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Saeid Eslamian

Wetland Hydrology

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Wetland Hydrology

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### 29.1 Introduction

The world wetlands are playing a potential role in economic and ecological point of view. Particular interest has been shown to a number of wetlands around the world with regard to their extent uniqueness and attributes. It includes coastal and inland deltas, riverine wetlands, salt marshes and mangroves, freshwater marshes, and peatlands. They are found on every continent except Antarctica and in very rough climates from the tropics to the tundra. A total of 750,000 km² of wetlands have been registered with the convention on wetlands of international importance as of 2000 (Mitsch and Gosselink, 1986).

Wetlands in different parts of the world have a great importance for the country’s economic, industrial, ecological, socioeconomic, and cultural context for certain reasons (Islam and Gnauck, 2007). They contain very rich components of biodiversity of all valuable ecosystems (Kundzewicz, 2003). This ecosystem serves as habitat for a variety of resident and migratory waterfowl and endangered and commercially important species of national and international interest (Nishat, 1993; Islam and Gnauck, 2009a). Moreover, it supports a rich biodiversity of flora and fauna, substantially contributing to socioeconomic improvement for millions of people living especially in rural areas. This created livelihood sustainability is providing opportunities for employment, food and nutrition, fuel, fodder, transportation, and irrigation (Nishat, 1993). The wetlands of developing countries such as in Asia, Latin America, and African have suffered drastically from the impacts of burgeoning human population and anthropogenic activities on the wetlands. Furthermore, wetlands are recognized as a driving force for biodiversity conservation and rural socioeconomic improvement (Nishat, 1993; Ahmed and Falk, 2008). The smart use of wetlands can solve the ecosystem problems in the floodplain areas. In the South Asian Ganges–Brahmaputra–Meghna floodplains alone, approximately 2.1 million ha of wetlands has
been lost due to flood control, drainage, and irrigation development (Khan et al., 1994); therefore, wetlands are facing serious challenges from environmental changes and anthropogenic impacts (Sarkar, 1993; Nair, 2004; Ahmed and Falk, 2008).

The modern approach of wetland construction is planning a potential role in socioeconomic improvement. In general, millions of industrial constructed wetlands have been used in treating wastewater or conventional water of different characteristics throughout the world in every year, including domestic wastewater, various types of industrial wastewater, agricultural wastewater, and storm water. The constructed wetlands in Bangladesh are seen in a very small scale.

Bangladesh is a land of wetlands; it lies in the eastern part of the Bengal Basin, one of the largest river floodplains in the world. Bangladesh has long depended on the basin’s three formidable rivers, the Padma (Ganges), the Jamuna (Brahmaputra), and the Meghna, as well as their numerous smaller tributaries and distributaries for freshwater, transportation, and fish and for the floods that deposit fertile silt on their farmland each year. In Bangladesh, where inland water bodies constitute nearly 50% of total land area, wetlands are critical to economic development and environmental improvement. The total area of wetlands in Bangladesh is estimated to be 70,000–80,000 km² of national land (Akonda, 1989; Khan et al., 1994). These include rivers, estuaries, mangrove swamps, marsh (haor), oxbow lake (baor) and beels, water storage reservoirs, fishponds, and some other lands (Khan, 1993; Hughes et al., 1994; Gopal and Wetzel, 1995; Islam and Gnauck, 2008). The major roles of wetland are nutrient retention/removal, support for food chains, fishery production, habitat for wildlife, recreation, natural heritage values, biomass production, water transport, biodiversity presentation, and microclimate stabilization.

There are five types of wetlands available in Bangladesh, such as saltwater wetlands, freshwater wetlands, palustrine wetlands, lacustrine wetlands, and man-made wetlands. Presently, most of the wetlands in country are under threat due to unsystematic utilization, encroachments and reclamation, urbanization and drawbacks from agricultural development, and flood control actions (Nishat, 1993; Khan et al., 1994; Gopal, 1999). The protection and management status of wetlands in developing countries are more or less complex and severe due to financial, technical, social, and political decision, as well as lack of integration of those sectors (Gopal and Wetzel, 1995; Islam and Gnauck, 2008; Sultana and Thompson, 2008). A comprehensive analysis of various issues leading to wetland degradation in the case areas in Bera, Santhia, Sujanagar upazilas in the middle location of Bangladesh, and Sundarbans mangrove wetlands in the southwestern region of the country has been chosen. This comparative wetland hydrologic analysis has been highlighted through applied research findings on the freshwater and saline water wetlands in Bangladesh.

The objective of this chapter is to understand the characteristics of wetlands hydrology and to investigate the wetland biodiversity conservation to promote the sustainable management of wetland biodiversity in Bera, Santhia, and Sujanagar upazilas in Pabna district in Bangladesh. One of the key components to foster for effective implementation of Ramsar Conventional Policies of wetlands in the context of sustainable wetland and natural resource management is supporting this endeavor. The following specific objectives of the wetlands biodiversity conservation are as follows:

- A special investigation will be limited on the two case areas in Bera, Santhia, Sujanagar upazilas for freshwater wetlands, and the Sundarbans mangrove saline coastal wetlands in Bangladesh.
- To protect the wetland ecosystems and conserve its biodiversity.
- To use wisely and sustain natural resources.
- Improve the livelihoods of the poor wetland communities in the Bera, Santhia, and Sujanagar upazila of the eastern part of the Pabna district where the Ganges (Padma) River meets the Brahmaputra (Jamuna) River and southwestern region the Sundarbans mangrove area.
- Prepare some recommendations for future development of wetlands in Bangladesh and ensure local food security to the dwellers.
29.2 Hydrology of the Wetlands

Hydrologic processes occurring in wetlands are the same processes that occur outside of wetlands and collectively are referred to as the hydrologic cycle. Major components of the hydrologic cycle are precipitation, surface water flow, groundwater flow, and evapotranspiration (ET). Wetlands and uplands continually receive or lose water through exchange with the atmosphere streams and groundwater. Water supply is necessary for the existence of wetlands.

The wetland water budget is the total inflows and outflows of water from a wetland. The functions, persistence, and size of wetlands are controlled by hydrologic processes.

Wetlands constitute a part of human heritage. It has played a significant role in the development of human culture and society. Moreover, it contains very rich components of biodiversity of local, national, and regional significance. They also provide a habitat for a variety of resident and migratory waterfowl, a significant number of endangered species, and a large number of commercially important species.

However, high population density has resulted in intense pressure on both land and water resources. Rice cultivation became the overriding priority, so that flood protection embankments, irrigation canals, sluice gates, and flood drainage structures were built in the 1980s to protect agriculture from flooding, cutting off many traditional fishing grounds from rivers and blocking fish migration routes. The impact on the wetland ecosystem, including the freshwater fisheries, was in many cases devastating—fish yields decreased in some areas by as much as 75%. The global climate change is further expected to impact the north Bengal wetlands by increasing drought, monsoonal rains, floods and bank erosion, accentuate food insecurity problems, and consequently rural poverty among others. Anthropogenic influences on the surface water and groundwater pollution through arsenic contamination are a new threat for community health risk in the northwestern region of Bangladesh.

