ORIGINAL ARTICLE

Modeling of freshwater wetland management strategies for building the public awareness at local level in Bangladesh

Md. Nazrul Islam · Daisuke Kitazawa

Abstract Bangladesh has a large aerial extent of freshwater wetlands for her deltaic character-istics. In 1970, the total area of wetlands in Bangladesh is estimated to be 70000–80000 km^2, approximately, i.e., 50 % of total national land area. In the recent years, most of these wetlands are being lost and degraded primarily because of flood control projects, irrigation and agricultural activities and others human interference. Unfortunately, over the last three decades in the name of wetland development, local habitats were not taken care of. In this paper, the stakeholder and scenario analyses are employed for measuring public views towards wetlands degradation in Bangladesh. Involvement of stakeholders helps reconcile their different conflicting interests in wetlands, hence creating a common understanding about the problem under study. An explor-atory scenario analysis illustrates different themes fulfilled by the wetlands and their associated services in case study *Chalan Beel*. The *Chalan Beel* once covered an area of approximately 651,230 acres in 1967. Currently, the permanent flooded area of the *Chalan Beel* has been reduced to about 18,120 acres. The scenarios show that most of the wetlands in Bangladesh are converted into agricultural lands, settlements, roads, and highways. Aquatic plants and animals are lost and endangered due to human interference and natural distur-bance. The government, policymakers and some private organizations are trying to design suitable policy for wetland management but they are not able to reach this goal. It is observed

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that the local and national policies are facing complexities to create an effective regime to set aside the wetlands management policy in Bangladesh. In this context, this paper proposed an Increased Public Awareness (IPA) policy model that could be pathways for both short and long-term solutions of wetlands degradation in developing nations like Bangladesh.

Keywords Wetland · DPSIR concept · Public awareness · Policy modeling · Bangladesh

1 Introduction

Recent scientific information on climate-wetlands interactions reveal that global climate variability affects the wetlands through increased air temperature and shifts in precipitation (Gardner and Connolly 2007). All of these impacts could affect species composition and wetland functions (Ren et al. 2011). Many wetlands and species are already under immense pressure of loss and degradation globally. Wetland land-use, and discharge, treatment and re-use of wastewater can all have profound effects on emissions and hence on the success of mitigation and adaptation strategies (Breitmeier 2008). Human alterations to the natural landscape have the potential to exert significant direct and indirect influence on wetland ontogeny and processes. Changes to natural hydrological, chemical, and physical regimes are affecting the production and succession of a wetland's ecology, and therefore its functions and values (Zhuang et al. 2011).

According to the 1971 RAMSAR (*"The Convention on Wetlands of International Importance especially as Waterfowl Habitat"*) Convention in article 1.1, the term wetland links together a wide range of inlands, coastal and marine habitats, which share a number of common features (Rashid 1991; Matthews 1993; Kim et al. 2006). Usually, wetlands occupy transitional zones between permanently wet and generally dry environment (Davis and Clarides 1993). From the perspective of a both developing and developed country, wetlands are important sources of commercial fishing, agriculture, seasonal livestock grazing, wood collection and ecotourism (Meixler and Bain 2010). The Ganges–Brahmaputra–Meghna river systems drain a total area of about 1.72 million km^2 (Ahmad et al. 2001) in India, China, Nepal, Bhutan and Bangladesh. Henceforth the name Ganges–Brahmaputra-Meghna (GBM) river basin. Due to global climate variability and withdrawal of surface water in the upstream reduces the surface and groundwater level in Bangladesh significantly (Davis 1978; Khan et al. 2010). In Bangladesh, wetlands are permanent and seasonal freshwater lakes and marshes of floodplains which known as 1) *Haor* (It is a bowl shaped depression between the natural levees of a river mostly found in the eastern region of greater Mymensigh and Sylhet districts). 2) *Baor* (It is called Oxbow Lakes is the dead arm of river situated in the moribund delta of the Ganges), and 3) *Beel (*It is the lowest part of the floodplain landscape, usually saucer shaped wetlands) (Table 1) (Akonda 1989; Nokashima and Khan 1993).

Wetlands in Bangladesh are also cherished for their eco-tourism and cultural importance to the nation. In terms of aesthetic values, wetlands of Bangladesh have many potential utilities (Khan et al. 1994; Nishat 2003). They contain very rich components of bio-diversity of local, national and regional significance (Khan 1993; Bennett et al. 1995; Talukder et al. 2009). Estuaries are a special sub-category of coastal wetlands, where fresh water and salt water mix in the wetland, making a habitat of varying salinity (Zhuang et al. 2011). In particular, freshwater habitats have been rapidly modified by human activities in many regions of the world (Hoq et al. 2006). When wetlands are threatened, many fish that spend the majority of their adult life at sea can also be threatened (Sato et al. 2010). This makes wetland protection important to the success of the worldwide fishing and shrimp (*Palaemonetus paludosus*) industries.

Table 1 Common type of wetlands in Bangladesh, their local or Bengali names and indentifying characteristics

Common type	Local/Bengali name	Characteristics
Multiple natural depressions	Haor	Single water body in the wet and split into a number of pockets
Ox-bow Lake	Baor	It is the dead arm of a river situated in the moribund delta of the Ganges
Single natural depression	Beel	Beel is the lowest part of the floodplain landscape and saucer shaped.
River	Nodi, Nod, Gang	Canalized flow in nature and rivers come from Indians hilly areas.
Lake	Lake, Roth	It is commonly constructed in urban areas
Pond	Pukur, Dighe	They are perennial. Usually it found in rural areas
Coral reef	Probal	Found at St. Martin Island
Flood plain	Bonna plabito alaka	Belt of low and flood ground. Both sides of a river inundate by flood
Creek	Nala	Coastal areas where brackish water remains during low tides
Ditch	Doba, Kanda, Pagar	Most are accumulation of rain water but some are perennial and small

Qussem 1986; Khan 1993; Nishat 1993; IUCN 2007

Global climate variability and increased population pressure in Bangladesh has resulted in large-scale demand of cultivable land for extra food production (Ali 1988; Rashid 1991; Zaman 1993; Bennett et al. 1995). Conversions into other uses have resulted in net loss of wetlands in Bangladesh (Khan 1993; Hughes et al. 1994). Despite the threats to wetland sites and species in Bangladesh, very few studies of the functions, uses, values and causes of degradation and of wetlands in Bangladesh is yet to be under taken (Nokashima and Khan 1993; Chowdhury 1998). In order to sustain wetland resources, there is the need to develop appropriate strategies for extensive study involving both physical and environmental conditions deemed necessary for optimization of resources utilization of wetlands in Bangladesh (Ali 1990; Khan et al. 2010). However, many stakeholders are involved in wetland activities and it is not easy to solve the challenges without proper policy model. It is therefore, important to build up the awareness of people who are directly related to the wetlands of Bangladesh. Given the problems as formulated in the earlier paragraphs and the different views, values and interests of the stakeholders, the following research objectives were formulated for this study. The primary aim is to illustrate the lack of freshwater management modeling at local level in Bangladesh. Regimes are a set of principles explicit or implicit norms, rules and decision-making procedures around which expectations of actors (states) converge in order to coordinate actors' behavior with respect to a concern to them all (Williams 2006) creation for wetlands management in Bangladesh. Therefore, the specific sub-objectives of this paper are:

(1) Simulate on wetlands degradation scenarios in Bangladesh,
(2) Identify regime creation challenges for wetlands management in local and national level, and
(3) Develop freshwater wetlands management strategies model in Bangladesh.

Participation of stakeholders can solve many problems of wetlands degradation. Moreover, with proper knowledge, participations of stakeholders can conserve the wetland and its eco-system at local level. Hence, for successful freshwater wetland management in Bangladesh, a participatory and integrated approach is essential. This paper raised an issue public awareness is very important for wetland management in local level. The proposed model of this paper could be the pathways of freshwater wetland management by the interaction of local peoples and increase their consensus.

