Geospatial Mapping of the Ecological Provinces: A Qualitative Study on the Ecosystem Services and Threats in the Coastal Zone of Bangladesh

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Abstract

'Blue economy' concept has opened a new window of opportunity for Bangladesh to exploit and utilize the coastal and marine resources in a sustainable way. To maintain sustainability and monitor the coastal ecosystems while exploiting resources for economic benefits, delineation of the major ecological provinces and systematic assessment of their ecosystems services is essential. This study aims to map and delineate the major ecological provinces of the coastal belt of Bangladesh. This study also aims to identify the ecosystem services provided by these ecosystems and finally to determine the threats of these ecosystems. Secondary data were collected through consultation and brief interviews with the experts on relevant fields, NGO's and field observation was chosen to identify the ecosystem services and threats towards the ecological provinces. Landsat-5TM/7ETM imageries were used for mapping the ecological provinces and other secondary data sources such as policy review, journals and newspaper articles were also used. The major ecological provinces- mangrove, coral, estuary, salt marsh and turtle nesting were identified along the coastal belt and delineated. The most significant and unique ecosystem services of the ecosystem and key threats were identified qualitatively. Mangrove ecological province is the largest and most beneficial active ecosystem in both ecological and economic aspects but human intervention is imposing a major threat. The coral ecological province in Saint Martin's island identified as the most vulnerable due to the constant tourism pressure. This study, however, recommended policy formulation and management planning to protect the coastal ecosystem to achieve sustainable development at the end.

Keywords: Ecosystem service, Ecological province, Geospatial mapping, Coastal zone, Bangladesh.

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1. Introduction

The concept of 'Blue Economy' has recently become a significant part of Bangladesh's post-2015 development agenda. The delimitation of sea boundary with Myanmar and India has indeed opened up a new window of opportunities in terms of additional natural resources. As Bangladesh has been blessed with a vast sea outlet and proper utilization of its living, non-living, and renewable coastal and marine resources can be very beneficial for the economy of this country (Sarker et al. 2018). As the population of this country is growing day by day, soon, it has to be dependent on these resources rather than the resources from terrestrial ecosystems. The government of Bangladesh needs to formulate policies to protect the coastal and marine ecosystems from human intervention and natural hazards lead by climate change to maintain the sustainability of the sea and ocean and feed future generations. According to a Bangladesh Bureau of Statistics (BBS) (2013) report, the population of the coastal zone of Bangladesh incorporates about 25% of the country's total population. For monitoring the coastal ecosystems and implementation of policies for proper management of the natural resources and conservation of the bio-diversity, assessment on the ecological provinces of the coastal region of Bangladesh and their services is a crucial need.

'Ecosystem approach' is a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable issues in an equitable way (Paolucci and Morris 1972). This approach requires that all the elements of an ecosystem and their mutual interactions, be taken into consideration in any management effort. For the implementation of this approach, the assessment of 'ecological provinces' is required. 'Ecosystem provinces' is a geographical unit characterized by a coherent set of environmental traits and it represents an extended region occupied by a specific ecosystem (Barale 2010). 'Ecosystem service' has been emerged recently as the most influential guiding principle for ecology, biodiversity conservation, and the management of natural resources (Mark Everard 2017). Millennium Ecosystem Assessment (MA) defined 'Ecosystem services' as the benefits people obtain from ecosystems and categorized them as provisioning services (e.g. food, fresh water, and fuel), regulating services (e.g. water purification and climate regulation), cultural services (e.g. recreation and education), and the supporting services needed for the production of all other ecosystem services (e.g. nutrient cycling and soil formation) (MA 2005).

