also a great source of knowledge for academicians and researchers. Unfortunately, there are several factors those are threats to the biodiversity of this unique mangrove forest. The aim of this study is to review past studies on the contribution of the SMF of Bangladesh, to discuss on the causes of biodiversity loss and finally compares the total economic value of SMF with that of other mangroves in the world.

2. COMMUNITY LIVELIHOOD

Though a large part of Sundarbans is free of permanent human habitation, most of the communities in the buffer zone of this forest depend on forest resources for their livelihoods. It has a population of over 4 million who collect wood and non-wood forest products from this forest.

Table 2 shows the plant-wise wood and non-wood forest uses of the SMF by the local people. Wood forest products (WFPs) include making timber, poles, posts, charcoal and tannin, while non-wood forest products (NWFPs) means thatching, fishing, killing wild animals, collecting honey, fodder and medicine etc. For making furniture, kankra, dhundul and passur trees are used, while Sundari, kankra and passur trees are used for house construction (Table 2).

Table 2. Major plant species in the Sundarbans mangrove forest and their economic uses (Siddiqi, 2001)

Local name	Scientific name	Type of plant	Main uses
Baen	*Avicennia officinalis*	Tree	Fuel wood, Anchor logs
Kankra	*Bruguiera sexangula.*	Tree	Furniture, Bridge and house construction
Goran	*Ceriops decandra*	Shrub or small tree	Fuel wood, houses posts, charcoal
Shingra	*Cynometra ramiflora*	Shrub or small tree	Fuel wood
Gewa	*Excoecaria agallocha*	Tree	Matchsticks and boxes, newsprint, and other papers.
Sundari	*Heritiera fomes*	Tree	House construction, boat building, electric poles, hard boards, fuel wood.
Kripa	*Lumnitzera racemosa*	Small Tree	Fuel wood, posts.
Golpata	*Nypa fruticans*	Recumbent palm	Thatching for houses
Hantal	*Phoenix paludosa*	Thorny palm	Post and rafters for huts
Keora	*Sonneratia apetala*	Tree	Packing boxes, construction material
Dhundul	*Xylocarpus granatum*	Tree	Furniture
Passur	*Xylocarpus mekongensis*	Tree	Furniture, bridges, house construction

Local people collect baen, goran, shingra, sundari, and kripa for fulfilling their fuel need. Some local people often converted the mangrove lands into salt ponds, agriculture or aquaculture purposes (FAO, 1994). About 85 percent of the people who have access to SMF are connected with harvesting non-wood forest products. Around 299,000 peoples are employed in collecting their means of NWFPs in Bangladesh and much of this employment continues throughout the year or at least during the agricultural off season. NWFPs from mangrove forests contribute an estimated Taka 717 million (US$ 17.9 million) annually to the Bangladesh economy, directly or indirectly (Basit, 1995). However, some factors such as water hijacking, illegal money collection by forest staff and collection of interest money by local lender lead to cut the income of forest-dependent community in the SMF area. From reconnaissance survey among 155 respondents, Islam (2011) found the net income (EURO 602.14) which was far smaller than the annual selling income (EURO 1481.70) due to these factors.

3. NATURE-BASED TOURISM

Although there was a great concern whether tourism conserves the nature, the number of visitors to protected areas has been increasing worldwide in last few decades (Balmford et al., 2009). Sundarbans may be a great source of tourism as it has exceptional scenic beauty and unique wildlife. The SMF has good potentials to attract local as well as foreign tourists and thereby foster the tourism sector of Bangladesh (Table 3).

The majority of Sundarbans tourists visit during October to April who are educated and employed in the service sector. Both local and foreign tourists visit the Sundarbans around the year for refreshment and gathering knowledge. Tourism in Sundarbans is highly park and reserved forest based (Salam et al., 2000). However, few tourists cannot visit the Sundarbans due to the difficulty and cost of arranging transport and to the lack of suitable accommodation and other facilities (The Encyclopedia of Earth, 2014).