2 Study area

Due to the deltaic characteristics of the country, Bangladesh has a large aerial extent of wetlands, probably one of the highest proportions in the world (Chowdhury 2001; IUCN 2007). The total area of the wetlands has been roughly estimated at seven to eight million hectares (Nishat 1993). Wetlands in Bangladesh include some natural and manmade ones. Table 2 shows the major wetlands distribution and area. These include a wide seasonally flooded plain. Some scientists and researchers think that most of the wetlands in Bangladesh could be considered as perennial wetland (Fig. 1). In this point of views wetlands of Bangladesh can be divided into two physiographic zones (Alam and Hossain 2004; Talukder et al. 2009). Such as: (a) the Ganges-Brahmaputra flood basin zones and (b) the haors and baors basin of the northeast zones (Ahmed et al. 2001; Khan et al. 2010). Some important freshwater wetlands of the country are *Chalan Beel,* Atrai Basin, Lower Punarbhaba Floodplain, Gopalganj-*Khulna Beels, Arial Beel,* and Surma-Kushiyara Floodplain. For preparing a policy scenario model, we considered the *Chalan Beel* wetlands unit as case study for this paper. *Chalan Beel* is a low-lying land of Bangladesh (Ahmed 1978; Islam 1997). It is the largest wetland in the northern and central part of Bangladesh. The *beel* is situated between 24.35° and 24.70°N and between 89.10° and 89.35°E.

Table 2 Wetland type, distribution, area and proportion of land-use in Bangladesh

Types	Area coverage/km^2	Percentage of area
River, canals and estuaries	10300.00	13.77
Natural depression	1141.69	1.52
Ponds	1619.43	2.16
Ox-bow lakes	544.88	0.73
Reservoirs	688.00	0.92
Seasonal flood lands	28000.00	37.42
Brackish water farms	873.00	1.17
Mangrove wetlands	6100.00	8.15
Beel and Haor	5000.00	6.68
Peat land	155.00	0.21
Swamp forest	20400.00	27.27
Total	74822.00	1020.00

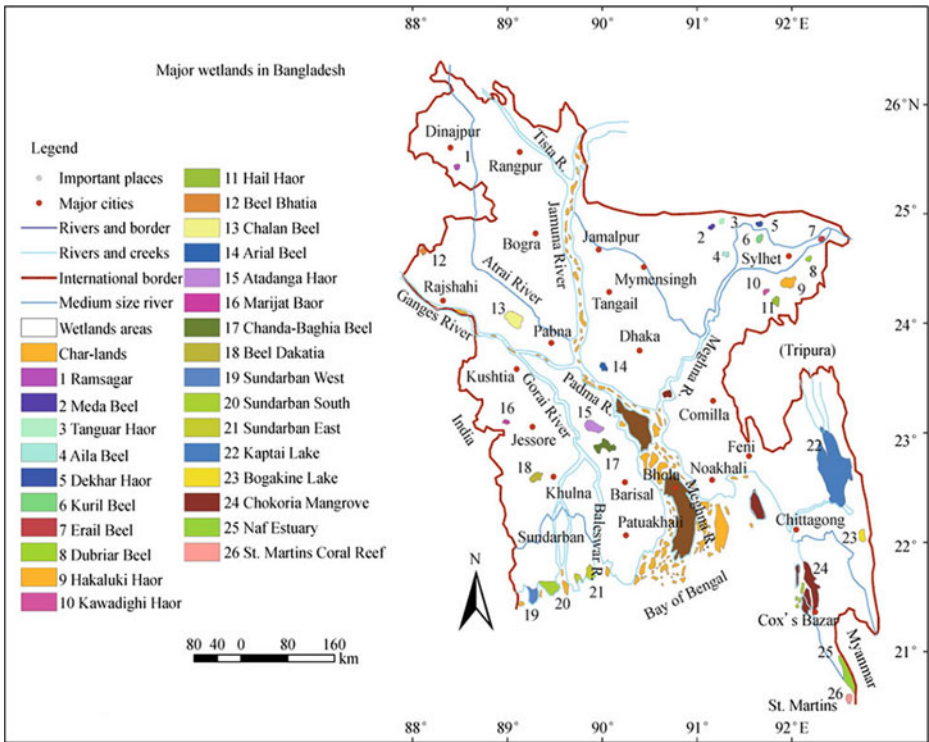Scott 1989; Nishat 1993; Rahman 1989; Islam 2010

Fig. 1 Wetland distribution in Bangladesh. The case unit *Chalan Beel* is shown the wetland number 13 (*Yellow box*) in near Atrai River in Rajshahi and Pabna Region in Bangladesh. (Source: BWDB 2007; Islam 2010)

3 Materials and methods

A mixed-methods approach is employed, nested within the Environmental Systems Analysis (ESA) tools (Findeisen and Quade 1997) e.g. scenario analysis and stakeholder participation. The freshwater degradation scenarios are assessed through a combination of observation and field study analysis. In this study, we have applied DPSIR (D-Driving force, P-Pressure, S-State, I-Impact and R-Response) concept, participatory rural appraisal (PRA) concepts for stakeholders' opinion analysis for developing a policy model for wetland management in developing nations like Bangladesh.

3.1 DPSIR concept analysis

The concept of DPSIR (D-Driving force, P-Pressure, S-State, I-Impact, R-Response) adopted by the European Environmental Agency (EEA) is one of the frameworks based on the concept of causality chains for data synthesis, which links environmental information using indicators of different categories (Kristensen 2004). As example: D=Driving forces are underlying of wetlands degradation, P=Pressure indicators describe the variables which directly cause of wetland degradation, S=State indicators show the current condition of wetlands, I=Impact indicators describe the ultimate effects of changes of state. R=Response indicators demonstrate the efforts of society on wetlands (i.e. policymakers, decision-makers and stakeholders) to solve the problems (RIVM 1995). The strength of P depends on the

nature and extent of the driving forces and on other factors, which shape human interference on wetland environment in this study. The I is related to wetland ecosystems and human well-being due to State modifications. The policy responses lead to changes in the DPSIR chain (Mourão et al. 2004). The application of this causality concept within a participatory rural appraisal framework context has the advantages of preparing the scenarios of wetlands degradation.

3.2 Applying participatory rural appraisal (PRA)

Analysis of stakeholders participation and DPSIR with the local inhabitants were arranged a Participatory Rural Appraisal (PRA) and critical discussion. The local peoples and some selected stakeholders identify some criteria and factors for degradation of wetlands in Bangladesh. Finally, local people gave their opinions about the factors that have direct negative impacts on wetlands. The survey team explained some wetlands degrading factors and requested the participant of PRA to give their views on degradation factor those very high influences wetlands. In this case, the survey team provided them some scoring indicator as if the factors impact is esteem, then they will put five seeds or coin on the selected factors. In this way, the participants choose very high with four seeds/coins, high with three seeds/coins, medium impacts with two seeds/coins and finally low impact with one seed/coin for identifying impact factors of wetland degradation (Table 3). After that, the survey team counted these values and ranked the most seven high scoring selected factors. These factors were then used for this study.

   However, some factors were interrelated and with similar impacts, but the local people think that they have some particular impacts. The DPSIR concept drivers (causes) include population growth, lack of awareness, settlements extension, agricultural extension and flood control projects. Pressures include the amount of waste discharged into wetlands, heavy metals, pathogenic organisms and acids and bases (Fig. 2).