The studies on ecosystems, ecosystem services, and ecosystem management in the coastal zones are currently the most prevalent and significant issues. Proper knowledge and plan on ecosystem-based management are vital for maintaining the distribution of ecosystem services in the coastal zones as these areas provide a massive amount of resources and economic services to human beings (Knutsen et al. 2010). A mapping approach for the identification and monitoring of coastal ecological provinces and their services can be helpful for the accurate assessment of ecosystem services to the decision-makers and policy support (Silvia Rova, Roberto Pastres, Matteo Zucchetta 2018) (Maes et al. 2012). As there have been found a tremendous amount of research

work in mapping ecosystem provinces and their services, Martínez-Harms stated that the majority of studies are based on secondary data (lookup tables, expert knowledge, and casual relationships) than primary data (extrapolation of primary data and regression models), applied at local and regional level, without validation techniques and it is a key priority to develop methods for assessing and monitoring ecosystem services to deliver accurate information to the decision-makers (Martnez-Harms and Balvanera 2012). Geospatial techniques consist of remote sensing from satellite imagery and GIS analysis can be a useful tool for mapping ecosystem services e.g. biological (Knutsen et al. 2010) and other resource mappings (Shahadat Hossain et al. 2007).

Over the past few decades, several studies and researches on the coastal zone in Bangladesh have been performed in local, regional, national, and sometimes on international levels separately. The majority of these studies are limited in the extent of some limited ecosystem services (aquaculture, shrimp farming, etc.) in the mangrove and estuary ecological provinces, geomorphological aspects of these regions, resource utilization and management, tourism, climate change, sea-level rise, disaster management, management for mangrove, estuary and disaster-prone areas and coastal degradation and pollution. Any detailed knowledge and study are absent in this vast area which makes it difficult to monitor the coastal ecosystems and their services. Some studies (Hossain et al 2016), (Uddin 2011), (Chowdhury, S. R., Hossain, M. S., Sharifuzzaman, S. M., Sarker 2015) attempted to research the ecosystem services of the selected parts of the Sundarban mangrove, but the number of baseline studies and researches on estuaries, coral reef, salt marsh, and the turtle-nesting ground is limited. These ecosystems are also playing a very significant role in the coastal dynamics of this region and provide immense ecosystem services. In addition to that, it is clear from the literature review that there has no effort taken yet to delineate major coastal ecosystems. It is a crucial need to delineate the ecosystems and identify the ecosystem services and the threats to monitor and plan for the proper management of the coastal ecosystems of Bangladesh. Based on this research gap this study aims to delineate the major coastal ecosystems of Bangladesh by geospatial techniques and identify their ecosystem services and threats in a qualitative manner.

However, the major objectives of this study are:

➢ Identification and delineation of the coastal ecological provinces of Bangladesh.

➢ Identification of the ecosystem services provided by each province.

➢ Determination of the threats the ecosystems are facing.

2.1 Study Area

The vast coastal zone is situated in the southern part of Bangladesh between 20°45′N to 23°20′N latitude and 88°57′E to 92°10′E longitude and it extends along the Bay of Bengal from the mouth of Naf (Myanmar-Bangladesh) river in the south-east to the

mouth of Raimangal river(India-Bangladesh) (S. M. N. Amin 2008). The coastal zone of Bangladesh can be broadly divided into three district regions: the deltaic western zone, the deltaic central zone, and non-deltaic eastern zone, based on the geomorphological features, topographic settings, coastal configuration, hydrological regime and circulation dynamics (Rashed 2008) as shown in Figure 1.
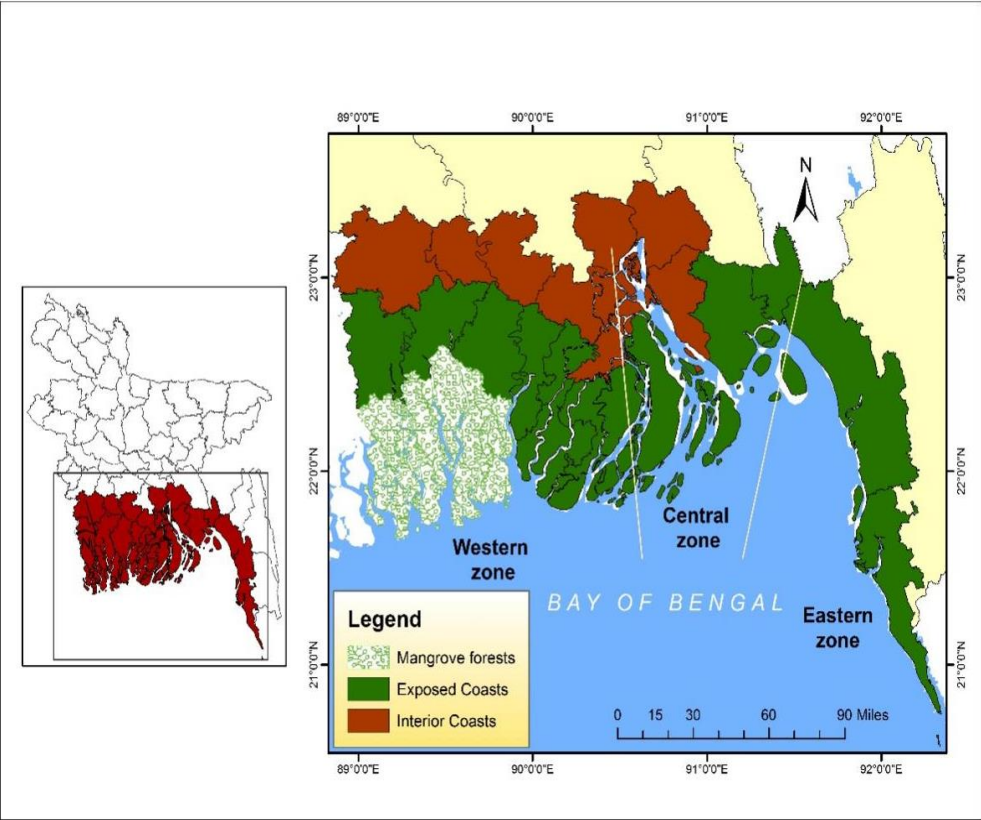