In addition, over half of all poor households catch fish for food or income; thus, the decline in wetland biodiversity and productivity has resulted in the loss of a vital safety net for poor people in the wet season. In the wetland biodiversity conservation project in three upazilas (Bera, Santhia, and Sujanagar) in the Pabna district in Bangladesh supported by the Department of Fisheries of the Ministry of Fisheries and Livestock, the Bangladesh Water Development Board of the Ministry of Water Resources is working to increase wetland biodiversity, restore vital freshwater fishery habitats, and improve the livelihoods of wetland dwellers, initially in Bera, Santhia, and Sujanagar upazilas of the eastern part of the Pabna district where the Ganges (Padma) meets the Brahmaputra River (Jamuna).

29.2.1 Special Distribution of World Wetlands

Wetlands are distributed unevenly throughout different climatic zones of the world because of the difference in geology, climate, and source of water. They occur in widely diverse settings ranging from coastal margins, where tides and river discharge are primary source of water, to high mountain valleys where rain and snowmelt are the primary source of water. Marine and saline wetlands are found at all the coastal states of the world. Estuary wetlands (where tidal saltwater and inland freshwater meet and mix) are most plentiful in the coastal region of the world.

The special distribution and differences in wetland type, vegetative composition, and soil type are caused primarily by geology, topography, and climate. In turn, the wetland soils and vegetation alter water velocities, flow paths, and chemistry. The hydrologic and water quality functions of wetlands, that is, the roles wetlands play in changing the quality or quantity of water moving through them, are related to the wetland physical setting (Carter, 2010).

There are thousands of wetlands distributed in different parts of the world (Figure 29.1). The 10 major great wetlands are distributed in the different continents of the world. The 10 large wetlands are as follows:
FIGURE 29.1  World wetland distribution. (From U.S. Department of Agriculture—(USDA), Natural Resources Conservation Service (NRCS)-Global distribution of wetlands map, USDA-NRCS, Soil Science division, World Soil Resources, Washington, DC, 2003.)
1. Pantanal (Brazil) is the world’s largest wetlands, lying mostly in western Brazil but extending in Bolivia and Paraguay as well. It is covering a region of 140,000 km².
2. The Sundarbans mangrove wetlands (Bangladesh and India). It is the largest littoral mangrove wetland and covering an area of 10,000 km².
3. Okavango delta wetland (Botswana). It is one of the world’s great inland wetlands. It is formed where the Okavango River empties onto a basin in the Kalahari Desert. The area of Okavango wetland is 15,000 km².
4. Everglades (Florida). It covers an area of 51,240 ha.
5. Kerala Backwaters (India) is 590 km along the coast and the largest lake area is covering an area of 200 km².
6. Kakadu wetlands (Australia) cover an area of 19,804 km².
7. Mekong delta wetlands (Vietnam) cover an area of 40,000 km².
8. iSimangaliso Wetland Park (South Africa). It covers an area of 3280 km².
9. Wasur National Park (Indonesia). It covers an area of 4138 km².
10. Camargo wetlands (France). It encompasses the Rhone River delta in the southeast of France and it covers an area of 150,300 ha (Figure 29.1).

These 10 world largest wetlands are playing a potential role in making a balance of wetland ecosystems and providing ecosystem services in surroundings.

In Bangladesh, the wetlands have suffered from human population, and approximately 2.1 million ha of wetlands has been lost to flood control, drainage, irrigation development, and other human developmental activities (Nishat, 1993, 2003). There are only 43 designated wetlands, and most of them are under threat from indiscriminate utilization, encroachments and reclamation, urbanization and drawbacks from agricultural development, and flood control. Almost 50% of the country’s people are directly dependent on wetland resources. The vast majority of the poor people in the wetland areas are dependent on wetland resources for their nourishment (Islam, 2010). Therefore, the hydrologic modeling and natural resource management plan and policy are needed toward the conservation of the invaluable unique wetland sites in Bangladesh and other countries as well.

29.2.2 Hydrologic Balance for Wetland Ecosystems

The term borsha has been widely used to denote regular flooding in order to contrast it with extreme flooding, which is referred as bona, as monsoonal rainfall and regular flooding do not necessarily lead to disasters. Seasonal flooding is needed to maintain the ecological and hydrologic balance, and rural people perceive this to be essential to their livelihoods. Floodplain people have developed wide-ranging and indigenous strategies for managing normal flood conditions. Extreme flooding can devastate crops, infrastructure, and livelihoods and bring misery for prolonged periods of time, creating disasters that challenge the resilience of the population (Sultana, 2010). Social process interacts with natural processes to produce the differentiated vulnerabilities and suffering that ensue, which have gendered implications. While poverty and vulnerability are not always correlated in much of rural Pabna district in Bangladesh, they interact to reinforce gendered powerlessness and suffering (Cannon, 2002). While women are often the victims, they are also resourceful agents who cope with disasters and play important roles in rebuilding, rehabilitation, care giving, and mitigation (Enarson and Morrow, 1998).

Gender power relations and socioecological transformations in each case interact with the root causes of poverty, marginalization, and inequities, but there are differences that can be highlighted. Flood control measures alter the hydrology and geomorphology of the Ganges–Jamuna River floodplain region, changing its ecology and socioecological systems. Coping strategies include marking portable stoves, saving footstock and fuel in dry places, trying processions to trees and huts, lifting belongings to platforms created just under the roof, and learning to live on the thatched roofs when the floods are too high. Huts are generally built on raised earth mounds or platforms, and this enables
most households to deal with annual flooding (Sultana, 2010). Drinking water collection is particularly difficult during times of extreme floods, as tube wells are often submerged, polluting the water. The freshwater and saline water wetlands are playing three types of functions (Figure 29.2); these are very much essential for the balance of ecosystem and its services as well as to ensure the local livelihood sustainability.

The Bera, Santhia, and Sujanagar upazilas are facing such natural calamities; furthermore, social and cultural conflicts and problems are arising. The Bera upazila has severe flooding and the people are facing the same problem almost every year (Sultana, 2010). Natural calamities and anthropogenic influences, which are damaging the wetland functions, are hampering provision of the natural ecoservices in the fresh- and saline-water wetlands in Bangladesh. As a whole, the natural resources as well as wetlands are reducing its area, losing its ecosystem and biodiversity. Considering the present vulnerability situation, the wetland biodiversity conservation project in Bera, Santhia, and Sujanagar upazilas and the coastal mangrove region in the southwestern region in Bangladesh could be a viable development and applied research project in Bangladesh, which will carry out tremendous findings and results for future development guideline framework for wetland biodiversity conservation in Bangladesh as well as similar areas for other countries.

