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Status and economic valuation of ecosystem services of Tanguar haor: A wetland of Bangladesh

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Abstract

Tanguar haor wetland is one of the listed Ramsar sites enrich with biodiversity variety and provides several ecosystem services with significant contribution to the national economy of Bangladesh. But these services were decreasing day by day due to natural and anthropogenic activities. The purposes of this study were to identify the utilized ecosystem services by communities, economic values of utilized ecosystem services and the basic reasons for depleting of ecosystem services. Data were collected through baseline survey, checklists, face to face questionnaire survey and focus group discussion (FGD) from 120 residential respondents and 50 tourist respondents by accepting random sampling techniques during November, 2016 to September, 2017. Physiochemical characteristics of the water were determined where the mean temperature and pH were 28.26°C and 7.72 respectively. The highest TDS, EC, DO, NO_3 and PO_4 values were 1020 (mg L^{-1}), 1460 (µS cm^{-1}), 8.56 (mg L^{-1}), 1.769 (mg L^{-1}) and 0.078 (mg L^{-1}), respectively. Commonly utilized ecosystem services were crops, vegetables, fuel, fresh water, fishes and migratory birds, climate regulation, water purification, natural hazards protection, aesthetic, social relations, recreation & tourism, health benefit, primary production, nutrient cycling, water cycling habitats for species and provision of habitat etc. Market Value Method (MVM) and Contingent Value Method (CVM) were applied to measure the economic value of Tanguar haor wetland services. DPSIR framework and Impact Matrix (IM) were applied for conceptual analysis to identify the effects on ecosystem services. Total economic value of 39 ecosystem services of Tanguar haor was estimated at 174039980 BDT $year^{-1}$. Mismanagement of biodiversity, over exploitation, sedimentation of haor, climate change, illegal hunting, land use changes and habitat changes were the responsible factors for depleting ecosystem services. The impact factor (4.161) was identified by natural and anthropogenic factors on ecosystem services. There have a vast prospect of the Tanguar haor wetland services for near communities. Finally the research suggested several sustainable management approaches which have the potentiality to protect the services of the wetland.

Introduction

Wetlands are the world's most productive environment that supplies a broad collection of profit and keeping ecological balance of ecosystem (RCS, 2013; Islam *et al.*, 2014) as well as essential to human wellbeing (Barbier *et al.*, 1997; MEA, 2005). The significance of wetland is universal like ecosystem services. Ecosystem services are natural assets (Barbier, 2011) generated by the environment and exploited by human being, such as clean air, water, food, fuel and other materials. These services have high monetary value (Barbier *et al.*, 1997) and contribute to social and cultural well-being (Fisher *et al.*, 2009). Ecosystem services are the benefits obtained from ecosystem to human being (Costanza *et al.*, 1997; Groot *et al.,* 2002; MEA, 2005). Nature generally provides four types of ecosystem services (MEA, 2005) such as "provisioning" (e.g. food, timber, woods), "regulating" (e.g. climate regulation, disaster risk reduction, soil erosion control), "cultural" (e.g. aesthetic, spiritual, education, recreation, ecotourism) and "supporting" e.g. soil formation and retention, nutrient cycling, water cycling) services (MEA, 2005; TEEB, 2010; Groot *et al.*, 2002).

Tanguar haor wetland is a freshwater wetland that offers social, economic and environmental benefits which helps community's livelihoods and creates income source (Khan, 1993). There have a significant economic and ecological importance on life and livelihoods of wetland ecosystem in Bangladesh (Kabir and Amin, 2006). Tanguar haor wetland provides food, fuel, fodder, genetic resources, flood regulation, hydrological services, aesthetic, spiritual, learning & knowledge, recreational use, photosynthesis, primary production etc (IUCN, 2015). It has a great importance in fish production, maintaining biodiversity and living place of migratory birds. Though there have a vast prospect of the economic value of Tanguar haor wetland, economic valuation of the ecosystem services of the wetland was not done properly yet. Different valid economic valuation of this wetland services might be helpful for sustainable management. In addition, many underlying causes those are potential for the depletion of ecosystem services like population pressure, land use change, over

exploitation, climate change and water & soil quality loss (Haque, 2012; Mamun *et al.*, 2013; Nahar, 2013; Morshed, 2013). Nowadays, wetland services are highly vulnerable due to natural and anthropogenic causes and decreasing day by day (Nahar, 2013; Morshed, 2013). Several works have been conducted to present status of wetlands but researches on economic valuation are limited. Therefore, the research was conducted to i) observe the status of water quality of haor wetlands ii) assess the economic values of ecosystem services and iii) identify the driving forces responsible for changes in the wetland ecosystem using DPSIR (Drivers-pressures-states-impacts-responses) framework.