Figure 1: The classification of the coastal zone of Bangladesh

2.2 Materials and Methods

The research method of this study is qualitative as it describes ecosystem services and threats to the coastal ecological provinces of Bangladesh. Satellite images, interviews, and other secondary data sources were the main sources of data to conduct this research.

The ecosystem services of the ecological provinces and their threats were determined based on the interviews and consultations with local stakeholders, experts on the south-western, south-central, and south-eastern coastal zone of Bangladesh. Information

through brief interviews from experts, other researchers of several NGOs working in different parts of the coast, and common individuals of the study area were collected for this study. In addition to this, data were gathered from studies, surveys that have been run by other people or for other research. Satellite data is the most significant data of this study. Freeware satellite data have been collected from the Landsat archive of the United States Geological Survey official website (earthexplorer.usgs.gov) other additional shapefiles for GIS layers were collected from Bangladesh Agricultural Research Council, LGED, and USGS websites.

The geo-spatial mapping of ecological provinces was fully based on the analysis of satellite data. The mapping process was done by following the mapping outline of prior work (Hasan et al. 2013). The analysis of the satellite had to go through three stages-pre-classification, image classification, and post-classification as shown in Figure-3.

As this research was following a qualitative structure, the results on ecosystem services and threats were presented fully raw based on the expert interviews without any statistical analysis.

The whole procedure of the research was executed following the underlying flowchart in Figure 2-
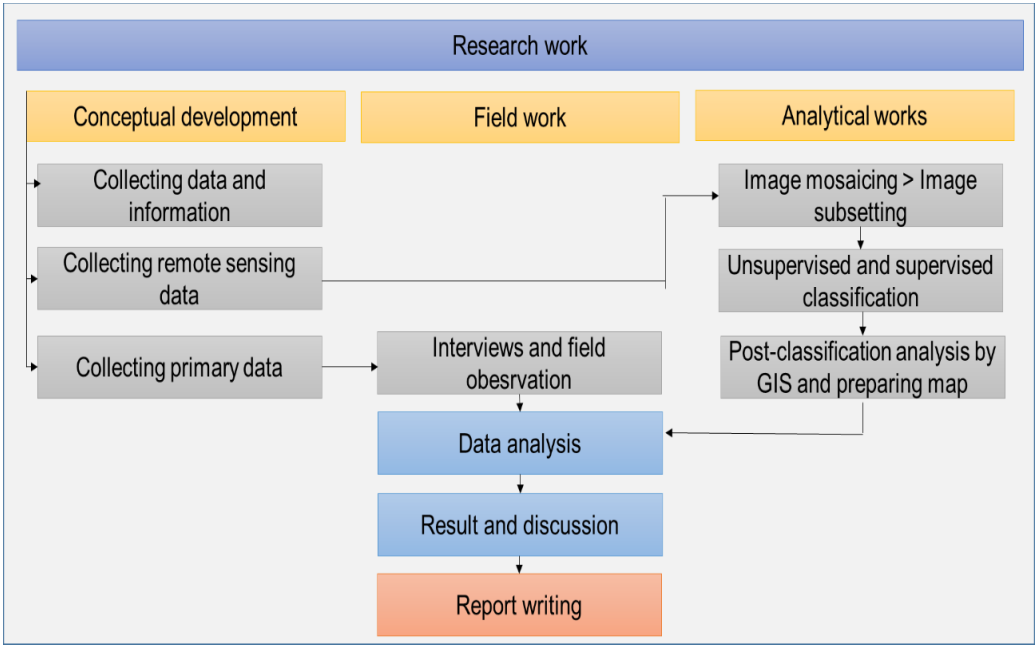