29.2.3 Wetland Plant Species

Wetlands have often been viewed as wastelands to most of the community people. Wetlands are used for different purposes and controlled by the landowners and landlords for their own purposes. At one time, landowners were encouraged to drain “water-logged” lands, but today, the wetlands are using multifarious purposes and playing a crucial role in society and is beginning to be understood and

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valued. Wetlands are one of the potential sources of community livelihoods, particularly for the cultivation of food crops, vegetables, fishing, and pasturelands (Khan et al., 1994). There are some special common vegetation plants that are relatively uniform in the haor, beel, and baor areas: the names of such trees are hizal (*Barringtonia acutangula*), tamal (*Diospyros cordifolia*), barun (*Crataeva nurvala*), madar (*Erythrina variegata*), gab (*Disopyros peregrine*), chalta (*Dillenia indica*), dehua (*Artocarpus lacucha*), and paniphal (*Trapa bispinosa*) (Akonda, 1989; Talukdar et al., 2008). Aside from those plants, a number of medicinal plants and species are available in the wetland areas, being widely used by the community and especially by the indigenous people. Some of these special plants are *polygonum*, locally known as *Akanda, Kalmi, Helencha, Aarnalata, Bashok, Bishkatali, and Kukra*. The flowers and seeds of *paddo* (Indian lotus) are prescribed for piles, as a cardiac tonic and for elimination of ringworm. The flowers of water lilies are reputed as a remedy for heart ailments (Khan et al., 1994; Rahman, 1995). The wetland plants and species are traditionally used by health practitioners, harvesting these medicinal resources for their livelihoods.

The wetland plants have been contributing substantially to the livelihood of the millions of rural people as a source of food, fuel, fodder, manure, thatching materials, medicine, and so forth. Varieties of macrophysics are eaten as vegetables and some are eaten raw. During monsoon, water hyacinth extensively used as fodder in many areas and nonfood aquatic resources retain the ecological balance for the local residents. These plants are harvested mostly by the rural poors and their access for this purpose is almost free for all. Wetlands provide a wide range of economic, social, and ecological benefits. Wetlands are one of the most productive and resourceful areas, which provide food. From the perspective of a developing country, wetlands are an important source of commercial fishing, agriculture, seasonal livestock grazing, wood collection, and ecotourism.

Beyond the obvious role of providing habitat for waterfowl and shore birds, the deeper role of wetlands is also becoming more and more apparent and understood. During high water and runoff seasons, wetlands act as a natural flood control. Wetlands also act as a natural filtration system. They remove sediments and even toxic chemicals from our water supplies. Some areas of the United States are even using wetlands as a natural sewage treatment system.

### 29.2.4 Hydrologic Modeling

Hydrologic models are the simplified and conceptual representation of a part of the hydrologic cycle or water cycle. Primarily it is used for hydrologic prediction and monitoring for understanding the hydrologic process on a certain area. In general, the wetland areas are dependent on the local water cycle process, and the local water cycle process is dependent on the surface and groundwater supply and situation, temperature, rainfall, soil moisture, ET, etc. Toward protecting and making the balance of the hydrologic cycle or water cycle of a certain region of the wetland areas, modeling is very much essential. The model can forecast the present to future situation.

In general, there are two types of hydrologic models that can be distinguished such as the stochastic model and process-based model. The stochastic model is a model of black box systems, and this is based on data and using mathematical and statistical concepts to link a certain input to the model output. In such model development, the rainfall, runoff, neural networks, and system identification are potential considering issues. The output of this type of model is called stochastic hydrologic model. The process-based model is attempted to represent the physical process that is observed in the real world. This model represents surface runoff, subsurface flow, ET, and channel flow, but it is more complicated and it is called deterministic hydrologic model.

Figure 29.3 shows the real-world hydrologic model of the case areas in the Pabna district and the coastal mangrove wetland region in Bangladesh. It is important to note that the water cycle or hydraulic cycle or hydraulic model has been designed to use the same input and similar model components as the operational hydrologic forecast model of the case areas. The two case areas have been chosen based on the ecological characteristics as well as freshwater and saline water wetlands. In both
cases, the elements of the hydrologic cycle are hampering the balance of water cycle of that case area. Therefore, Figure 29.3 illustrates the proper functions of all elements; some elements are not working properly; this is why for understanding the real situation and forecasting, the condition of the hydrologic model is necessary for the wetland resource management and conservation, its biodiversity, and community livelihood sustainability.

29.2.5 Phytoremediation Effect

Environmental pollution with metals and xenobiotics is a global problem, and the development of phytoremediation technologies for the plant-based cleanup of contaminated soil is therefore of significant interest. Phytoremediation technologies are currently available for only a small subject of pollution problems such as arsenic and salinity intrusion. Salinity and arsenic removal employ naturally selected hyperaccumulator ferns, which accumulate very high concentrations of arsenic specifically in aboveground tissues. Elegant two-gene transgenic approaches have been designed for the development of mercury or arsenic phytoremediation technologies.

Arsenic concentration in the groundwater of the Ganges floodplain wetland areas of the Bengal delta region was first discovered in the 1980s in the west Bengal of India. Arsenic presence in well water in three districts in the northwest region of Bangladesh was discovered in 1993. A number of theories and hypothesis have been developed to explain the origin and basic cause of Arsenic calamity in the wetlands in Bangladesh (BGS and DPHE, 2001). Arsenic (As) in groundwater used for drinking water is slowly poisoning tens of millions of people all over the world. The extent of this disaster was not internationally recognized until the mid-1990s (Moore et al., 2000). A few years later, arsenic (As) was found in the Ganges deltaic floodplains to contain arsenic (As) above the 10 μg/L, which is the WHO guideline value. Figure 29.4 illustrates the arsenic-contaminated groundwater in the wetland areas in Gopalganj and Madaripur districts in Bangladesh (Chowdhury, 2009).

The chronic levels of 50 μg/L can cause health problems after 10–15 years of exposure (Moore et al., 2000). The wetlands in the Bengal delta region are affected as an estimated 35 million people have been drinking arsenic-contaminated water for the last 25–35 years (Smedley and Kinniburgh, 2002). The examination for arsenic dermatologic symptoms in 29,000 people showed that 15% had skin lesions
Handbook of Engineering Hydrology: Fundamentals and Applications (Chowdhury, 2009). The coastal region (47,000 km²) of Bangladesh is affected by high-saline water. Therefore, the coastal wetlands in the southern region of Bangladesh are highly contaminated and are vulnerable regions for drinking water, cultivation, and livelihood sustainability. In the development of the science, scientists come up with two ecologically friendly and economically reliable methods to tract wastewater by combining knowledge of botany and chemistry. These are phytoremediation, which uses living plants, and biosorption, which uses dead plant materials. Therefore, phytoremediation technique is used in the initial process of wastewater treatment, and constructed wetlands are used in phytoremediation technique where plants are growing in the artificial wetland.

The constructed wetland is also highly productive and can provide a useful tool to prevent eutrophication in surface waters while generating a potentially valuable crop for farmers. In Bangladesh, only the large city areas have developed the wastewater treatment plants to purify drinking water for the urban citizens. Free water surface constructed wetlands with emergent macrophyte functions as land-intensive biological treatment systems. Suspended solid removal is usually a fairly rapid physical process. Therefore, constructed wetland or conventional wetland development initiatives are not enough in Bangladesh, and it should be considered as an alternative source of quality water for drinking and irrigation. The constructed wetlands in Bangladesh could carry out a tremendous positive influence in society for fundamental development of water quality.