Table 3 Wetlands degradation causes prioritized and ranked by applying Participant Rural Appraisal (PRA) in *Chalan Beel* in Bangladesh (2010–2011)

Degradation causes	Respondents										Total Score	Rank
	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8	R-9	R-10		
Population increase	***	**	***	**	***	***	***	**	***	***	27	1
Lack of public awareness	***	**	***	***	**	***	**	**	*	**	23	2
Socioeconomic impacts	*	***	**	*	*	**	**	*	*	**	16	5
Agriculture & settlements	***	***	*	**	**	**	**	*	**	**	20	3
Lack of national policy	–	–	–	*	–	–	*	–	*	*	04	8
Flood control projects	*	**	**	***	**	**	*	*	**	**	18	4
Over fishing	–	**	*	*	**	–	*	**	*	**	12	6
Natural siltation	–	–	**	–	*	**	–	*	**	*	09	7

Participatory Rural Appraisal (PRA) session in *Chalan Beel a*rea 2010–2011

Score (***) (3) means the highest impact on wetlands degradation

Score (**) (2) means the medium impact on wetland degradation

Score (*) (1) means the low impact on the wetland degradation

Score (−) (Dash) means the participant unable to identify the impact level.
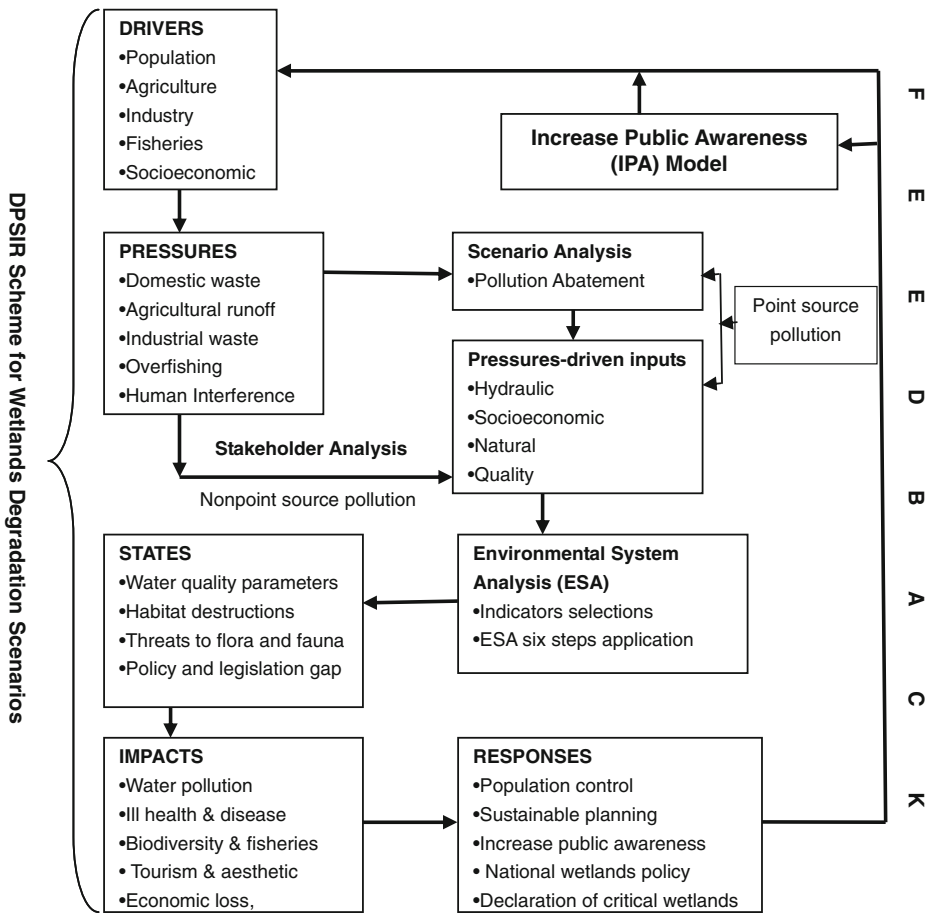
Fig. 2 A causal diagram for identifying the driving forces, current states, impacts and necessary of policy responses need for increase public awareness building further wetland degradation in Bangladesh by DPSIR concept

3.3 Stakeholder and scenario analysis

According to Hage and Leroy (2008), stakeholder participation can bring many benefits, which include the presence of important knowledge about the underlying causes of wetlands degradation. Participants include various stakeholders such as farmers, anglers, fishing leaseholders, boat operators, grass and aquatic vegetation collections, fishing gear traders, government agencies, union chairpersons, teachers, private businesspersons and NGOs (Non-government organization) activists in *Chalan Beel,* the study area. The goal of scenario analysis is to anticipate future developments of society and the environment, and to evaluate strategies for responding to these developments. A key idea is to explore alternative future developments (Alcamo et al. 1998), an exploratory or descriptive scenario was used. The four elements of the exploratory scenarios that were employed in this study are; a) a base year (1973) and a description of the state of things in that year; b) a time horizon (1973–2023) and the intervals of 10 years with description of the state of things are at the period; c) an environmental coverage of wetlands management policy, with the

introduction of the geographical preface is introduced of the scenarios in Bangladesh; d) A description of stepwise changes and the events between the base year and the time horizon, which explains how the future situation will occur based on the present.

3.4 Description of increased public awareness (IPA) model

This paper proposes an Increase Public Awareness (IPA) policy model that could be helpful for wetlands management and conservation policy in developing countries including Bangladesh. The proposed IPA model is structured by several parameters and components such as Decreased Public Awareness (DPA) sub model for the development of hypothetical scenarios (Table 4). The Increased Public Awareness model is constructed by spatial boundary of Bangladesh and the case study unit is *Chalan Beel.* The essence of public awareness is that the public should be informed about the values, functions, benefits and scarcity of wetland resources. The concept IPA is a value that the targeted audience or public plays a major role in contributing to wetland management for achieving values and goals of the model.

Two alternative and two policy measurements are constructed by the choice of the user. First, the user can choose an alternative Increased Public Awareness (IPA) or Decrease Public Awareness (DPA) by the scenario option of the model (Fig. 3). Then, the user can choose the policy measures that are presented by the model as Efficient Wetland Management Measures (EWMM-Efficient Wetland Management Measures are defined by the international environmental regime, protocols and amendments especially RAMSAR Convention, Convention on Biological Diversity (CBD) and United Nations Framework Convention on Climate Change Kyoto protocol. In this paper, this term are used for understanding wetlands values and government and local administrations are successfully applied the proper wetland management policy according to international regimes) and Inefficient Wetland Management Measures (IWMM-Inefficient Wetland Management Measures are defined by the international environmental regime, protocols and amendments especially RAMSAR Convention, Convention on Biological Diversity (CBD) and Kyoto protocol. In this paper, this term are used for understanding wetlands values and government and local administrations are significantly failed to apply the proper wetland management policy according to international regimes). The users will able find a relationship between Increased Public Awareness and Efficient Wetland Management Measures e.g. optimum view and ideal state. Similarly, the users will get Increased Public Awareness and Inefficient Wetland Management Measures mixed situation and moderate ideal state. Accordingly,

Table 4 Scenarios for conceptual alternatives of changing public awareness off wetlands management in *Chalan Beel* of Bangladesh