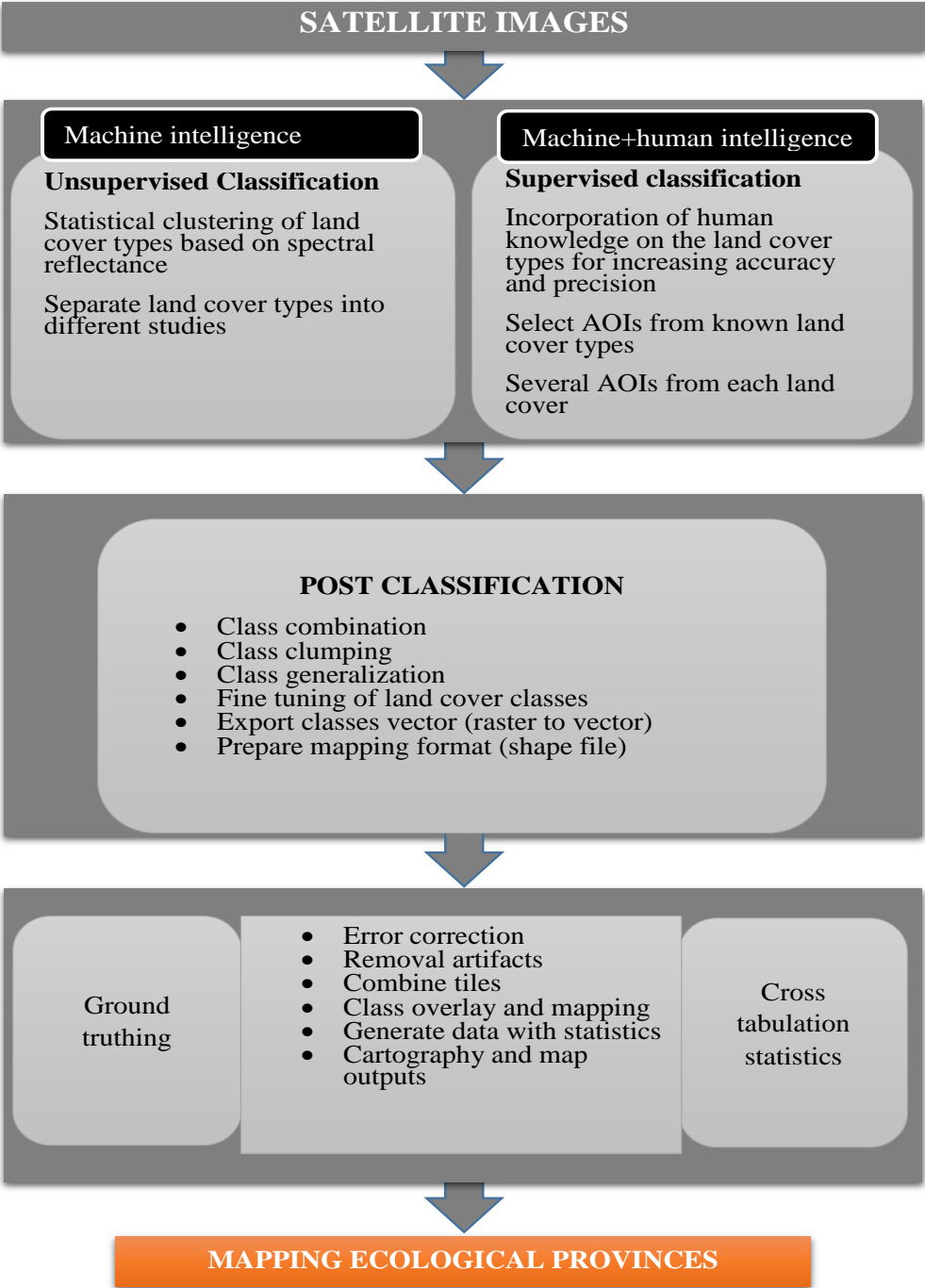Figure 2: A flow chart showing the research work