In Indian Sundarbans, about 64 thousands of tourists visited in 2005-2006 mainly from Kolkata and other parts of West Bengal. Guha and Ghosh (2009) estimated that the total revenue from Sundarbans tourism could be increased by 300% by charging a higher entry fee to the visitors. Since the Sundarbans mangrove forest has many attractions as shown in Table 3, adequate transport and accommodation facilities may be provided to tourists unless this tourism will not affect the ecosystem adversely and bring economic benefits to the country as well as to the local people.

Table 3. Attractions of the Sundarbans reserve forest for tourists (Vere Moss, 1993)

Characteristics	Comments
Location	On the Bay of Bengal and largest mangrove formation in one of the world's largest river deltas
Tropical climate	Cool and dry during the tourist season
Waterways	Large and small waterways providing opportunities for cruising and jungle boating
Wildlife	The largest single population of the Bengal tiger and exceptional population of spotted deer and wild boar, adequate bird watching, migratory species and raptors in particular
Beaches	Unspoiled, wild, unpolluted and totally undeveloped beaches throughout along the Bay of Bengal and around some islands
History/archeology	Rare sites set in the forest
Sociology	Fishermen in particular, otter fishermen, also other traditional collectors of forest produce.
Cuisine	Many different species of edible fish, prawns and crabs
Culture	Annual festivals at Dubla and diverse cultures

4. CARBON MITIGATION

Forests play an important role in mitigating global climate change through sequestering atmospheric carbon (Adame et al., 2013). However, deforestation of mangroves was very widespread in the last few decades (Giri et al., 2011) that have driven the policymakers to look for the new approach to save the mangroves. Reducing emissions from deforestation and forest degradation (REDD+) is such a climate change mitigation approach that will generate economic benefits for the country. The Sundarbans is, nationally and internationally, of great conservation significance for its environmental services and biodiversity (Seidensticker and Hai, 1983; Iftekhar and Saenger, 2008). To aid in the conservation of the forest and to benefit from various global initiatives, e.g., carbon trading, an assessment of the carbon sequestration (above and below ground) in Sundarbans is immensely important. Although the SMF has no baseline data directly related to carbon storage, few studies quantified the carbon storage of this forest based on sampling data. Conducting a survey of 25 mangrove forest across the Indo-Pacific region, Donato et al. (2011) claimed that mangroves are the most carbon rich forest in the tropics and particularly the Indian Sundarbans absorbs 212.5 to 312.5 Mg C/ha. Mitra et al. (2011) performed another study on carbon storage by above-ground structures of three dominant mangrove species (*Sonneratia apetala*, *Avicennia alba* and *Excoecaria agallocha*) in the Indian Sundarbans. Based on average values of 15 plots from the central and western region, this study observed 73.14-84.79 ton C/ha in *S. apetala*, 9.82-11.02 ton C/ha in *E. agallocha* and 21.12-23.32 ton C/ha in *A. alba* in the western region. Since the distribution of mangrove species in the Bangladesh Sundarbans differs from that of Indian portion, let we consider other carbon estimate conducted in Bangladesh Sundarbans.

Table 4. Carbon density of the Sundarbans mangrove forest

Site	Ecosystem carbon stocks (C/ha)	Source
Indian Sundarbans	212.5-312.5 Mg	Donato et al. (2011)
Indian Sundarbans	73.14-84.79 ton (*Sonneratia apetala*), 9.82-11.02 ton (*Excoecariaag allocha*), 21.12-23.32 ton (*Avicennia alba*)	Mitra et al. (2011)
Bangladesh Sundarbans	256.7 (±17) Mg	Ahmed and Iqbal (2011)
Bangladesh Sundarbans	159.5-360.0 Mg (vegetation types)	Rahman et al. (2015)
Bangladesh Sundarbans	170.1-336.1 Mg (salinity zones)	Rahman et al. (2015)