29.2.6 Effect of Vegetation on Wetland Flow

The water flows in the wetland areas are playing a potential role in protecting the functional activities. The water flows and quantities and quality of surface water are the main sources and balance wetland flows. The plants and vegetation of wetland areas are dependent on the surface water flows. Asian, South American, and African countries are suffering from surface water flows and wetland flow; as a result, the vegetation of such regions is damaging its diversity and succession. All over the world, the

FIGURE 29.4 Phytoremediation effect by arsenic contamination in the wetlands and floodplain region in Bangladesh.

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freshwater wetlands and saline water wetlands are facing similar types of natural and anthropogenic actions. The quality of river flow enriches the special types of vegetation; moreover, it contains very rich compounds of biodiversity of local, national, and regional significance.

The quality of freshwater flows also provides habitats for a variety of resident and migratory water flows, a significant number of endangered species, and a large number of commercially important species. In general, the coastal, saline wetlands are affected by sea level rise and saline water penetration. The coastal mangrove wetlands are connected with upstream freshwater flow in the world. In the case of Bangladesh, the wetlands of Bera, Santhia, and Sujanagar upazilas are the freshwater wetlands, and these are dependent on the Ganges and the Brahmaputra (Jamuna) River water flow condition. These two rivers supply freshwater to the wetlands of these three upazila wetlands in the wet season. It is in the records that almost all of the wetlands are annually inundated. Some wetlands are losing its area and water depthness because of high temperature and high ET, irrigation and agricultural land extension, and settlement development in the wetland areas in the Pabna district in Bangladesh. On the other hand, the Sundarbans mangrove wetlands and coastal wetlands are affected due to high-salinity intrusion and shrimp cultivation, settlement development, and urbanization process, because the Sundarbans mangrove wetlands are located at the Bengal coast and are crisscrossed by a vast network of rivers and channels. These occupy around 10% of the total coastal area. The combined flow of these water courses is about 140,000–200,000 m³/s (Islam and Gnauck, 2007, 2009, 2009a). A major portion of this flow enters into the Sundarbans river estuaries and mangrove wetlands in the coastal region. The annual pattern of salinity changes inside the Sundarbans is also related with the changes of freshwater flow from upstream rivers. The peak salinity was found to be about 56,186 dS/m in 2001 and 2002, and the minimum salinity during postmonsoon was found to be about 10,805 dS/m (IWM, 2003).

### 29.3 Case Study in Bangladesh

According to the Ramsar 1971 Convention (“The Convention on Wetlands of International Importance especially as Waterfowl Habitat”) in Article 1.1, the term wetland links together a wide range of inland, coastal, and marine habitats, which share a number of common features (Rashid 1991; Mather et al., 1993; Kim et al. 2006). Usually, wetlands occupy transitional zones between permanently wet and generally dry environment (Davies and Claridge 1993). In Bangladesh, wetlands are permanent, and seasonal freshwater lakes and marshes of floodplains are known in different names such as (1) haor (it is a bowl-shaped depression between the natural levees of a river mostly found in the eastern region of the greater Mymensingh and Sylhet districts), (2) baor (it is called oxbow lakes and is the dead arm of the 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 29.2) (Akonda, 1989; Nokashima, and Khan 1993).

The total area of wetlands in Bangladesh is estimated to be 70,000–80,000 km²; it is about 50% of the total national land (Akonda, 1989; Khan et al., 1994). These include rivers, estuaries, mangrove swamps, marsh (haor), oxbow lake (baor) and beels, water storage reservoirs, fishponds, and some other lands, which suffer from seasonal inundation (Khan, 1993; Hughes et al., 1994; Gopal and Wetzel, 1995; Islam and Gnauck, 2008). In the Ganges–Brahmaputra–Meghna floodplain alone, approximately 2.1 million ha of wetlands has been lost to flood control and a million ha of wetlands has been lost to drainage and irrigation development (Khan et al., 1994). Therefore, wetlands are facing serious challenges from environmental changes and anthropogenic impacts (Sarkar, 1993; Nair, 2004; Ahmed and Falk, 2008).

There are four categories of wetland values that have been recognized in the society in Bangladesh. However, they are categorized as environmental values, economic values (direct, indirect, option, existence, and bequest values), and social and cultural values. Based on this category, wetland ecosystem offers different types of services for the communities. The wetland ecosystem types in Bangladesh have
been categorized in Table 29.2. Wetlands in three (Bera, Santhia, and Sujanagar) upazilas in the Pabna district and the Sundarbans coastal mangrove wetlands contain very rich components of biodiversity of local, national, and regional significance (Khan et al., 1994; Rahman, 1995).

The wetland environment unites the inhabitants into a society, which has a definite shape, culture, and livelihood pattern. Due to the availability of a wide variety of harvestable products, the people in and around the wetlands are traditionally self-reliant and have subsistence-oriented economy and livelihoods. Despite all these support to human livelihoods, many parts of the country have experienced loss or degradation of wetlands on a huge scale because of agricultural use, urbanization, and excessive exploitation by the local population. The wetlands in Bera, Santhia, and Sujanagar are also facing similar kinds of threats mainly due to overexploitation, which ultimately deteriorates the wetland ecology. Owing to continuous degradation of the wetland ecology, the respondents of the wetlands give emphasis about the importance of conserving the wetlands in the case areas in Pabna district. So there is a clear interlinkage between the economic and ecological functions of wetlands in Pabna district. The development of integrated management plan with a provision of the participation of local stakeholders may become the possible way of conserving this wetland ecology. Figure 29.5 illustrates the freshwater wetland distribution in the Bera, Santhia, and Sujanagar upazilas of Pabna district in Bangladesh. The freshwater wetlands and community people in Pabna district are under threats due to anthropogenic influences, natural calamities such as devastating floods, riverbank erosion, and climate change impacts. Figure 29.5 shows the critical geographical location and the characteristics of the freshwater wetlands in Bera, Santhia, and Sujanagar upazilas of Pabna district in Bangladesh.

The Bera, Santhia, and Sujanagar upazilas together cover an area of 914.16 km². The total area is a rich and unique wetland biodiversity in the northwestern part of Bangladesh. There are 118,232 households that cover the total population of 706,492 (2007) in these three upazilas (Table 29.1). The groundwater of the Bera upazila is gradually polluted by arsenic (As) contamination. The groundwater of this upazila was focused to contain arsenic above 10 μg/L, which is a threat and risk for human health. A long duration of drinking of Arsenic contaminated ground water as a result of accumulation in the human body. The riverbank erosion of the braided Jamuna River in Bera upazila is one of the major natural disasters and a severe problem in Bangladesh. Thousands of hectares of floodplain land are eroded each year, leaving many people homeless with damaging or destroying infrastructures and wetlands by the mighty Jamuna River (Mansour et al., 2011).