Materials and Methods

Study area

The Tanguar haor wetland is located in the Sunamganj district of Bangladesh, lies in the northeastern part of the country adjacent to the Indian border at 25°05'–25°12' North and 91°01'-91°07' East (Fig. 1). It covers an area of 100 km^2 and supporting at least 60,000 populations of Dharmapasha and Tahirpur upazilla's. This wetland has been recognized as a wetland of global importance under the Ramsar agreement since 2000, and it has rich biodiversity. The haor consists of 120 beels of different sizes.

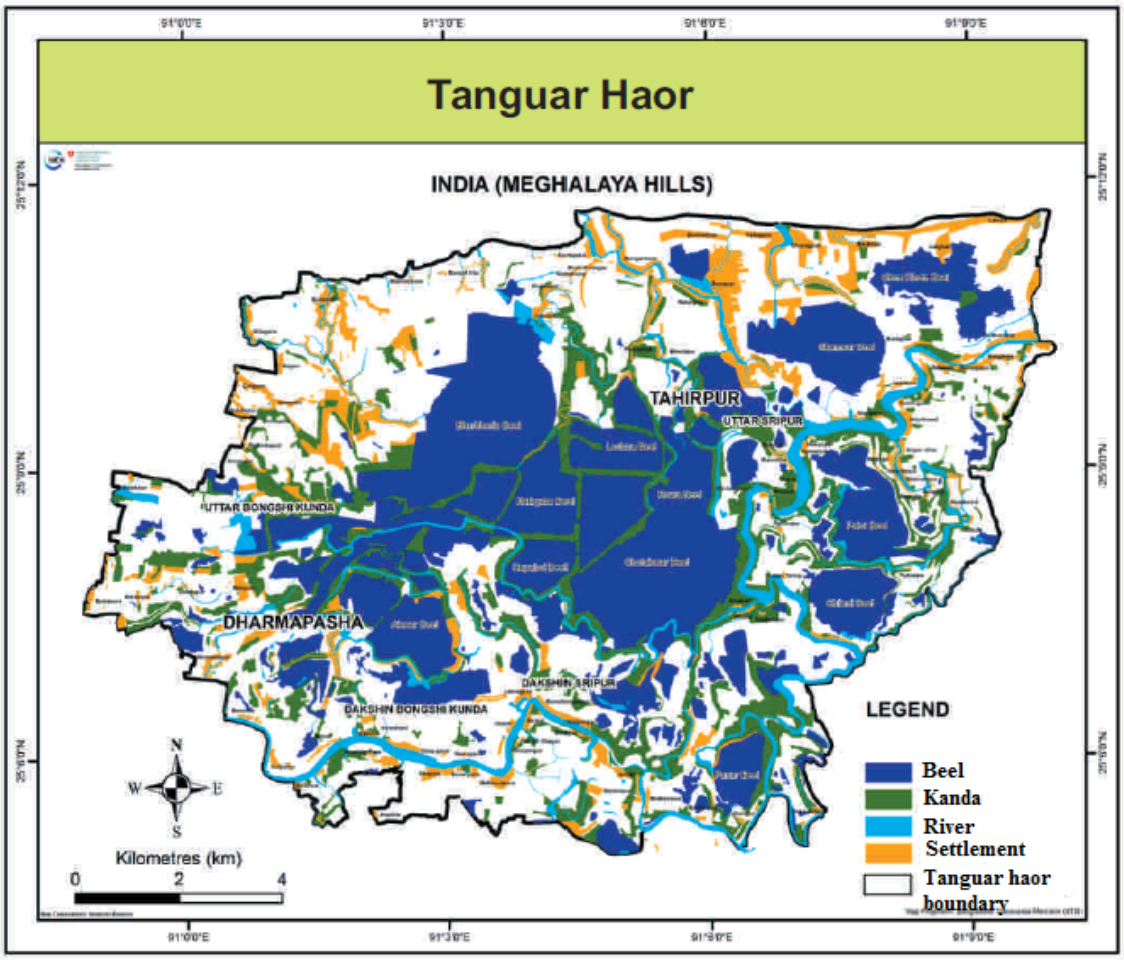

Fig. 1. Map of Tanguar haor wetland. (Source: IUCN, 2015)