* Mg = mega gram, C/ha = carbon per hectare, 1 megaton = 10^6 Mg

Based on above ground and below ground pools at 155 plots in the Bangladesh Sundarbans, the mean carbon density (including soil) was found 256.7 Mg C/ha (Ahmed and Iqbal, 2011). In recent, Rahman et al. (2015) estimated the carbon stock of 159.5-360.0 Mg/ha for vegetation types, where Sundari-dominated forest contained the highest amount of ecosystem carbon which is 360.0 Mg/ha. For salinity types, the estimated carbon stock was found 170.1-336.1 Mg/ha, although no significant difference was found for salinity types. That is, carbon density is completely independent of both vegetation and salinity. Finally, total carbon storage of Bangladesh Sundarbans is 105.70 megaton, assuming that the Sundarbans reserved forest covers 4,110,693 ha of total forest land (Ahmed and Iqbal, 2011).

5. LOSS OF BIODIVERSITY

Though the Sundarbans formed a uniquely rich ecosystem, it is now in captious position. Many floral and faunal species are either extinct or in endangered. Several factors are liable for bio-diversity losses in the Sundarbans mangroves.

Forest of the Sundarbans is showing signs of degradation (Iftekhar and Islam, 2004b). Forest cover,

species diversity, and ecosystem function have been declining in the last century. Though Sundarbans was familiar with its floral diversity earlier, now it has only three tree species, sundari (*Heritiera fomes*), gewa (*Excoecaria agallocha*) and goran (*Ceriops decandra*) those covers 95% of total SMF area (Iftekhar and Saenger, 2008). Sundari is spread over 67% of the vegetated area and concentrated mostly on the northeastern side, constitutes 75% of the density of the trees. On the contrary, gewa is spread over 74% of the vegetated area of the forest and constitutes 39% of the density of the tress. Even the dominance (density of trees) of gewa is declining at a faster rate than sundari during this period. Studies claim that deforestation in the reserved forest affects the climatic condition and its' biodiversity, particularly many faunal species fall into extinction (Saikia, 2013).

Table 5. Status of threatened amphibians, reptiles, birds and mammals of the Sundarbans (Khan, 1982; Hussain and Acharya, 1994; IUCN, 2000)

Class	English name (scientific name)	Status
Amphibians (*Amphibia*)	Green frog (*Euphlyctis hexadactylus*)	Endangered
	Ornate microhylid (*Microhyla ornata*)	Rare
Reptiles (*Reptilia*)	Estuarine crocodile (*Crocodylus porosus*), River Terrapin (*Balagur baska*), Asiatic Softshell turtle (*Chitra indica*), Russels Viper (*Vipera russelli*)	Critically Endangered
	Blank Pond turtle (*Geoclemys hamitoni*), Threekeeled Land Tortoise (*Melanchelys tricarinata*), Bengal Monitor (*Varanus bengalensis*), Yellow Monitor (*Varanus flavescens*), Common Krait (*Bungarus caeruleus*), Banded Krait (*Bungarus fasciatus*), King cobra (*Ophiophagus hannah*), Spot-tailed Pit Viper (*Trimeresurus erythrurus*),	Endangered
	Yellow turtle (*Morenia petersi*), Spotted Flapshell turtle (*Lissemys punctata*), Bibron's Softshell turtle (*Pelochelys bibroni*), Gecko (*Gekko geko*), Ring lizard (*Varanus salvator*), Common Vine snake (*Ahaetulla nasutus*), Dog-faced water snake (*Cerberus rhynchops*), Common Bronzeback Tree snake (*Dendrelaphis tristis*), Dark-bellied Marsh snake (*Xenochrophis piscator*), Monocellate cobra (*Naja kaouthia*),	Vulnerable
Birds (*Aves*)	Swamp partridge (*Francolinus gularis*)	Critically Endangered
	Red Jungle fowl (*Gallus gallus*), Whitebacked vulture (*Gyps bengalensis*), Griffon vulture (*Gyps fulvus*)	Rare
Mammals (*Mammalia*)	Rhesus macaque (*Macaca mulatta*), Jackal (*Canis aureus*), Bengal fox (*Vulpes bengalensis*), Common mongoose (*Herpestes edwardsi*), Palm civet (*Paradoxurus harmaphroditus*), Small Civet (*Viverricula indica*)	Vulnerable
	Jungle cat (*Felis chaus*), Fishing cat (*Felis viverrina*), Clawless otter (*Aonyx cinerea*), Finless Porpoise (*Neophocaenoides*), Ganges River dolphin (*Platanista gangetica*)	Endangered
	tiger (*Panthera tigris*), Irrawaddy dolphin (*Orcaella brevirostris*)	Critically Endangered