Table 29.1 shows the dynamic poor wetland communities in Bera, Santhia, and Sujanagar upazilas, which are more vulnerable to climate change, because they tend to be located in geographically vulnerable areas, such as flood-prone, riverbank erosion-prone, and tornado-prone areas of Bangladesh. Most of the community people are dependent on wetland natural resources for their livelihoods (Reid et al., 2010). Climate change refers to short-, medium-, and long-term changes in weather patterns and temperature that are predicted to happen or already happening as a result of anthropogenic emissions of greenhouse gases such as carbon dioxide. These changes include extreme weather, temperature increase, floods, and long duration of monsoonal rainfalls, and dryness character in the case area is recognized as a new threat for wetland ecosystem (IPCC, 2007; Reid et al., 2010). Vulnerability to floods and riverbank erosion and climate change is not just a function of geography or dependence on natural resources; it also has social, economic, and political dimensions that influence how climate change affects different groups (Action Aid, 2005). Based on the climatic and geographical condition, the wetlands in Bangladesh have categories in different groups (Table 29.2).

According to Sarkar and Nishat (1993), Bangladesh is more than 68,722 km² of closed freshwater areas and 6,100 km² of brackish water and mangrove swamp areas that are recognized as wetlands in Bangladesh. Inlands including haors, baors, and beels are vanishing or ecologically degraded due to various natural and anthropogenic causes, such as population growth, demand for wetland products in markets, unplanned floodplain conservation, and maintaining their ecological and hydrologic

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functions (Thompson and Sultana, 1996; Sultana and Thompson, 2008). Presently, there are 43 sites that
have been identified in Bangladesh as wetlands and protected areas, and most of them are ecologically
sensitive sites (Figure 29.6) (Rahman and Ahmed, 2002; Talukdar et al., 2008). The major wetlands and
ecologically sensitive sites in Bangladesh are shown in Figure 29.6, where 15 sites are declared as pro-
tected area by the Ministry of Environment and Forest of Bangladesh. These sites are not well protected,
and at present there is no management and conservation policy. As a whole, the management strategies
for the natural constructed wetlands in Bangladesh are not well structured.

FIGURE 29.5 The freshwater case area (Bera, Santhia, and Sujanagar upazilas) in Bangladesh.
29.3.1 Geography and Geological History

Bangladesh is located in South Asia between 20° 34’ to 26° 38’ N latitude and 88° 1’ to 92° 42’ E longitude, with a national territory of 147,570 km². Located in the southeastern part of the Indian subcontinent, it is bordered by India on the west, north, and east, except for a small portion in the east by Myanmar (Burma), sharing a 288 km border. The south is a highly irregular deltaic coastline of about 710 km long, which is dissected by many rivers and streams flowing into the Bay of Bengal. It has a population of about 150 million until 2009, with a very low per capita gross national product (GNP) of US $ 690. Bangladesh consists mainly of floodplains, except terraces in the Madhupur, Barind tract, and hills in Sylhet and Chittagong hill tracts. The major types of landscapes in Bangladesh are floodplains (80% of total land), terraces (8%), and hills (12%) (Hassan and Mulamootti, 1994). Except the eastern hilly region, the country mostly lies in the delta of the three active rivers, that is, the Ganges, Brahmaputra, and Meghna.

The alluvial sediments of the three mighty rivers formed the deltaic floodplain and the wetlands in Bera, Santhia, and Sujanagar upazilas of Pabna district where the Brahmaputra (Jamuna) and the Ganges Rivers have joined. On the other hand, the south coastal region developed accordingly through alluvial sedimentation. The Sundarbans mangrove wetland region enjoys humid tropical monsoon climate with proximity to sea as an added advantage. The wetland area has an average elevation of 0.9 to 2.1 above mean sea level. Considering the geological statements, the mangrove wetlands in Bangladesh originated at least 53,000–7,000 years ago, which is a relatively short age compacted with the global age of mangrove (Islam and Gnauck, 2008; Islam, 2010). Wetlands in Bangladesh are also cherished for their ecotourism 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 biodiversity of local, national, and regional significance (Khan, 1993; Bennett et al., 1995; Talukdar et al., 2008). In the

<table>
<thead>
<tr>
<th>Table 29.1</th>
<th>Scenarios of Bera, Santhia, and Sujanagar Upazilas of Pabna District</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upazilas</td>
<td>Area km²</td>
</tr>
<tr>
<td>Bera</td>
<td>248.6</td>
</tr>
<tr>
<td>Santhia</td>
<td>331.56</td>
</tr>
<tr>
<td>Sujanagar</td>
<td>334.4</td>
</tr>
<tr>
<td>Total</td>
<td>914.16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 29.2</th>
<th>Different Wetland Types and Areas in Bangladesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetland Types</td>
<td>Area Coverage/km²</td>
</tr>
<tr>
<td>Rivers, canals, and estuaries</td>
<td>10,300.00</td>
</tr>
<tr>
<td>Natural depressions</td>
<td>1,141.69</td>
</tr>
<tr>
<td>Ponds</td>
<td>1,619.43</td>
</tr>
<tr>
<td>Oxbow lakes</td>
<td>544.88</td>
</tr>
<tr>
<td>Reservoirs</td>
<td>688.00</td>
</tr>
<tr>
<td>Seasonal flood lands</td>
<td>28,000.00</td>
</tr>
<tr>
<td>Brackish water farms</td>
<td>873.00</td>
</tr>
<tr>
<td>Mangrove wetlands</td>
<td>6,100.00</td>
</tr>
<tr>
<td>Beel and haor</td>
<td>5,000.00</td>
</tr>
<tr>
<td>Peatland</td>
<td>155.00</td>
</tr>
<tr>
<td>Swamp forest</td>
<td>20,400.00</td>
</tr>
<tr>
<td>Total</td>
<td>74,822.00</td>
</tr>
</tbody>
</table>
early nineteenth century, Chalan beel used to cover an area of about 1085 km$^2$, but it was reduced to 368 km$^2$ in 1909, of which only 85 km$^2$ remains underwater throughout the year. It has since shrunk to only 26 km$^2$. This is the very common scenario in Bangladesh. The wetlands in Bera, Santhia, and Sujanagar upazilas have been reduced at the similar rate as Chalan beel reduced.

Global climate variability and increased population pressure in Bangladesh have resulted in large-scale demand of cultivable land for extra food production (Ali, 1988; Rasid, 1993; Zaman, 1993; Bennett et al., 1995). Conversions into other uses have resulted in net loss of wetlands in Bangladesh (Khan, 1993;
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 are yet to be undertaken (Nokashima and Khan, 1993; Chowdhury, 1988). 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 the optimization of resource utilization of wetlands in Bangladesh (Ali, 1990; Khan et al., 1994). 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 (Islam and Kitazawa, 2012).