Data collection and analysis

Data sources

Baseline surveys and preliminary discussion with communities were conducted for selection of study area. Literature review, baseline survey, checklists, preliminary discussion with communities, face to face questionnaires survey and FGDs were conducted from November, 2016 to September, 2017. Purposive sampling was conducted for data collection because Tanguar haor is a vast area and many people obtain different benefits from this haor. Negative responses were excluded from the calculations like residential who are not accepted paddy, migratory birds and fuel etc. and who didn't get health benefits. Secondary data has been collected from different journals, reports, research papers, websites, and government and non-government organizations.

Water quality measurement

The water samples were collected from five locations of Tanguar haor e.g. Rupaboi beel (L_1), Muinsakhali beel (L_2), Chatrar beel (L_3), Boddof beel (L_4), and Kolma beel (L_5), during November, 2016 to February, 2017.

Water was collected in 100 ml plastic bottles. Before collecting water, the bottles were cleaned and washed up with distilled water. pH was measured by digital pocket pH meter at the sampling site. Electrical conductivity (EC) was measured by digital EC (Model: 8033, Hanna) meter and temperature was measured by digital thermometer. Total dissolved solid (TDS) and dissolved oxygen (DO) were measured by digital portable pocket TDS (Model: HI9813-5) and DO (Model: H19143, Hanna) meters, respectively. On the other hands NO_3 and PO_4 were measured using spectrophotometer in department of Soil Science, Bangladesh Agricultural University, Bangladesh.

Economic valuation of ecosystem services

The market value method is one of the most direct ways to approximate the value of material production and services of the haor system (Li and Gao, 2016). People obtain different resources from Tanguar haor and those resources have its own market value. The formula (Li and Gao, 2016) is given in detail as follows:

$$V_{Ps} = \sum_{i=1}^{n} (Qi \times Mi) \quad \text{.....(1)}$$

Here, V_{Ps} is the value of provisioning ecosystem services (BDT). Qi is the quantity of obtained resource (Mon or kg or pieces) of type i services. Mi is the average market prices (BDT-*Mon* or kg or pieces) of type i material (1*Mon*=40 Kg).

Contingent value method is used to estimate the fiscal value of ecosystem services of the haor according to residential and tourist perceptions. This study used an open questionnaire and asked respondents to select their willingness to pay (WTP) (Li and Gao, 2016).

Impacts analysis

To identify the relatively impacts on ecosystem by natural and anthropogenic causes, here we applied DPSIR (Driver – Pressure – State – Impact – Response) framework (EEA, 1999). The simplest matrices used to recognize the rate of impacts on ecosystem services due to anthropogenic and natural activities. The impacts are calculated as low, tolerable, medium, high and finally very high. Here a scale from 0 to 5 for impact magnitude used for giving score (scale:0 – no observable effect; 1 – Low effect; 2 – Tolerable effect; 3 – Medium high effect;4 – High effect; 5 – Very high effect).

Results and Discussion

Water quality of Tanguar haor

Water samples were collected from different locations of the Tanguar haor to observe the present water quality status (Table 1). The water temperature among all the sampling stations of Tanguar haor ranged from 27.2°C to 29.4°C with a mean value of 28.28°C. Similar mean value of temperature (27.98°C) was found by Mamun *et al.* (2013) from Tanguar haor water. Average pH of the water samples ranged from 7.3 to 8.7. Averages DO of the water sample ranged from 4.27 mg L^{-1} to 8.56 mg L^{-1}. But Mamun *et al.* (2013) found the highest DO value was 5.5 mg L^{-1} at Majampur and the lowest value was 4.5 mg L^{-1} at Hoirakuna. Normal TDS of the water samples ranged from 731 to 1020 mg L^{-1}. The highest TDS value was 1036 mg L^{-1} at Lamagau beel and the lowest value was 670 mg L^{-1}at Lamagau (Mamun *et al.*, 2013). The higher TDS value of water may be due to the high contents of dissolved ions in water that flows from upstream, nearby agricultural land and domestic materials. EC value measured at different sampling stations ranged from 1120 to 1460 µS cm^{-1} with the mean value of 1231 µS cm^{-1}. NO_3 of the water samples ranged from 0.763 to 1.769 mg L^{-1}. Islam *et al.* (2014) found the average NO_3 value about 15.6 mg L^{-1} at Pre-monsoon (March-May) in Hakaluki haor. PO_4 of the water samples ranged from 0.022 to 0.078 mg L^{-1}. PO_4 value was about 5.58 mg L^{-1} at pre-monsoon (March-May) in Hakaluki haor (Islam *et al.*, 2014). It is apparent from the above value of water sample, that the water was suitable for fish production and other aquatic organisms at Tanguar haor wetland.