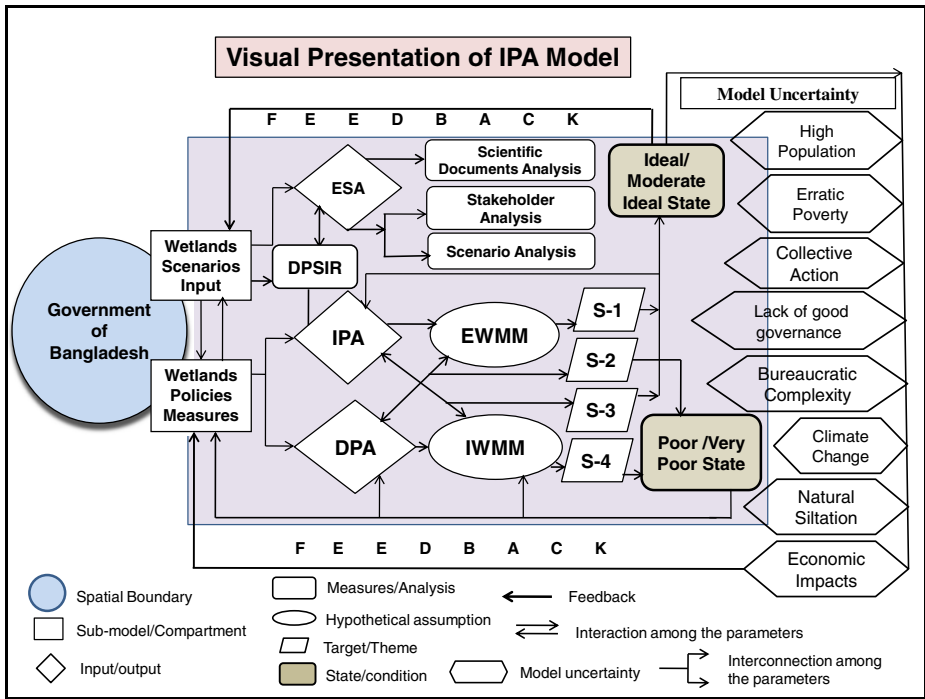| Selected alternatives	Efficient Wetland management Measures (EWMM)	Inefficient Wetland management Measures (IWMM)
Increase Public Awareness (IPA)	Optimum view: Ideal Scenario 1	Mixed Situations Moderate Ideal Scenario 2
Decrease Public Awareness (DPA)	Mixed situations Poor State Scenario 3	Complex situations Very Poor State Scenario 4

Fig. 3 Visual representation of proposed Increased Public Awareness (IPA) model, its components and model uncertainties for wetlands freshwater management in Bangladesh

Decrease Public Awareness and Inefficient Wetland Management Measures shows simple relationship like mixed situation and poor state. Finally, combing with Decrease Public Awareness and Inefficient Wetland Management Measures the users will receive a complex situation and very poor state respectively (Table 4). Hence, the user comes up with some policy scenarios on wetlands management approaches. The user can communicate with the stakeholders and wetlands related inhabitants to verify the IPA output policy scenarios. The users, policymakers, or officials can recommend policy scenarios that are well fitted for policy modeling for certain wetland areas.

4 Results and discussion

4.1 Wetlands degradation scenarios in Bangladesh

Bangladesh wetlands are of little concern to many people. The wetlands of Bangladesh have distinct characteristics, and that is permanent wetland to seasonal wetland, seasonal wetland to flooded wetland or agricultural land. Transformation of wetlands is accelerated by new human settlements, roads and highways. Physical wetlands changes fragment and isolate fauna and flora eventually leading to endangerment or extinction. (Table 5). Because of push and pull factors, rural people move from rural to urban areas (Rana et al. 2009). As a result, developers and slum dwellers reclaim urban wetlands and this was observed in this study. Figure 4a and b show that the functions of wetlands and Fig. 4c and d show that land filling

Table 5 Due to wetland degradation by global climate variability and human interference the following major flora and fauna are lost, vulnerable and endangered from the wetlands in Bangladesh

Diversity	Types	Local Name	Scientific Name	Status	Causes of decline
Flora	Shrubs	Kalmishak	*Ipomoea aquatic*	Endangered	Anthropogenic
Flora	Shrubs	Ghechu	*Aponogeton echinatus*	Lost	Habitat Destruction
Flora	Shrubs	Padma	*Nelumbo Nucifera*	Vulnerable	Habitat Destruction
Flora	Shrubs	Shapla	*Nymphaea nouchali*	Vulnerable	Habitat Destruction
Flora	Shrubs	Helencha	*Enhydra fluctuans*	Endangered	Anthropogenic
Flora	Shrubs	Panilajja	*Neptunia natans*	Lost	Habitat Destruction
Flora	Shrubs	Borotipata	*Polygonum plebejum*	Lost	Habitat Destruction
Flora	Tree	Hijal	*Barringtonia Acutangula*	Lost	Anthropogenic
Flora	Tree	Chatim	*Alstonia scholaris*	Lost	Anthropogenic
Flora	Tree	Dumur	*Ficus hispida*	Endangered	Anthropogenic
Flora	Tree	Chalta	Dillenia indica	Lost	Anthropogenic
Fauna	Reptiles	Kashim	*Lissemys panctata*	Lost	Hunting
Fauna	Reptiles	Dora Shap	*Amphiesma stolata*	Vulnerable	Habitats reduce.
Fauna	Amphibia	Sona Bang	*Rana tigrina*	Endangered	Anthropogenic
Fauna	Fish	Aair	*Aoichthys aor*	Lost	Over Fishing
Fauna	Fish	Baim	*Basim Species*	Vulnerable	Over Fishing
Fauna	Fish	Bheda	*Nandas nandas*	Endangered	Habitats reduce.
Fauna	Fish	Boal	*Wallgu atta*	Vulnerable	Habitats reduce.
Fauna	Fish	Chetal	*Notopotcus Chitala*	Endangered	Habitats reduce
Fauna	Fish	Foli	*Notopterus Species*	Vulnerable	Over Fishing
Fauna	Fish	Koi	*Anabus testadineis*	Endangered	Habitats reduce.
Fauna	Fish	Shing	*Neteropreuste Species*	Lost	Over Fishing
Fauna	Fish	Shol	*Channa striatus*	Vulnerable	Habitats reduce.

Akonda 1989; Khan et al. 1994; GOB 1999; Nishat 2003; IUCN 2007; Khan et al. 2010

and unplanned urbanization and housing estate or slums reclaim wetlands. These types of development were often done without proper planning or without paying due regard to natural water flows. These poorly planned structures create water logs and had serious impact on wetlands. Although the government of Bangladesh takes some initiatives such as signing international environmental treaties, the situation of wetland management have not changed yet. Nevertheless, in Bangladesh it is difficult to declare wetlands as a protected area because many poor people are directly or indirectly dependent on wetlands. Without proper alternatives for the wetland dependent poor people, it is not possible to declare critical wetland as protected area.

4.2 Case unit of *Chalan Beel* wetlands scenarios

Chalan Beel is diverse in natural resources of numerous types, even if most are now at the verge of extinction (Islam 1997; SRDI 2010). Once it was very abundant in fish and aquatic resources. In this wetland, there are about 1,600 villages spreading over 823 square miles of its area with more than two million populations. The *beel* once covered an area of approximately 651,230 acres in 1967 (Hamid 1967). Currently, the permanent flooded areas of the *beel* has been reduced to about 18,120 acres and the greater part of the *beel* dries out leaving

Fig. 4 **a** Wetlands decreasing trends in *Chalan Beel* area from 1965–1988. **b** Wetlands decreasing trends in *Chalan Beel* area from 1988–1998. **c** Wetlands decreasing trends in *Chalan Beel* area from 1998-2010. **d** Wetlands decreasing trends scenarios in *Chalan Beel* area from 1967–2023

only a small area of shallow and interconnected water bodies. Various unplanned dams and embankments have been constructed for irrigation and flood control. Figure 5 shows the decreasing trends of this *beel* in 1967–2010. The wetland of *Chalan Beel* area have been
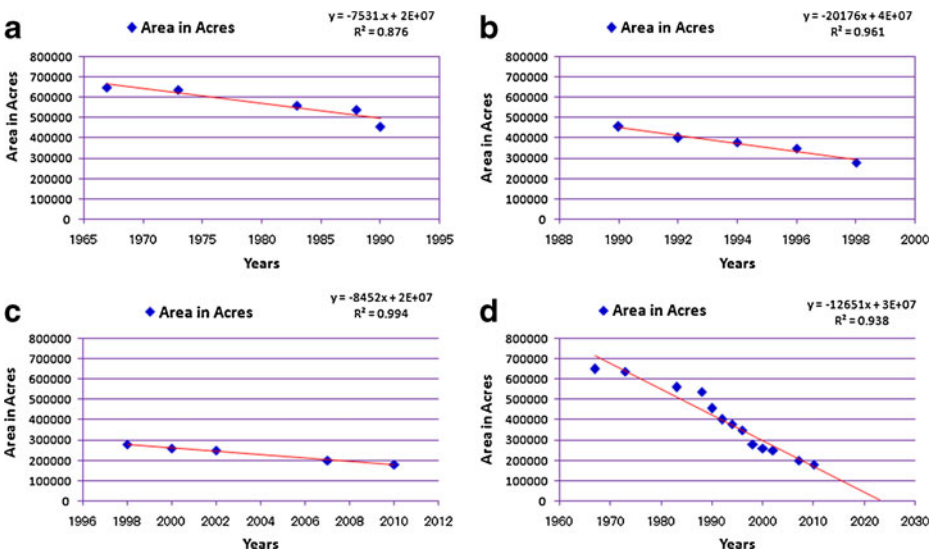