The wetlands of Bangladesh have distinct characteristics, and that is permanent wetland to seasonal wetland and seasonal wetland to flooded wetland or agricultural land. The transformation of wetlands is accelerated by new human settlements, roads, and highways. Physical wetland changes fragment and isolate fauna and flora, eventually leading to endangerment or extinction. Because of push and pull factors, rural people move from rural to urban areas (Rana et al., 2009; Islam and Kitazawa, 2012). These poorly planned structures create waterlogs and had serious impact on wetlands. Although the Government of Bangladesh (GOB) takes some initiatives such as signing international environmental treaties, the situation of wetland management has 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 (Islam and Kitazawa, 2012).

### 29.3.2 Data and Methodology

The study has been conducted based on primary and secondary data sources. The primary data on freshwater and coastal mangrove wetland and livelihood information were collected from the local people using nonstructural and structural and semistructural questionnaire around the Sundarbans and in Bera, Santhia, and Sujanagar upazilas in Pabna district in Bangladesh. The participatory rural appraisal (PRA) practices were arranged in the Sundarbans region in greater Khulna region, Gangbhanga beel (Santhia), Ghugudaha beel, (Santhia), Hatkhali and Raninagar beel area (Sujanagar), Char beel, and Nadiar beel in Bera upazila of Pabna district.

This study was also conducted with the author’s field visit and personal observation for the past 10 years in the study area. Geomorphologic anthropological village-settled study and questionnaire survey for benchmark data collection were conducted with local community and stakeholders. The households covering the hand-holding pattern, tenancy, agricultural cropping systems and crop marketing, occupation, demographic character, literacy, etc., were collected in 2003, 2008, and 2011. A number of approaches for information and data collection and analysis were used including literature review, which helps obtain the basic understanding of wetlands, degradation, and natural livelihoods.

The secondary data inputs were collected from different publications of the government agencies, NGO reports, and research organization in Bangladesh and other countries. Collected data and information were analyzed and visualized using Microsoft Excel, Origin 8, and ArcGIS 10.

### 29.3.3 Surface Water Supply

The Bengal delta is the world’s largest delta comprising 100,000 km² of riverine floodplain and deltaic plain (Goodbred et al., 2003; Hori and Saito, 2007). The high-tide energy results in tide-dominated deltas like the Meghna estuary, where distributary channels with linear river mouth bars are present (Hori and Saito, 2007). Sediment deposition occurs only by river flushing in the river-dominated delta, while in tide-dominated deltas, sediments are reworked and redeposited (Hori and Saito, 2007). Every year, about 1 x 10¹² m³/s of freshwater is brought into the Meghna estuary by the three major rivers, the Ganges, the Jamuna, and the upper Meghna. These rivers are major sources of water supply to the wetlands and balance the wetland ecosystems. The largest rivers in Asia are created from the Himalayas and
Tibetan plateau. There are 32 large rivers that are located around the Himalayas range and run through the long way and join with the sea. The water source of these large rivers is supplying surface freshwater and protecting the Asian wetlands. Accordingly in Bangladesh, the major rivers are supplying freshwater and balance the wetlands in Bangladesh. As a whole, the Brahmaputra (Jamuna) River carries water flow 60,000–100,000 m$^3$/s and about 600 million tons of sediment particles; most part of this particle is sand and clay in every year (FAP 24, 1993) [19]. The Ganges flow was 37,000 m$^3$/s in 1962, whereas it has reduced to 364 m$^3$/s in 2006. These two river flows are supplying sufficient freshwater and protecting the freshwater wetlands in Bera, Santhia, and Sujanagar upazilas in Pabna district. The reduction of the Ganges freshwater in the upstream area is the root cause of salinity intrusion in the southwestern region, which is affecting the Sundarbans coastal mangrove saline wetlands in Bangladesh.

29.3.4 Indigenous Management and Conservation of Wetlands

The public and private institutes tried to coordinate with the Ramsar regime on wetlands (1971–1998) and the Conservation of Biodiversity Development (CBD) regime (1992–1998). Besides, there are initiatives that have been taken by the different government periods. The legislation on wetland management has been considered by the government, and some initiatives have been taken as well as the Haor Development Board Ordinance, 1997; the Bangladesh Environmental Conservation Act, 1995; the East Bengal Protection of Conservation of Fish Act, 1950; the East Bengal State Acquisition and Tenancy Act, 1950; the Land Reform Board Act, 1989; the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974; the Environment Policy 1992; and the Bangladesh Environmental Conservation Act, 1995, which give due importance to wetlands, and related issues are as follows: rivers, canal, roads, lakes, haor, beels, baors, and all other water bodies should be kept free from pollution. Besides the national laws, Bangladesh is signatory of Ramsar convention, CITES–(Convention on International Trade in Endangered Species of Wild Fauna and Flora), CBD–(Convention on Biological Diversity), UNESCO–(United Nations Educational Scientific and Cultural Organization), IUCN–(International Union for Conservation of Nature), etc., but unfortunately, the scenarios of wetland degradation in Bangladesh did not change yet due to unplanned policy implementation; lack of knowledge, skills, and capacity; and less research activities.

Local regimes have three classes of parties as country government, civil society, and the secretariats. Many challenges and uncertainty build up a regime for better wetland 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 wetland regimes. These include British colonial regime and postindependent Bangladesh regime. Unfortunately, due to lack of political stability of the country, policymakers are not able to build an international standard wetland management policy. Finally, political instability plays a role in any kind of management including wetland management in the Pabna district as well as in the whole Bangladesh (Islam and Kitazawa, 2012).

The National Water Policy (NWPo) of Bangladesh (1999) also gives due importance on research and development of knowledge and capacity building for sustainable management. In Article 3, the objectives of NWPo are to develop a state of knowledge and capacity that will enable the country to design water resource management plans by itself with economic efficiency, gender equity, social justice, and environmental awareness. In Article 4.15, the following specific objectives are not ensued such as appropriate technologies, development and promotion of water management techniques, and production of skilled professionals for water resource management. The NWPo of Bangladesh is a guideline framework for the nation but unfortunately not any strong guideline direction for wetland management over there (Akter et al., 2010). A study of the Economic and Social Council for Asia and the Pacific (ESCAP) in 1988 and GOB has referred five sets of constraints to the development of a strategy for coastal wetland resource management in Bangladesh such as policymaking, planning for coastal resources, integrated resource management, coastal wetland and marine resource sustainability, local environmental ecological perspective, and lack in knowledge of coastal environment and understanding (Islam and Gnauck, 2009, 2009a).
The National Wetland Policy has been drafted by the Ministry of Environment and Forestry, but it still remains in the preliminary stage and not yet implemented. The main features of this policy include the following: maintenance of biodiversity and landscape protection, maintenance of ecosystem functions and ensuring socioeconomic benefits, and promotion of economic development and establishment of principles for sustainable resource utilization. Considering the present hostile situation of wetland biodiversity, a long-term wetland management plan for the sustainable use of wetland natural resources is urgently needed. The current ongoing development project like Wetland Biodiversity Conservation issues in Bera, Santhia, and Sujanagar upazilas in Pabna district and coastal wetland region in Bangladesh could be a new hope for the new strategies for the future development and sustainability of wetland biodiversity conservation in Bangladesh.