Table 1. Status of water quality parameters at different beels of Tanguar haor wetland

Parameters	Rupaboi Beel	Muinsakhali Beel	Choatrar Beel	Boddof Beel	Kolma Beel	Mean	Standard Deviation
Temperature (°C)	27.2	27.6	29.2	29.4	27.9	28.26	0.98
pH	7.5	8.7	7.5	7.6	7.3	7.72	0.56
TDS (mg L^{-1})	1020	981	805	988	731	905	128.6
EC (µS cm^{-1})	1070	1255	1460	1120	1250	1231	7.14
DO (mg L^{-1})	8.56	4.27	4.67	5.18	7.18	5.57	1.83
NO_3 (mg L^{-1})	0.763	1.153	1.339	0.962	1.769	1.2	0.38
PO_4 (mg L^{-1})	0.043	0.052	0.035	0.022	0.078	0.05	0.02

Demographic characteristics of the residential and tourist respondents: Mainly young and adult married male peoples accepted the ecosystem services from Tanguar haor. The educational level was very low in this region due to insufficient educational institution, communication and finally economical status. Fishermen and boatmen were the highest percentage profession among the respondents. Fisherman catch fish and boatman engaged with driving boat all over the year. This may be because of high opportunities and availability of fish and availability of tourists. More than fifty percent respondent income was 12001-20000 BDT $month^{-1}$. Most important occupation near Tanguar haor area is farming, fishing, handicraft, small business and

livestock husbandry while 41.7% household involved with fishing and 36.3% with farming (IUCN, 2015). Most of the tourists were male and married. But they were young and most of them were student and the reason behind that young married person and students are more interested to visit Tanguar haor for refreshment and educational purposes. The majority tourist's income level were > 40000 BDT month^{-1}. Most of the residential respondents had no knowledge about ecosystem services. This is occurred due to low educational background. Approximately, fifty percent of the tourists were familiar with ecosystem services.

Respondent's perception about ecosystem services

The most commonly used and obtained ecosystem services by the residential inhabitant's were provisioning, regulatory, cultural and supporting services (Table 2). Amongst 120 residential respondents, eighty three (83) never heard about ecosystem services before. On the other hand, 26 tourists were familiared with ES services first time. According to residential respondents, "provisioning" services were highly accepted and valuable services among four ecosystem services of Tanguar haor wetland whereas regulatory" services were least accepted and prioritized services. This is due to the difficulty of accept, less knowledge and valuation problem. But tourist respondents accept cultural services mostly with a little provisioning service. Overall change of ecosystem service was identified by residential respondents, where "provisioning" and "supporting" services have been decreasing from last 10 years (Fig. 1). But according to tourists "provisioning" and "regulatory" services have been decreasing from last 10 years due to environmental changes, natural hazards, settlement, and mismanagement of biodiversities with over exploitation (Uddin *et al.,* 2015; Haque and Basak, 2017).

On the other hand tourist perceived that they have no knowledge about supporting services changes due to the coming from far distance and have negligible knowledge about supporting services (Bhandari *et al.,* 2016). Land use policies, land use planning, population growth mismanagement of biodiversity were responsible for decreasing Tanguar haor wetland services (Liu *et al.*, 2012; Sun *et al.,* 2017).