SATELLITE IMAGES

Machine intelligence

Unsupervised Classification

Statistical clustering of land cover types based on spectral reflectance

Separate land cover types into different studies

Machine+human intelligence

Supervised classification

Incorporation of human knowledge on the land cover types for increasing accuracy and precision

Select AOIs from known land cover types

Several AOIs from each land cover

POST CLASSIFICATION

- Class combination
- Class clumping
- Class generalization
- Fine tuning of land cover classes
- Export classes vector (raster to vector)
- Prepare mapping format (shape file)

Ground truthing

- Error correction
- Removal artifacts
- Combine tiles
- Class overlay and mapping
- Generate data with statistics
- Cartography and map outputs

Cross tabulation statistics

MAPPING ECOLOGICAL PROVINCES

Figure 3: A hybrid interpretation of satellite image for land cover/ land use classification in Bangladesh

3. Result and Discussion

3.1 Ecological provinces

In this study, we have delineated the major five ecological provinces; of the coastal zone of Bangladesh. The major ecological provinces are the mangroves, the coral, the estuary, the saltmarshes, and the turtle nesting grounds which are described below:

3.1.1 Mangrove ecosystem in the coastal ecosystem of Bangladesh
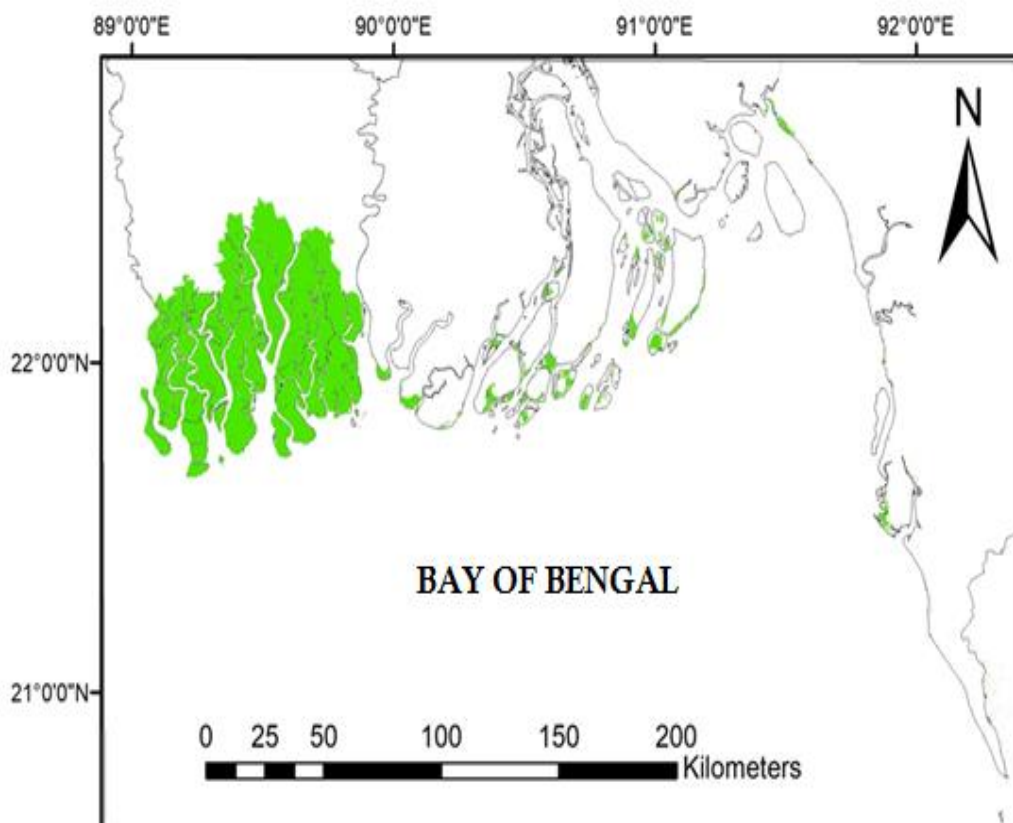

Figure 4: Spatial distribution of mangrove ecosystem in the coastal area of Bangladesh