29.4 Results and Discussions

Wetland is the most important issue in nature and natural resource effectiveness and management. Most of the wetlands are very complex regarding their hydrologic, biological, and geomorphological functioning and dynamics. These wetlands have been utilized by farmers, fisherman, and other stakeholders in terms of drainage and annual banning for stock farming for hundreds or even thousands of years. Wetlands are used as the driving force of ecosystem services, biodiversity conservation, and community livelihood sustainability. In general, millions of people are directly dependent on wetland resources and its services and goods. Unfortunately, a million ha of wetlands is declined due to natural and anthropogenic impacts. In the case of Bangladesh, there are five types of wetlands that are used substantially, and the area is gradually reducing. The major freshwater wetlands and saline water wetlands are polluted due to climate change impacts and salinity intrusion in the coastal wetlands and arsenic contamination in groundwater in the freshwater wetland region in Bangladesh. The present management of wetlands in Bangladesh is not a sophisticated management system; the GOB has developed a draft for wetland management policy and conservation.

29.4.1 Water Quality in the Wetland Regions

Freshwater quality in the wetland areas has been degraded owing to devastating floods and lowland inundation. Floods and sedimentation, industrial waste dumping, chemical fertilizer used in crop production, riverbank erosion, and accretion causes are responsible for water quality degradation. On the other hand, eugenic and biogenic causes are also potential issues for water quality damage. However, the net cropped area in the wetland region of the coastal zone in Bangladesh has been decreasing over the year due to various purposes, and the most common one is the land inundation and salinity intrusion by tidal water. Freshwater reduction along with intrusion of saline water is perhaps the most devastating consequence of climate change in the coast of Bangladesh. The freshwater quality of the wetlands in the Bera, Santhia, and Sujanagar upazilas is gradually degrading because of unplanned and substantial use of water resources; besides, annual flood inundation is the main reason of quality degradation.

The dominant wetland and land use in the coastal region of Bangladesh is about 144,085 and 83,416 ha, respectively (Islam and Gnauck, 2009). It has been estimated that 830,000 million ha of coastal wetlands has been identified, which are affected by soil salinity at different degrees. It is estimated that a net reduction of 0.5 million metric tons of rice production will take place due to a 0.3 m sea level rise in coastal areas of Bangladesh (IPCC, 2007). The quality of water in the coastal wetlands and Sundarbans region is also degraded especially in the dry season when high-salinity intrusion occurs. The CEGIS study result shows that water quality has degraded in the coastal rivers where 60% water is of poor quality, considering the parameter of EC dS/m is over 4.0; that means 40% are of good quality, considering the EC dS/m rate is less than 2.0 (EGIS, 2000). Where water quality is damaging at that case, the other elements of ecosystem like soil, wildlife, and vegetation are also damaging due to high salinity, siltation, and shortage of freshwater.
29.4.2 Water and Soil Salinity in the Wetlands

The wetland areas in the coastal region of Bangladesh are affected due to the high rate of water and soil salinity intrusion. In general, the annual pattern of salinity changes in the Sundarbans region is also related with the changes of freshwater flow from upstream rivers. The adverse effects of salinity intrusion on ecosystem of the Sundarbans mangrove wetlands are manifested in the drying of tops of Sundari (Heritiera fomes) trees retrogression of forest types, slow forest growth, and reduced productivity of forest sites (MPO, 1986). The peak salinity was found to be about 56,186 dS/m in 2001 and 2002, and minimum salinity during postmonsoon was found to be about 10,805 dS/m (IWM, 2003). This salinity rate has crossed the salinity threshold value for the mangrove wetland ecosystems in the coastal region. Some mangrove species have been dried and displaced due to high-salinity penetration and intrusion in the coastal area in Bangladesh.

Salinity in the southern part of the bay remains less than 10,805 dS/m during monsoon and starts to increase at a steady rate up to about 32,415 dS/m during the dry season (IWM, 2003). Salinity in the western part is not reduced to a low-salinity range even during monsoon period; salinity increases at a steady rate during the dry periods. Almost 265 km² $H.~fomes$ type of forest moderately and 210 km² areas are severely affected, which is one of the main threats for a sustainable mangrove forest management and its ecosystems.

The highest soil salinity levels measured were ECs 41.2 dS/m at Nilkamal and ECs 40 dS/m at Mirganj, and third highest rate of soil salinity is ECs 24 dS/m at Munchiganj point in the northwestern Sundarbans mangrove coastal wetland region. The increasing salinity levels are major threats for both biotic and abiotic factors of mangrove wetland ecosystems in the region (Islam and Gnauck, 2009). The coastal region covers an area of about 29,000 km² or about 20% of the country. The coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity. Salinity causes unfavorable environment and hydrologic situations that restrict the normal crop production throughout the year. The factors that contribute significantly to the development of saline soil are tidal flooding during wet season, direct inundation by saline water, and upward or lateral movement of saline groundwater during dry season. The severity of salinity problem in the coastal wetlands increases with the desiccation of the soil.

29.4.3 Degraded Wetland Ecosystem Services

The freshwater wetlands in Bera, Santhia, and Sujanagar upazila wetland sites in Pabna district and the coastal mangrove wetlands in the southwestern region in Bangladesh are playing a potential role in socioeconomic improvement in the local community. It is estimated that over 6 million people are benefitting either directly or indirectly on the Sundarbans mangrove wetland resources in the coastal region (Anon, 1995). An area of 121,000 ha of the mangrove wetlands has experienced catastrophic losses over the past 100 years. Since the diversion of upstream freshwater, salinity has penetrated up to 173 km north from the coast. The change of salinity affected mangrove wetland plant species and animals in a variety of ways (Islam, 2010). Almost 45% mangrove wetlands are destroyed due to shrimp cultivation, construction, and other developmental activities in Bangladesh.

Considering the water quality in the Sundarbans coastal wetland region, the average values of DO concentration ranges (2002) were found to be high at the eastern rivers while low in the western part where DO ranges from 4.90 to 6.90 mg/L with an average value of 5.99 mg/L, and BOD is found to be 8.03 mg/L in the coast and 12.98 mg/L in the west site. The values of COD were found to be 26.28 mg/L in the east and 215.29 mg/L in the west, and the values of NH₃-N were found to be 5.61 mg/L in the west during the dry season (March–June). All these values of water quality parameters including NaCl, DO, BOD, COD, and NH₃-N have crossed the considerable limits of water quality in the lower tidally active delta in the coastal region. The ecosystem process and functions are the biological, chemical, and physical interactions between ecosystem components (IWM, 2003; Islam and Gnauck, 2007, 2008,
The four types of coastal mangrove wetland services are functioning in the lower tidally active deltaic region. Therefore, the water quality maintenance is necessary in the coastal saline water wetland ecosystem in the Bengal coast in Bangladesh.