Table 2. Lists of utilized ES by the respondents

Ecosystem Services	Examples
Provisioning	Paddy, vegetables, fuel, biochemical's& natural medicines, genetic resources, fresh water, fodder, shade and shelter, fish production and migratory birds
Regulatory	Climate regulation, carbon sequestration, water purification, natural hazards regulation, water regulation, waste treatment, pollination, soil fertility maintenance
Cultural	inspiration for art, folklore, social relations, aesthetic values, cultural heritage values, recreation & tourism, health benefit, knowledge, sense of place
Supporting	Soil formation and retention, nutrient cycling, primary production, water cycling, provision of habitat, habitats for species, photosynthesis

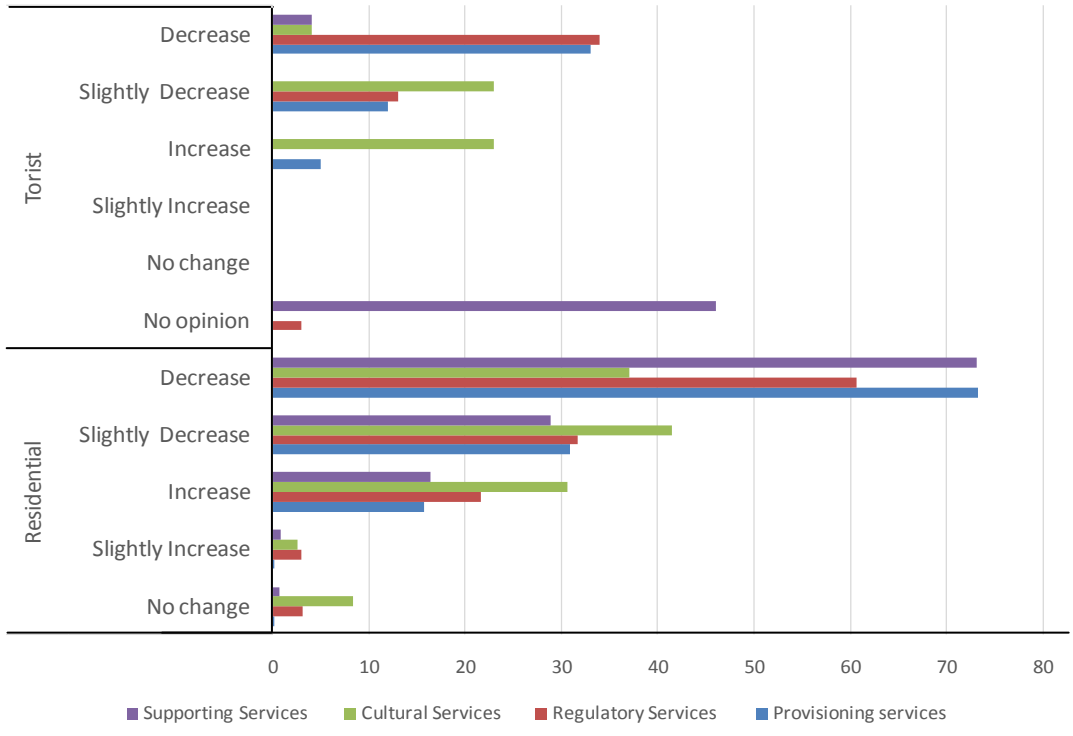

Fig. 1. Changes of ecosystem services during last 10 years at Tanguar haor

Economic valuations of ES

Total economic value of ecosystem services from Tanguar haor wetland estimated was 174039980 BDT year^{-1} (Table 3). But total annual benefit from Tanguar haor was estimated as BDT 1.59 billion or USD 20.46 million (Haque *et al.,* 2012). This is partially similar with our findings because of the author calculation was based on individual services but we examined only 120 respondents and all services together. World Conservation Union (IUCN) has estimated that the economic value of Hakaluki haor was BDT 585.75 year^{-1} (IUCN, 2006).

Table 3. Monetary value of the Tanguar haor wetland ecosystem services

Ecosystem service	Valuation Methods	Amount of resources (BDT year^{-1})
Provisioning (10)	MVM and CVM	171850980
Regulatory (8)	CVM	480700
Cultural (8)	CVM	570900
Supporting (7)	CVM	914900
	Total (33)	173817480
Tourists perceived economic value of cultural services (6)	CVM	222500
	Total (39)	**174039980BDT year^{-1}**

Detailed break-up of monetary value from provisioning ecosystem has been in Table 4. Economic value of paddy, vegetables, fuel, fodder, fish and migratory birds were calculated by equation no (1) using MVM. Economic values of all provisioning services from Tanguar haor were 171850980 BDT year^{-1} while per person value calculated as 1432091.5 BDT year^{-1}.