As shown in Table 5, among four class of animal species, some critically endangered species those live in Sundarbans are Royal Bengal tigers (*Panthera tigris tigris*), Irrawaddy dolphin (*Orcaella brevirostris*), Swamp Partridge (*Francolinus gularis*), Estuarine crocodile (*Crocodylus porosus*), River Terrapin (*Balagur baska*), Asiatic Softshell turtle (*Chitra indica*), Russels Viper (*Vipera russelli*) etc. Some species are either in endangered such as Jungle cat (*Felis chaus*), Fishing cat (*Felis viverrina*), Clawless otter (*Aonyx cinerea*), Finless Porpoise (*Neophocaenoides*), Ganges River dolphin (*Platanista gangetica*), Blank Pond turtle (*Geoclemys hamitoni*), Threekeeled Land tortoise (*Melanchelys tricarinata*) etc, or vulnerable such as Yellow turtle (*Morenia petersi*), Spotted Flapshell turtle (*Lissemys punctata*), Bibron's Softshell turtle (*Pelochelys bibroni*), Gecko (*Gekko geko*), Palm civet (*Paradoxurus harmaphroditus*), Small civet (*Viverricula indica*) etc.

Most importantly, few species become very rare in the Sundarbans. Moreover, a number of species are already extinct in the middle of 20th century including hog deer (*Axis porcinus*), water buffalos (*Bubalus bubalis*), swamp deer (*Cervus duvauceli*), Javan rhinoceros (*Rhinoceros sondaicus*), single horned rhinoceros (*Rhinoceros unicornis*), and the mugger crocodiles (*Crocodylus palustris*) in the Sundarbans (Sarker, 1993).

Table 6. Status of mammals, birds, reptiles and amphibians in the Sundarbans (Rashid et al., 1994; Siddiqi, 1996; IUCN, 2000)

Type of animal species	Number of existing species	Number of existing species	Number of endangered species
Mammals (*Mammalia*)	49	4	10
Birds (*Aves*)	261	2	11
Reptiles (*Reptilia*)	50	1	16
Amphibians (*Amphibia*)	8	-	1

According to Table 6, the number of existing, extinct and endangered mammal species is 49, 4 and 10, respectively. Among bird species, 2 are extinct and 11 are endangered. For reptiles and amphibian, 16 and 1 species are in endangered respectively in the Sundarbans.

Major causes of deforestation and subsequent effect on biodiversity loss are excessive human intervention in the forest area, the rapid expansion of shrimp farming, illegal cutting of trees, encroachment of forest areas, illegal poaching of wildlife and pollution in the surrounded forest area etc. (Rahman et al., 2010). Mining and oil exploration leads to contaminating fresh water resources in the Sundarbans area which is another threat to biodiversity (Gopal and Chauhan, 2006). Moreover, weak management of reserved forest is identified as a cause of over-extraction of forest resources by the local community (Iftekhar and Islam, 2004a; Roy et al., 2012). Recently, tanker crash in the Shela River and subsequent oil spill in the Sundarbans area caused a new threat to the Sundarbans biodiversity particularly of Royal Bengal tigers and dolphins (National Geographic, 2014).