### 29.4.4 Threats for Wetland Biodiversity

A social–ecological system consists of a biogeophysical unit and its associated social actors and institutions. The management of agro-wetland biodiversity can be observed in the case of wetlands, medicinal plants, multifunctional farms, and organic farms. The biodiversity policies in Bangladesh and the “protection of flora and fauna varieties and community rights frame the legal situation and the governance structure for many issues relevant for the management of wetland biodiversity.”

The baseline biodiversity survey report in 2011 conducted by the Flood Hazard Research Centre, Bangladesh (fhrc), stated that there were 105 river bird species that were available in three upazilas in Pabna district. There are 94 bird species that were available in 2009–2010, whereas only 82 birds were available in 2010–2011 wet seasons. The report also stated that 63 fish species are available in Bera, Santhia, and Sujanagar upazilas in Pabna district. That means the report finding shows that the species are gradually reducing due to time and seasons. The fishing yields have declined sharply and the number of fish species has been greatly reduced. About 20 species are regarded as officially endangered species. Within the project area, there are 19 national birds that are endangered bird species in the world context. In the Sundarbans mangrove wetland case, a number of species like the Javan rhinoceros (*Rhinoceros sondaicus*), water buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvauceli*), gaur (*Bos gaurus*), hog deer (*Axis porcinus*), and marsh crocodile (*Crocodylus palustris*) became extinct in the Sundarbans mangrove wetland region. In the coastal wetlands in Bangladesh, there are 15 plant species that are listed in the International Union for Conservation of Nature (IUCN) red book list. Most of these species cannot tolerate the high water and soil salinity in the coastal region. The effect of climate change is a threat to biodiversity and natural resources of the increase of local population. The main reasons are a lack of cross-sectoral cooperation in the management of wetland and floodplain disciplines involved with several ministries and weak decentralized specialized authorities. The negative effects are the substantial use of natural resources and degradation of wetland ecosystem, which is the reason for loss of biodiversity and a growing decline in fish stocks. Therefore, it can be stated that there are some negative influences that are disturbing the species settlement in the case areas. Although the baseline report did not work on flora and other fauna, the medicinal plant species are very potential issues for the sustainable natural wetland resource management and conservation point of view. The report of Flood Hazard Research Centre (2011) also mentioned about the primary initiatives of the GOB.

### 29.4.5 Approach for Wetland Sustainability and Natural Resource Management

The study findings illustrated minor initiatives undertaken by the Ministry of Environment and Forest and the Ministry of Water Resources of the Bangladesh Government. In general, the freshwater and saline water wetlands are controlled by the local elite groups. Actions that aimed to retain water resources have been undertaken to a lesser extent. The raising groundwater level in wetland areas may increase ET, and as a result, it can reduce runoff in the summer period. The freshwater wetland sites in Pabna district are losing their hydrologic cycle, and the scarcity of freshwater is creating ecological damage in the Bera, Santhia, and Sujanagar upazila wetland sites. On the other hand, the mangrove wetland sites of the southern coastal region of Bangladesh are affected by saline water intrusion and water quality degradation. The anthropogenic influences on wetland resources in 15 sites have already been marked with a red list. The study result also reveals that the authority does not follow any policy guideline or appropriate management approaches for the wetland conservation in Bangladesh (Islam, 2010).
Figure 29.7 illustrates the conceptual model of wetland and natural resource management that could ensure sustainability.

The fundamental elements of natural resource management and sustainability such as institutional support, planning and policy support, biodiversity support, livelihood support, organizational support, and indigenous support have made the policy framework of wetland sustainability and natural resource management for freshwater and saline water wetland sites. The natural resource management situation and its ecological, socioeconomic, cultural, and environmental impacts are tragic in all freshwater and saline water wetland sites in Bangladesh (Islam and Ganuck, 2007; Islam et al., 2012). The National Wetland Policy has been drafted by the Ministry of Environment and Forestry, but it is not in implementation stage. The main features of this policy include the following issues:

- Maintenance of biodiversity and landscape protection
- Maintenance of ecosystem functions and ensuring socioeconomic benefits
- Promotion of economical development and establishment of principles for sustainable resource utilization

For better planning and sustainable management of wetland resources, the fundamental model structure and policy framework and its prime factors and subfactors should follow properly. The conceptual model (Figure 29.7) should be implemented in freshwater and saline water wetland sites in Bangladesh that could achieve a good result for better management and that could ensure livelihood sustainability (Cambers, 1992; DFID, 1999). The finding of this study could become an important guideline for planning and sustainable management of wetland and site conservation in Bangladesh as well as similar categories of wetland sites in other parts of the world.
29.5 Summary and Conclusions

Wetlands can be a driving force for community social and economic development. They have the ability to focus tremendous energy and to generate significant creative and economic betterment. In general, the country’s wetland natural resources as well as the ecosystems are degrading due to anthropogenic influences and natural calamities. The freshwater and saline water wetlands in Bangladesh are in alarming situation. The hydrologic cycle of the wetland areas is losing the balance. The country needs an adequate interdisciplinary policy and strategies and political wills to implement it for sustainable management and protection of wetlands and ecologically sensitive wetland ecosystems in Bangladesh. The methods for the generation of transformation knowledge to achieve and maintain natural resources, agro-farming system development, fishing development, and, in general, wise use of wetland natural resources could protect the biodiversity in the freshwater wetlands and coastal saline mangrove wetland areas. The following recommendations could be followed in the implementation and management stages:

- To increase people’s awareness, a yearly local cultural festival on international wetland day in different parts of the world as well as in the case areas in Bangladesh. The local culture and Heritage, wetland ecosystem services and goods could be demonstrated and marketed to enforce the local capacity of income generation could be arranged.
- Capacity building training for the stakeholders and resource users could be arranged through this local-based wetland project implementation for the local government authorities for skills development and good governance.
- The requirement to ensure the provision of adequate institutional capacity for policy development, delivery, and monitoring; the importance of considering wetlands as water management infrastructure rather than nature reserves; and the need to consider the wise use of wetlands both within and beyond urban boundaries and understand the interconnectivity of watershed-scale issues.
- Traditionally, frameworks and spatial plans are area based and structured on administrative boundaries. This approach fails to address or in many cases even recognize that these boundaries are not functional or commensurate with the environment or boundaries required for the protection of wetland or ecosystem services.
- There is a clear need to develop wetland policies and plans around the protection of ecosystem services; however, there is limited awareness of this concept within both national governments and local administrations.
- In the developing world, considerable issues related to unplanned or informal settlement usefully fall outside of the normal planning framework; however, they are often hot spots of environmental degradation.

For time series analysis, the satellite and remote sensing imageries could be used to compare the historical changes of agricultural cropping systems, land-use pattern, shrinking trends of wetlands, and present scenario measures. Special data analysis result shows services of wetland ecosystems in three upazilas of Pabna district and the southwestern coastal mangrove wetlands in Bangladesh. As a whole, the developed wetland biodiversity conservation planning and policy framework could be the fundamental output of applied research that could be implemented in the protected and sensitive wetlands in Bangladesh as well as other parts of the world.

References