"Mismanagement of biodiversity" was highly responsible factor for depleting ES of Tanguar haor. Whereas second top prioritize factor was given to "sedimentation of haor" (Fig. 2). Impact matrix was calculated and provisioning services had the highest effects and its impact factor was 4.85. Mismanagement of biodiversity and climate change had very high potentiality to deplete ecosystem services of Tanguar haor wetland. Final impact factor was found 4.16 by cross relation between ecosystem services and its depleting factors (natural and anthropogenic).

Table 4. Monetary value of provisioning ecosystem services from Tanguar haor wetland

Provisioning services	Quantity of collected resource	Market price /Mon or Kg	Valuation method	Cost of resources (BDT year^{-1})
Paddy	13840 Mon year^{-1}	1000 BDT	MVM	13840000
Vegetables	41040 Kg year^{-1}	20 BDT	MVM	820800
Fuel	2614 Mon year^{-1}	120 BDT	MVM	313680
Fodder	338760 Kg year^{-1}	15 BDT	MVM	5081400
Fish	755640 Kg year^{-1}	200 BDT	MVM	151128000
Migratory birds	2345 Pieces year^{-1}	250 BDT	MVM	586250
Biochemical's& natural medicines	-	-	CVM	25630
Genetic resources	-	-	CVM	17580
Fresh water	-	-	CVM	24240
Shade and shelter	-	-	CVM	13400
			Total	**171850980 BDT year^{-1}**

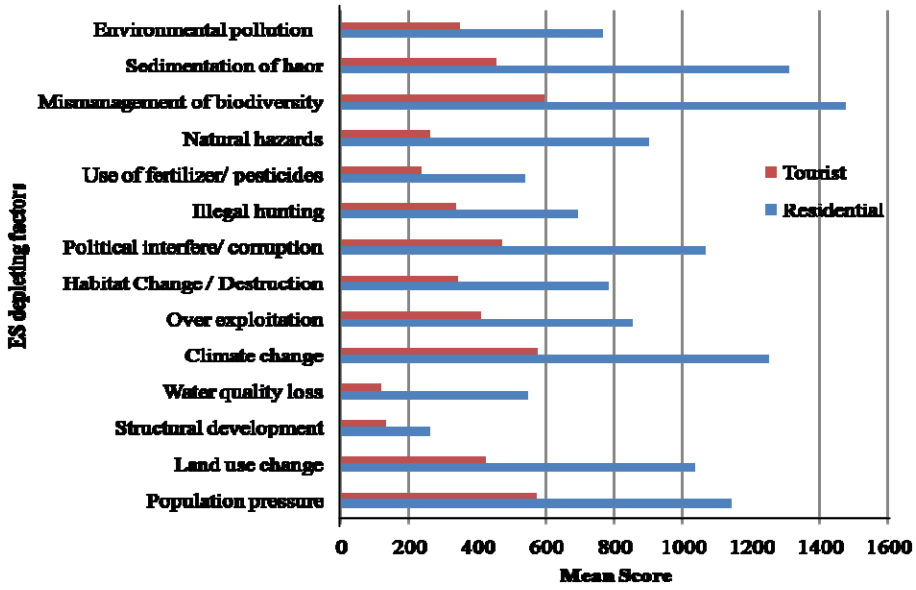

Fig. 2. Perception about depletion of ecosystem services in Tanguar haor

Ecosystem services within the DPSIR framework

Most common driving forces observed as demographic, population, economic, cultural factors and land based activities. Pressures and states detected as climate change, natural hazards, land use changes and soil & water pollution, sedimentation and changes of ecosystem services, respectively. Serious impacts was found as environmental & economic impacts, loss of water resources, fewer habitats for fishes and birds, migration, extinction of species and opportunities of livelihoods activities etc. These common impacts has the potentially to destroy the ecological status of Tanguar haor as well as ecosystem services near future. The possible impacts from human and natural activities on wetland such as over-exploitation, habitat loss and fragmentation, pollution, climate change, agricultural land loss and the spread of invasive alien species (Haque, 2012; Nahar, 2013; Morshed, 2013).

Human responses against these changes have included integrated wetland management, sustainable use of resources, afforestation, alternative livelihoods and voluntary agreements and so on (Fig. 3). Nowadays it is apparent that wetland faced severe impacts in spite of different activities by various organizations. So it's urgent to take actual steps for protection of wetland services like haor management laws & policy, more afforestation, penalty for over hunting & use of haor resources, natural vegetation and encourage conservation practices.