Fig. 5 **a** Wetlands decreasing trends in *Chalan Beel* area from 1965-1988. **b** Wetlands decreasing trends in *Chalan Beel* area from 1988-1998. **c** Wetlands decreasing trends in *Chalan Beel* area from 1998-2010. **d** Wetlands decreasing trends scenarios in *Chalan Beel* area from 1967-2023

noticeably changed during 1967–2010. Most of the wetlands have been transferred into agricultural lands and settlements. After implementing of *Chalan Beel* irrigation polder project and flood control project the wetlands of this area have certain distinct characteristics in 1973, 1978 and 1987. In 1988, a devastating flood transported huge sediment into the *Chalan Beel* area as a result; *beel* was filled up by natural siltation. As a result, many small Rivers, *Khal, Zola, Dhors* (local wetlands names) of *Chalan Beel* have silted up. Therefore, the net areal extents of wetlands have significantly reduced in *Chalan Beel* area.On the other hand, wetlands depression and permanent water bodies have been changed largely and converted into agricultural lands, settlements, roads and highways by 1998–2010. The secondary information reveals that in 1973, about 70% area of *Chalan Beel* was covered permanently with wetlands, and rest was seasonally flooded. Nevertheless, in 2010, the most part of 254 Chalan Beel wetlands area are converted intor agricultural lands, settlements, roads and 255 highways. Both human and natural driving forces created the pressures on the Chalan Beel.

4.2.1 Reduction of fish habitat, fish population and diversity

The human population of *Chalan Beel* area has increased dramatically. Thus, the demands for lands and wetland services have substantially increased, putting pressures on the wetlands flora and fauna. During the last half-century, development interventions have been undertaken in this area; mainly to increase food production for an increasing population, improve roads and highways network systems, build up small industries etc. All of these come to a cost of valuable wetlands and their resources. Bangladesh is lower riparian country with common international boundaries and rivers with India. Unluckily, India has been diverting Ganges-Brahmaputra water by the Farakka barrage during low flow period since 1975, and Bangladesh is suffering from acute shortage of water since then. Reduction of Ganges-Brahmaputra flow is likely to result in a much larger adverse effect on the wetlands, socio-economy, environment, and ecological balance in Bangladesh (Takahashi and Nakamura 2011).

This in turn causes limitless misery in the livelihoods of thousands of people, particularly the poor fishers and others who depend on fisheries and other wetland resources and navigation for these livelihoods. A large number of faunal such as fish, mammals, amphibians, some floral are now locally lost. About 260 species of freshwater fishes are found in the inland water bodies of Bangladesh with about 63 species of fishes were recorded from the water bodies of *Chalan Beel*.

4.2.2 Extinction and reduction of wildlife including birds and reptiles

A large number of faunal and floral resources, mammals and amphibians are now locally lost. Various species of *Chalan Beel* include blue-winged teal *(Anas discors)*, mallard (*Anas platyrhynchos)*, gadwall (*Anas strepera*), common teal (*Anas crecca*), tufted duck, (*Aythya fuligula*), common pochard (*Aythya ferina*), ruddy shell duck (*Tadorna ferruginea*), cotton pygmy goose (*Nettapus coromandelianus*), fulvous whistling duck (Dendrocygna bicolor), lesser whistling duck (Dendrocygna javanica), grey lag geese (*Anser anser*), common shell duck (*Tadorna tadorna*) and other migratory birds.

Another wildlife species are grey heron (*Ardea cinerea*), cattle egret (*Bubulcus ibis*), great egret (*Casmerodius albus*), large egret (*Ardea modesta*), little egret (*Egretta Garzetta*), purple swamp hen (*Porphyrio porphyrio*), pheasant-tailed jacana (*Hydrophasianus chirurgus*), little grebe (*Tachybaptus ruficollis*), great crested grebe (*Podiceps cristatus*), Little cormorant (*Phalacrocorax niger*), Asian open bill (*Anastomus oscitans*), common coot (*Fulica atra*), pintail snipe (*Gallinago stenur*), marsh sandpiper (*Tringa glareola*), little ringed plover (*Charadrius*

dubius), golden plover (Pluvialis fulva), wood sandpiper (Tringa glareola), green shank (Tringa nebularia), red shank (Tringa tetanus), red-wattled lapwing (Vanellus indicus), brown-headed gull (Larus brunnicephalus) and black-headed gull (Chroicocephalus ridibundus) etc.

4.3 Causes, effects and possible solutions of wetland degradation

Unplanned construction of bridges, culverts, sluice gates, flood control embankments, among others have disrupted the spawning, breeding and feeding of migratory fishes and other aquatic animals in *Chalan Beel* area. According to the case study of wetlands degradation scenarios, it is clear that the wetlands of Bangladesh are facing the following impacts:1) reduction of fish habitat, fish population and diversity; 2) extinction and reduction of wildlife including birds and reptiles; 3) extinction of many indigenous varieties of rice with the propagation of high yielding varieties; 4) loss of many indigenous aquatic plants, weeds and shrubs; 5) loss of natural soil nutrients; 6) loss of natural water reservoirs and degeneration of wetland-based ecosystems, and 7) change occupations, socio-economic institutions and cultures.

The alternative solutions to these problems include agricultural policies, improved agricultural and industrial technology, efficient waste management system, efficient wetlands management measures, sustainable urban–rural development planning and improved wetlands management policies. According to stakeholders' opinions, the following common solutions measures could be implemented. 1) significance of wetlands in the national, zonal and local level planning process must be recognized; 2) sustainable and comprehensive agricultural practices and land use patterns need to be devised; 3) functions of selected wetlands be rehabilitated; 4) introduction of sustainable management practices at all levels; 5) technical knowledge, planning and management capabilities be enhanced; 6) attention given to awareness, education and research aspects. Systematic researches are needed for wetland mapping and landscape planning at the local and national level; 7) declaration of critical wetlands as protected areas, and 8) conservation and protection measures including eutrophication abatement,

4.4 Challenges of wetlands management modeling in Bangladesh

The management of wetlands in Bangladesh is administratively fragmented. Various authorities comprising the Ministry of Works, the Fisheries Department and the Department of Environments are all involved in the operation and maintenance of these wetlands. The Ministry of Works has its ownership, the Fisheries Department looks after the fish stock, while the wetland related research institute exercises some responsibilities in its improvement (Rahman 1989; Islam 1993). The Department of Environment looks after the aspects of environment and protection of aquatic resources of wetlands in Bangladesh. The pollution related problems manifested shortly afterwards due to poor maintenance and poor coordination from the various sectors or departments involved in its operation and management (Chowdhury 1987; Ali 1990; Ahmed et al. 2008). The stakeholders involved in the use of these wetlands have different conflicting agenda and interests. For instance, inhabitants of these wetland areas and the Department of Environment are interested in solving the wetland degradation problems and protection of biodiversity (Sadeq and Islam 1993; Mirza et al. 2001). But since many stakeholders are involved in wetland activities it is not easy to solve the problems without proper policy model. It is therefore, important to build up the awareness of people who are directly related to these wetlands. Wetlands management is not addressed separately in the water management policy of Bangladesh. The National Water Policy (NWP) controls the present wetlands management of Bangladesh (GOB 1999; Qayyum and Islam 2010). These policies are dependent on some old acts. such as:

(1)   Protection and Conservation of Fish Act 1950,
(2)   The Haor Development Board Ordinance 1977,
(3)   The Environment Policy 1992, which gives due importance to wetland and related
       issues are:

   •   Rivers, canals, roads, lakes, haors, beels, baors and all other water bodies should be
        kept free from pollution,

Table 6 Exploratory/descriptive scenarios of wetland degradation and net loss in Bangladesh from 1973 to
2011 and the future scenarios are defined in this table from 2013 to 2023

Departure point	Time duration	exploratory scenarios
S_0	1973	Baseline scenario (assuming no intervention is made)
S_0–S_1	1973–1983	Since the emperor Mughal period all types of natural resources have been used as sources of revenue collection for the government. This act thus restricted the local people's access rights relating to land and natural resources. There had been no significant substantial changes in the natural resources management approach since the independence of the country (as East Pakistan in 1947 and as Bangladesh in 1971). After the independence of Bangladesh in 1971, a number of initiatives were taken by the government to find an appropriate management approach for wetlands resources. But most of the approaches are failed to conserver the wetlands due to over populations. After Ramsar convention (1971) the national policymakers and academician are seriously concerned and they are tried to raise their opinion in the forum but population pressure and lack of awareness have destroyed all of initiatives.
S_1–S_2	1983–1993	After Ramsar convention the national policy and academician were started to concern about the wetlands values and functions and the government of Bangladesh was taken some excellent initiatives but it was not fruitful due to lack of public participation and awareness. In this perspective on 6 May 1992, Ministry of Environment and Forests, signed as a party to the CBD (Convention on Biological Diversity). Unfortunately the scenarios of wetlands degradation in Bangladesh didn't change until now.
S_2–S_3	1993–2003	Increasing population pressure need to be build up new settlements, roads and high ways and develop infrastructures and to arrange cultivable land for extra food production for the surplus peoples. For this reason, many of the seasonal wetlands were transformed into agricultural land and settlements or infrastructure development. In the mean time, the Millennium Ecosystem Assessment 2002 report has shown a concern about the long term affects of aquatic or terrestrial ecosystem all the nations including Bangladesh. But actual scenarios of wetlands degradation are not changed at all.
S_3–S_4	2003–2013	Maximum wetlands in Bangladesh are degraded. Some wetlands are still fighting with the natural and human disturbance but policy measures are not developed at all. Although the government and policymakers have significant interest to protect the further degradation of these wetlands but some illegal agencies or stakeholders destroy rest of the wetlands of Bangladesh in the name of so called real estate development.
S_4–S_5	2013–2023	It is very important to create public awareness soon. If the countrymen are not aware and effective policies/regime are not implement about the wetlands conservation policy in Bangladesh the rest of the wetlands could be destroyed totally very soon,
S_5	2023	End point of the scenario in this study. National and micro-level climate could bechanged and environmental degradation would be occurred in the near future.

Akonda 1989; Khan et al. 1994; GOB 1999; Nishat 2003

- wetland should be conserved for the protection of migratory birds,
- Activities which diminish the wetlands habitats of flora and fauna should be prevented,
- Existing projects on water resources development, flood control and irrigation should be examined to determine their adverse impact,
- Environmental and social impact assessment should be conducted before undertaking new projects for water resources development and managements.

(4) Bangladesh Environmental conservation Acts 1995. The wetland and landscape management unit of International Union for Nature Conservation (IUCN) Bangladesh tasked to oversee the natural resource of the country (Matthews 1993; Muttenzer 2002).

The public and private institutes tried to coordinate with RAMSAR regime on Wetlands (1971–1998), and Conservation of Biodiversity Development (CBD) regime (1992–1998). Local regimes have three classes of parties as country government, civil society and the secretariats. Many challenges and uncertainty becomes to build up a regime for better wetlands management in Bangladesh. These include 1) collective action and free rider problems; 2) poverty and education break; 3) lack of good governance; 4) policy and legislation gap; and 5) natural challenge and uncertainty. Before independence, which was in 1971, these regions had two wetlands regimes. These include British colonial regime and post-independent Bangladesh regime (Table 6). Unfortunately, due to lack of political stability of the country policy-makers are not able to build an international standard wetland management policy.

People in the floodplains of Bangladesh are mostly poor. These vulnerable people are constrained by not having space for agronomic cropping or of access to or ownership of lands. Due to this, farmers are filling up the wetlands and cultivate there for extra food production. Increase in poverty, population, and political instability are key reasons for degradation and unsustainable use of wetlands resources in the country. Rural push and urban pull factors lead to rural–urban migration. As a result, urban populations keep increasing and they need for extra housing and infrastructures. This urban growth have profound adverse effect on water bodies in the cities. Though the government of Bangladesh has taken some good initiatives to solve these problems, but in political points of view the new government has no interest to continue the old government development activities. Governments need to do many things to encourage the development activities of previous government. They need to build and maintain infrastructures, and raise and spend finance wisely, on the right projects. When governments are inept at managing infrastructures, development is impossible. Finally, political instability plays a role in any kind of management including wetlands management in Bangladesh. All the rivers flowing through Bangladesh originate from outside the country and these rivers carry heavy loads of silt, sediments and other debris, including domestic, agrochemical and industrial wastes, from far-away places. Together with these, local wastes are added, thus making the water saturated and at times oversaturated with organic and inorganic pollutants. The wetlands of the country become the dumping grounds for these sediments and pollutants and flushing out of materials to the Bay of Bengal is quite slow. The result is serious deterioration of the aquatic resources. Most of the rivers are connected with each other and different mills and factories are situated on their banks, the recovery of the water from the effects of the effluent is very low and during the non-monsoon period, conditions become worse.

4.5 Implications of increased public awareness (IPA) model

For building strategies model, it is important to fix the appropriate management alternatives, measures and scenarios. This paper wetlands strategy modeling measures have assumed that

the combination between Increased Public Awareness (IPA) with Efficient Wetland Man-
agement Measures (EWMM) and Increased Public Awareness (IPA) with Inefficient Wet-
land Management Measures (IWMM) model signify the Scenario 1 (S-1) and Scenario (S-2)
respectively. These two themes reflect optimum view and ideal state, mixed situation and
moderate ideal state of the wetlands in future, if public awareness is increase. The Decreased
Public Awareness (DPA) sub-model combined with Decreased Public Awareness with
Efficient Wetland Management Measures and Decreased Public Awareness with Inefficient
Wetland Management Measures signifies the Scenario 3 (S-3) and Scenario 4 (S-4) respec-
tively if public awareness is decrease. These two themes have shown mixed situation and
poor state, complex situation and very poor state of the wetlands respectively. The models
also find that the relationship between IPA and EWMM is optimum. It is not easy to achieve
both Increased Public Awareness and Efficient Wetland Management Measures without
minimizing the several common uncertainties such as economic impacts, population control,
poverty alleviation and climate change impacts etc. Therefore, it is quite difficult to achieve
the S-1 ideal policy scenario of wetland management in Bangladesh. Secondly, the relation-
ship between IPA and IWMM is mixed situation and moderate ideal policy scenario.