6. TOTAL ECONOMIC VALUE

Usually, total economic value (TEV) covers direct value, indirect value, option value, bequest value, existence value and intrinsic value etc. As we discussed earlier that the SMF provides various types of direct value such as crops, fish, firewood, timber, and non-timber products which can be traded and the value becomes visible. As an indirect value, it provides different ecosystem services such as flood control, storm protection, soil conservation, scenic beauty, and nature-based tourism etc. those cannot be traded but significant. Thirdly, it has option value to the next generations as it will be possible to derive benefits from future use. The Sundarbans mangrove forest also has bequest value, because we can conserve this forest for future generations, for instance, refraining from fishing or extracting forest resources today means keeping those resources for the future generations. However, this forest has absolute existence value in terms of culture, heritage and spirituality etc. Finally, the SMF carries the intrinsic value, for example, the existence of Royal Bengal tiger as a living resource in its own right makes this forest unrelated to human utilization.

Table 7. The Sundarbans mangrove forest at a glance

Characteristics	Particulars	Source
UNESCO World Heritage Site	Period of declaration: 1997	UNESCO (2014)
Total Area	10,000 square kilometer	Siddiqi (2001)
Bangladesh Sundarbans	6,000 square kilometer (approx.)	Siddiqi (2001)
Population	4 million (approx.)	Chowdhury (2010)
Dependent poor community	0.5 million (approx.)	Chowdhury (2010)
Community dependent on NWFPs	0.299 million (approx.)	Basit (1995)
Annual income from NWFPs	Tk. 717 million (estimated)	Basit (1995)
Annual income from WFPs	EURO 1481 per Household	Islam (2011)
Total C storage by SMF (Bangladesh)	105.70 megaton	Ahmed and Iqbal (2011)
Total CO_2 storage by SMF (Bangladesh)	387.90 megaton	Ahmed and Iqbal (2011)
Value of total C of SMF (Bangladesh)	US$ 11,077.36 million (approx.)	Author's calculation

* NWFPs = non-wood forest products, WFPs = wood forest products, C = carbon, SMF = Sundarbans mangrove forest

As we seen from the Table 7, the economic benefits from the Sundarbans are not only quantitative but also qualitative in nature. SMF serves to the local as well as the global community by its treasure trove that ranges from feeding poor community to carbon sequestration. It is now clear that the Sundarbans absorbs a huge amount of carbon each year. Economists have already developed carbon price based on marginal social costs associated with emission (Mandell, 2010). The mean value of carbon per ton is US$ 104.80 and the interval estimate of carbon per ton ranges from US$ -6.60 to US$ 2400. Based on US$ 104.80 per ton of carbon, value of total carbon storage is therefore US$ 11,077.36 million from the Sundarbans forest stocks.

TEV of different mangrove forests across the world varies significantly. These variations in the values realized may be due to the geographical characteristics of the mangroves and the communities' access to various use and non-use benefits of mangroves.

Table 8. Total Economic Value (TEV) of different mangroves

Country	Estimate	Source
Thailand	US$ 853.5 ha/year	Sathirathai (1997)
Malaysia	US$ 61,357 ha/year	Leong (1999)
Mexico	US$ 2,772 ha/year	Cabrera et al. (1998)
Philippines	US$ 315 ha/year	Walton et al. (2006)
Sri Lanka	US$ 12,229 ha/year	Iftekhar (2008)
Bangladesh	US$ 631 ha/year	Costanza et al. (1997)

As shown in Table 8, the highest total economic value was found for Malaysia (US$ 61,357) while the lowest economic value was found US$ 315 ha/year in Phillippines. The total economic value of mangrove in Thailand, Mexico, and Sri Lanka was US$ 853.5, US$ 2,772, and US$ 12,229 ha/year, respectively. The real contribution of the Sundarbans reserve forest to the national economy has not been evaluated so far. Compare to mangrove forests in other parts of the world, the annual economic value of Bangladesh Sundarbans was considerably low (US$ 631 ha/year) due to considering only the ecological services.