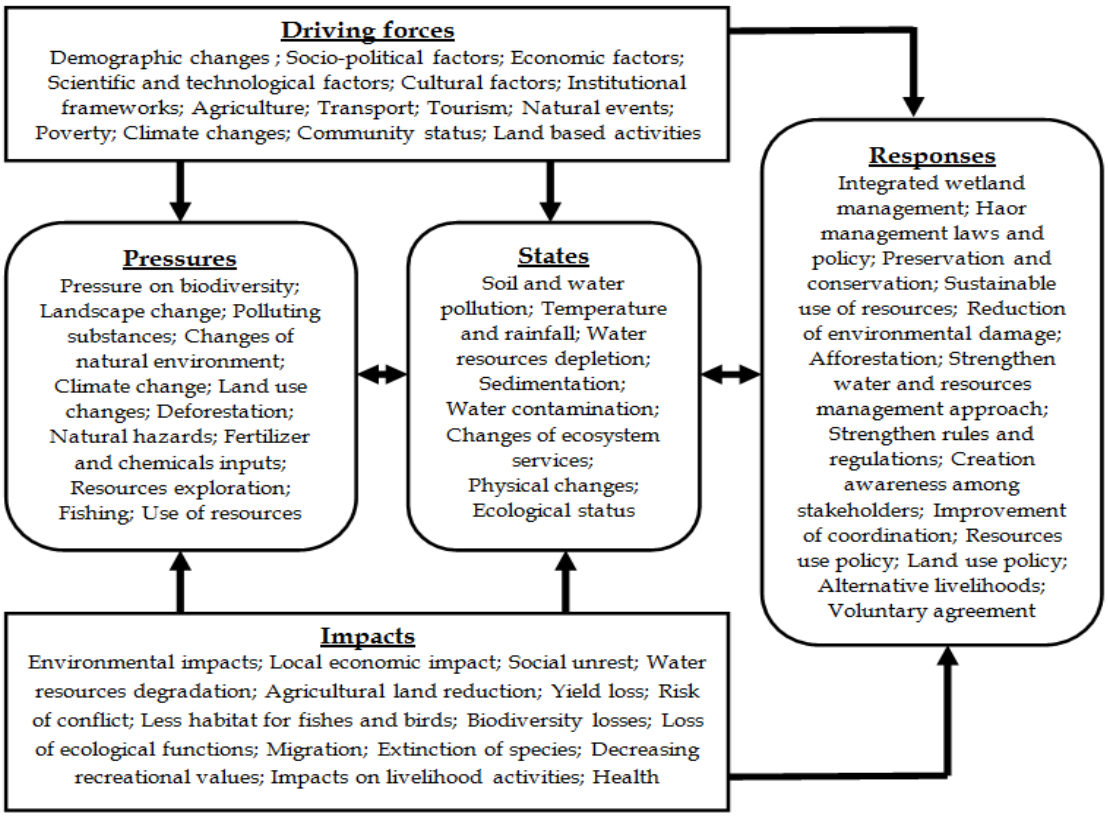

Fig. 3. Impacts and changes of ecosystem services: DPSIR framework.

Conclusion

Although the residential respondents had no knowledge about ecosystem services, four types of ecosystem services such as provisioning, regulatory, cultural and supporting were received by the residential respondents from the Tanguar haor. Different scenarios were observed for the tourists and they accept mainly cultural services. Total economic value of ecosystem services of Tanguar haor estimated at 173817480 BDT year^{-1} whereas tourists perceived economic values of cultural services estimated at 4450 BDT year^{-1} tourist^{-1}. Impact factor among ecosystem services was identified and its depleting factors were identified as 4.16. On the contrary, by applying DPSIR framework, identified impacts were environmental and economic impacts, loss of water resources, fewer habitats for fishes and birds, extinction of species and opportunities of livelihoods activities etc. Probable responses by communities were identified as sustainable use of resources, afforestation, alternative livelihoods, raising awareness and apply conservation techniques. Mismanagement of biodiversity was the highly responsible underlying factor for depleting ecosystem services at Tanguar haor. But over exploitation, sedimentation of haor, climate change, illegal hunting, land use changes and habitat changes also responsible for depleting these services. This study indicates that Tanguar haor has pivotal importance not only for human well being but also local and national

economy as well as biodiversity and environment. In brief, this research work analyzed the possibility of vast amount of economic value from Tanguar haor wetland as well as provided a clear direction of sustainable management of ecosystem services by identifying the possible impacts and pressure.

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