However, is it possible to achieve? Increased Public Awareness (IPA) in a local level or
national level without EWMM. It might be possible by using stakeholder participation
approach or a public-awareness program designed to achieve several objectives about IPA.
For example: 1) targeted audiences; 2) a commitment to developing collaborative
approaches with local communities and to ensure that the management of Chalan Beel is
driven by local level interests and needs; 3) identify, in collaboration with local community
groups, suitable alternative income generating activities to help reduce pressure on the
wetland in Chalan Beel (MACH 2005); 4) organize education and awareness activities that
promote an understanding of the need for wetland resources conservation in Chalan Beel; 5)
village conservation groups are considered a mechanism through which the implementation
of field level conservation activities can be initiated and coordinated; 6) carry-out, in
collaboration with local community groups, ad hoc education. The following measures
could be included: teaching materials, posters and pamphlet for birds, fish, swamp species,
T-shirts and hats, radio announcements, theatre and plays and integrating conservation
concerns into religious teachings. The Scenario 3 (S-3) shows the combinations with
Decreasing Public Awareness (DPA) and Efficient Wetland Management Measures
(EWMM) in the IPA model show the mixed situation and management scenario is defined
poor state. It is also a bit difficult to achieve the goal without high economic impacts or
development. The relationships between DPA and IWMM have shown a complex situation
and the scenario is very poor state. Many wetlands in least developed or developing
countries are facing very critical and complex situations. Many wetland sites scenarios of
Bangladesh similar to Scenario 4 (S-4) of IPA model.

4.5.1 Assumptions and limitations of this study

The findings of this study proposed an Increased Public Awareness (IPA) policy model that
could be helpful for both short and long-term solutions of wetland degradation in Bangla-
desh. In this context, land and water managers must pay attention to issues related to
wetlands ecosystems. Moreover, public awareness has to be developed for wetlands con-
servation in developing countries like Bangladesh. This paper will support policymakers and
stakeholders who are interested in creating eco-friendly policy/regime on wetlands manage-
ment in Bangladesh. The focal points of wetlands degradation in developing countries like
Bangladesh are poverty and lack of public awareness. Most of the people are not aware of

wetlands conservation or environment protection. They think that their problem is only with poverty, and not the environment. In this context, it is not easy to implement any policy or act by the Government for improving the wetlands management strategies.

The IPA model has some strong points which are 1) it is very simple and has a qualitative concept; 2) the model could be very helpful for better management in developing countries; 3) public awareness making is as impressive concept and it is helpful for better environment; and 4) the model contains very simple matrix. On the contrary, the proposed model has several weak points are 1) it does not carry enough quantitative validity; 2) It is quite difficult to minimize the common unavoidable uncertainties to attain the IPA model goals; 3) it is not suitable for simulation modeling and predicting.

4.5.2 Increased public awareness (IPA) model uncertainties and sources

This IPA model considers uncertainty for achieving the model's goals and objectives. Nevertheless, all of the unavoidable uncertainties of this model affects the wetlands policy measures especially rapid population growth and economic impacts is very high. In this paper, the IPA model's vision is considered a different one. It is very difficult to attain the goals of the management scenario S-1 to minimize or solve these uncertainties for a developing country like Bangladesh. For this reason the IPA model, propose that the management scenario S-2 is better for short-term wetlands conservation policy in developing countries.

5 Conclusion

The findings of this study revealed that the wetlands of Bangladesh have been degraded due to lack local people awareness about the functions and values of wetlands. Global climate variability, withdraw the water in upstream, huge population pressure for extra food production and flood management projects.

As a result, local aquatic ecosystems are destroyed and biodiversity are lost and endangered. Most of the aquatic plants and animals have been are either lost or extinction. Fisheries resources and wildlife have been declined. The local people are not concerned with this critical problem. Government agencies and some private organizations tried to make a suitable wetland management policy but due to economic constraints and lack of participation, they have failed. Actually, in developing countries it is not easy to implement efficient wetland management measurers, because it is highly interrelated with economic aspects of the country. However, considering the critical conditions of wetlands in Bangladesh there is an immediate need for increase in public awareness to protect further degradation of wetlands. Therefore, without increasing public awareness and participation at local level it could be challenging to build up wetlands related policy and regime.

The following recommendations should be helpful for prevent further degradation of wetlands in developing nations:

- Resource managers must pay attention to issues related to wetlands resources,
- Development of systems for resolving conflicts among fish, land and water management approaches the need to implement appropriate land-use policy/ strategy
- need to implement,
- Creation of awareness on relevant issues at all level (policy level as well as at project level) should be created;

- Elaborate application of a further study and research with public participation and awareness buildup agenda.

References

Ahmad QK, Biswas AK, Rangachari R, Sainju MM, (eds.) (2001) Ganges–Brahmaputra–Meghna Region: A framework for sustainable development. University Press Limited, Dhaka, Bangladesh.

Ahmed N (1978) An Analysis of the Fisheries of Pabna with a Few Aspects of the Fisheries of Bangladesh. Dhaka, University of Dhaka, pp 24–75

Ahmed I, Deaton BJ, Sarker R, Virani T (2008) Wetland ownership and management in a common property resource setting: A case study of Hakaluki Haor in Bangladesh. Ecol Econ 68(1–2):429–436. doi:10.1016/j.ecolecon.2008.04.016

Alam MS, Hossain MS (2004) Haor. In: Islam S (ed) "Banglapedia: the national encyclopedia of Bangladesh". Asiatic Society of Bangladesh, Dhaka, pp 50–59

Alcamo J, Leemans R, Kreileman GJJ (1998) Global change scenarios of the 21st century. Results from the Image 21 Model. Pergamon & Elseviers Science, London

Ali MY (1988) Open water fisheries and environmental changes. In: Rahman AA, Huq S, Conway GR (eds) Environmental aspects of surface water systems of Bangladesh. University Press Limited, Dhaka

Ali SI (1990) Haor Basin Ecosystem. In: Rahman AA, Huq S, Gony GR (eds) Environmental Aspects of Surface Water System of Bangladesh. University Press Limited, Dhaka, pp 38–72

Akonda AW (1989) A Directory of Asian wetlands in Bangladesh, IUCN. Available at http://www.banglapedia.org/httpdocs/HT/W_0051.HTM

Bennett S, Scott D, Karim A, Sobhan I, Khan A, Rashid SMA (1995) Wetland resources specialist study, northeast regional water management plan. Bangladesh Flood Action Plan (FAP), Bangladesh: 1–145

Breitmeier H (2008) The Legitimacy of International Regimes: Findings from The International Regimes Database, Ashgate Publication: 23–176

BBS (2010) Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics (BBS), Dhaka

BWDB (2007) Perennial and main wetlands of Bangladesh. Bangladesh Water Development Board (BWDB), Ministry of Water Resources, Dhaka: Bangladesh

Chowdhury AM (1987) Study of North Western Bangladesh Using Aerial Photographs and LANDSAT Imagery. Rajshahi University, Rajshahi

Chowdhury S (1998) Saving our oceans: some thoughts on fisheries conservation. The Daily Star 2(100):6–7

Chowdhury MAK (2001) Changes in mangrove forest soils: a comparison between cultured and naturally inundated conditions. Wetlands Ecol Manag 9(2):81–89

Davis J, Clarides G (eds) (1993) Wetlands Benefits, the Potential for Wetlands to Support and Maintain Development. America, Asian Wetlands Bureau, pp 46–52

Davis TJ (1994) The RAMSAR Convention Manual. RAMSAR Convention Bureau, Japan

Findeisen W, Quade ES (1997) The methodology of systems analysis: An introduction and overview. In: Quade ES and Miser HJ (1997) (ed.) Handbook of systems analysis: Overview of uses, procedures, application and practice, Chichester 1(4): 117–149

Gardner RC, Connolly KD (2007) The Ramsar convention on Wetlands: Assessment of international designations within the United States, Environmental Law Reviewer ELR 10089, USA 2 (37): 1–25

GOB (1999) National Water Policy (NWP). Ministry of Water Resources, Dhaka: Bangladesh, 7(2): 75–93

Hage M, Leroy P (2008) Stakeholder Participation Guidance for the Netherlands Environmental Assessment Agency Practice Guide, Netherlands Environmental Assessment Agency (NEAA) and Radbound University Nijmegen, MNP Publication: 6–40

Hamid A (1967) Chalal Beel Er Eti Kota (History of Chalan Beel), Amader Home Prokashoni. Pabna, Bangladesh (in Bengali)