7. DISCUSSION

Some issues have come forward through this study for the sustainable management of the Sundarbans mangrove forest. Over-consumption of forest resources is the common phenomenon in the Sundarbans region; particularly non-agricultural households depend highly on the Sundarbans as a means of their livelihood. Moreover, conflict of interest and hijacking are also prevalent in the mangrove area (Islam, 2011). Bangladesh Forest Department should, therefore, define the optimum limit for consumption at the local level. Evidence shows that alternative sources of income for livelihood can reduce the pressure on protected areas (Saikia, 2013). We thereby recommend that sufficient employment opportunities should be created by government for local communities or should provide necessary support to them to divert to agricultural farming so that dependent communities becomes less harmful to the SMF.

The tragedy of commons is a common phenomenon in the case of common property resource. Enforcing State rules is not sufficient to preserve the traditional reserve forest. Participatory forest management approach should, therefore, develop to conserve the biodiversity of SMF. In this regard, both government (GOs) and non-government organizations (NGOs) should motivate stakeholders ethically by providing necessary training and workshops or by campaigning.

Since the mangroves have been clearing for aquaculture and silviculture practices, more attention should be paid to monitor those practices in the SMF area and restore those degraded forest lands. In the long run, advanced research on aquaculture and silviculture are needed to improve these practices.

Tourism facilities in the Indian Sundarbans attract more local and international tourists than in the Bangladesh Sundarbans. Different resorts, parks, and transport facilities are available in the Indian Sundarbans. While it is possible to collect 300 percent more revenue from tourists in the Indian Sundarbans, it would be hardly possible to collect the same amount of revenue due to the remoteness of Bangladesh Sundarbans and necessary support from local tourism entrepreneurs. A well-equipped sustainable tourism approach should, therefore, be introduced by Government to earn substantial revenue from this sector. Moreover, campaigning on this world heritage and sufficient transport and accommodation facilities outside the reserved forest are necessary to attract international tourists.

We found economic value of carbon sequestration of the SMF which remains as a primary estimate within current literature. If carbon sequestration by SMF based on all species in the SMF can be calculated, then we can monetize this carbon value more accurately. However, government of Bangladesh may involve with carbon trading under REDD+ program with advanced industrialized countries based on the economic value of carbon as estimated from the Bangladesh Sundarbans (Table 7). Under this approach, the government may save the degraded Sundarbans mangrove by conserving various plant species.

8. CONCLUSIONS

Mangrove is invaluable Sundarbans mangrove forest provides ecosystem services in numerous ways to people; however, we found the economic value of SMF in terms of livelihood, tourism, and carbon sequestration. While one-third of the world's mangrove forests has lost in past fifty years (Alongi, 2002). Sundarbans, the largest mangrove forest in the world has also lost its ecological diversity due to natural and anthropogenic causes. Since the estimated economic value may differ from the actual value it is, therefore, necessary to estimate the total economic value covering as many services as provided by the SMF. Different benefits of ecosystem services, as well as loss of biodiversity of the SMF under this study will bear a signal to national and international policy makers for sustainable forests management.

Due to data insufficiency, future researchers may calculate total economic value of SMF by applying market as well as non-market valuation techniques. Since the value generated from nature-based tourism cannot be found directly, enthusiastic researchers can also estimate the value to recreation from the Sundarbans using travel cost method.

ACKNOWLEDGEMENTS

The author would like to thank Professor Dr. Md. Danesh Miah of the Institute of Forestry & Environmental Sciences at the University of Chittagong for giving his valuable suggestions on this paper.

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