Hoq ME, Wahab MA, Islam MN (2006) Hydrographic status of Sundarbans mangrove. Bangladesh with special reference to post-larvae and juveniles fish and shrimp abundance. Wetlands Ecol Manag 14:79–93. doi:10.1007/s11273-005-2569-9

Hughes R, Adnan S, Clayton BD (1994) Floodplains or flood plans? A review of approaches to water management in Bangladesh, International Institute for Environment and Development (IIED). Available at http://pubs.iied.org/7757IIED.html

Islam AKMN (1993) Ecological characteristics and dynamics of Wetlands Soils. In: Nishat et al. (1993) (ed.) Freshwater Wetlands in Bangladesh Issues and Approaches of Management, Dhaka: IUCN, The World Conservation Union

Islam MN (1997) Human Interference and Its Impact on Wetlands: A Case Study of Chalan Beel, Jahangirnagar University, Dhaka, Bangladesh. J Geogr 21:67–81 (in Bengali)

Islam (2010) Threatened wetlands and ecologically sensitive ecosystems management in Bangladesh. Front Earth Sci 4(4):438–448

IUCN (2007) Community based haor and floodplain resource management project document. Ministry of Environment and Forest: Dhaka, Bangladesh 3:74–103

Khan AA (1993) Freshwater wetlands in Bangladesh: opportunities and options. In: Nishat A, Hussain Z, Roy MK, Karim A (eds) Freshwater wetlands in Bangladesh-issues and approaches for management. IUCN, Dhaka

Khan MS, Haq E, Huq S, Rahman AA, Rashid SMA, Ahmed H (1994) Wetlands of Bangladesh. Holiday Printers Ltd., Bangladesh

Khan SM, Hannan MM, Haque C (2010) Wetland resource management in Bangladesh: implications for marginalization and vulnerability of local harvester, Journal of Environmental Hazards: 76–89

Kim GK, Park YM, Choi SH (2006) Developing a wetland-type classification system in the Republic of Korea. Landscape Ecol Eng 2:93–110. doi:10.1007/s11355-006-0012-x

Kristensen P (2004) The DPSIR Framework European Topic Centre on Water, European Environment Agency. Paper presented at the 27–29 September 2004 workshop on a comprehensive/detailed assessment of the vulnerability of water resources to environmental change in Africa using river basin approach. UNEP Headquarters: Nairobi, Kenya

MACH (2005) Local Governance and Empowerment of the Poor for Improved Wetland Management in Bangladesh. Management of Aquatic Ecosystem through Community Husbandry. Winrock International, Dhaka, Bangladesh

Matthews GVT (1993) The Ramsar convention on Wetlands: Its history and development (Ramsar 1993) The history of the movement throughout the 1960s from which evolved the Ramsar convention in 1971 and its development since up to about 1993

Meixler MS, Bain MB (2010) Landscape scale assessment of stream channel and riparian habitat restoration needs. Landscape Ecol Eng 6(2):235–245. doi:10.1007/s11355-010-0103-6

Mirza QMM, Warrick AR, Ericksen JN, Kenny JG (2001) Are floods getting worse in the Ganges, Brahmaputra and Meghna basins? Environmental Hazards 3:37–48

Mourão I, Caeiro S, Costa MH, Ramos TB, Painho M (2004) Application of the DPSIR model to the Sado Estuary in a GIS context Social and Economical Pressures, Toppen F, Prastacos P (eds) Proceedings of 7th Conference on Geographic Information Science. Crete University Press. AGILE 2004, 29 April-1 May, Crete, Greece: 391–402

Muttenzer F (2002) Local Government and the International Biodiversity Regime Collective Bargaining over State Forest in Madagasgaska, paper presented at the 9th Biennial Conference of The International Association for the Study of Common Property, Sub-theme "Globalization, Governance and the Commons", Victoria Falls, Zimbabwe, 1–5 June: 7–21

Nishat A (1993) Fresh water Wetlands in Bangladesh Status and Issues, in Nishat A (et al.) (eds) Fresh Water Wetland in Bangladesh Issues and Approaches for Management, Dhaka: IUCN

Nishat A (2003) Management of fresh water wetlands in Bangladesh: issues and strategy at "http://www.doe-bd.org/cwbmp/inception_report/grp3_nishat_wetl_use.ppt" visited on 26 October 2007

Nokashima S, Khan MH (1993) A Basic Guide Book to Understanding the Environmental Impacts of Rural Roads on the Wetlands. Care International in Bangladesh, Dhaka

Qayyum MA, Islam MA (2010) Livelihood Adaptation in Wetland Bangladesh: Pro-Poor Risk Reduction and Adaptation Strategies, Bangladesh: The Environments of the Poor in the Context of Climate Change and the Green Economy, Making Sustainable Development Inclusive, New Delhi, India: 24–26 November 2010: 1–13

Qussem MA (1986) Distribution and Use of Water Bodies in Bangladesh. BAU, Survey Findings, Bangladesh

Rahman AKA (1989) Freshwater Fishes in Bangladesh, Dhaka: Zoological Society of Bangladesh: 364

Rashid MA (1991) Wetland and Waterfowl Conservation in Bangladesh, Karachi: IWRB, Special Publication, No. 25: 23–29

Rana MP, Chowdhury MSH, Sohel MSI, Akhter S, Koike M (2009) Status and socio-economic significance of wetland in the tropics a study from Bangladesh. iForest 2:172–177. doi:10.3832/ifor0512-002

Ren H, Wu X, Ning T, Huang G, Wang J, Jian S, Lu H (2011) Wetland changes and mangrove restoration planning in Shenzhen Bay, Southern China. Landscape Ecol Eng 7(2):241–250. doi:10.1007/s11355-010-0126-z

RIVM (1995) A General Strategy for Integrated Environmental Assessment at the European Environmental Agency. National Institute of Public Health and Environmental Protection, Bilthoven, The Netherlands

Sadeq SM, Islam MA (1993) Socioeconomic Characteristics of Freshwater Wetlands in Bangladesh. In: Nishat et al. (1993) (ed.) Freshwater Wetland in Bangladesh Issues and Approaches for Management, Dhaka: The World Conservation Program, IUCN, Bangladesh

Sato M, Kawaguchi Y, Nakajima J, Takahiko Mukai T, Shimatani Y, Norio Onikura N (2010) A review of the research on introduced freshwater fishes: new perspectives, the need for research, and management implications. Landscape Ecol Eng 6(1):99–108. doi:10.1007/s11355-009-0086-3

Scott DA (1989) A Directory of Asian Wetlands, IUCN, International Waterfowl and Wetlands Research Bureau, Slimbridge, and Asian Wetland Bureau, Kuala Lumpur

SRDI (2010) Thana Nirdeshika Series Land and Soil Utilization Guide Tarash, Chatmohar and Gurudaspur Thana, Dhaka: Soil Resource Development Institute (SRDI), 7:187–201. (in Bengali)

Talukder B, Nobukazu N, Rashid MS (2009) State and management of wetlands in Bangladesh. Landscape Ecol Eng 5(1):81–90. doi:10.1007/s11355-008-0052-5

Takahashi M, Nakamura F (2011) Impacts of dam-regulated flows on channel morphology and riparian vegetation: a longitudinal analysis of Satsunai River, Japan. Landscape Ecol Eng 7:65–77. doi:10.1007/s11355-010-0114-3

Williams SF (2006) Liberal reform in an illiberal regime: The creation of private property in Russia, 1906–1915. Stanford, CA: Hoover Institution Press, pp xiv + 320: ISBN: 0-8179-4722-1

Zaman SMH (1993) Agricultural Development and Sustainability of Wetlands, in Nishat A (et al.) (eds) Freshwater Wetland in Bangladesh Issues Approaches for Management, Dhaka: IUCN, The World Conservation

Zhuang DC, Ding DS, Dong MH (2011) A wetland ecological construction study on reclaiming a lake from an area in Dongting Lake Plain. World Regional Studies 2:107–112