The largest mangrove ecosystem of the country as well as of the world is lying in the south-western part of the coastal zone of Bangladesh. There are some also planted mangroves in the south-central and south-eastern parts of the coastal zone. Figure 4 shows the location of the mangrove ecosystem in the coastal zone of Bangladesh.

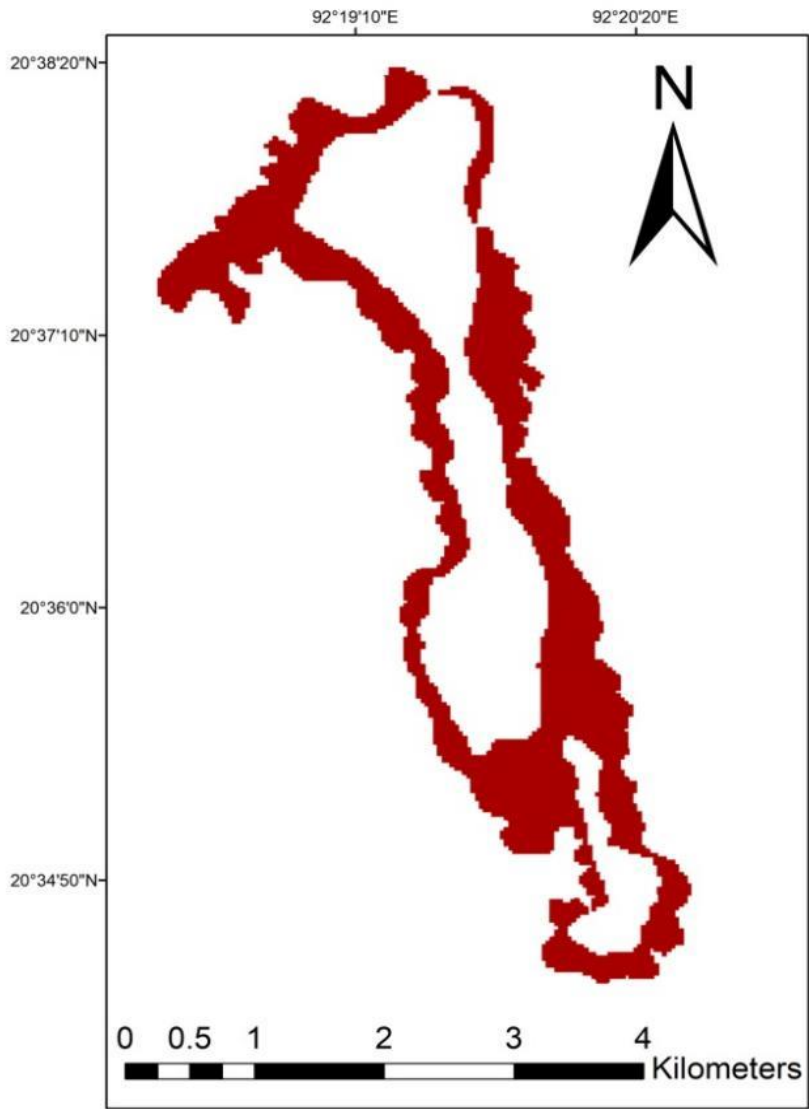*3.1.2 Coral ecosystem in the coastal ecosystem of Bangladesh*

Figure 5: Spatial distribution of coral ecosystem in the coastal area of Bangladesh

The one and only coral ecosystem in Bangladesh is found in Saint Martin's Island which is situated between 20°36′47″N latitude and 92°19′36″E longitude as shown in Figure 5. The island offers a wide variety of corals, algae, seaweeds, grasses and mangroves (Shahadat Hossain et al. 2007).

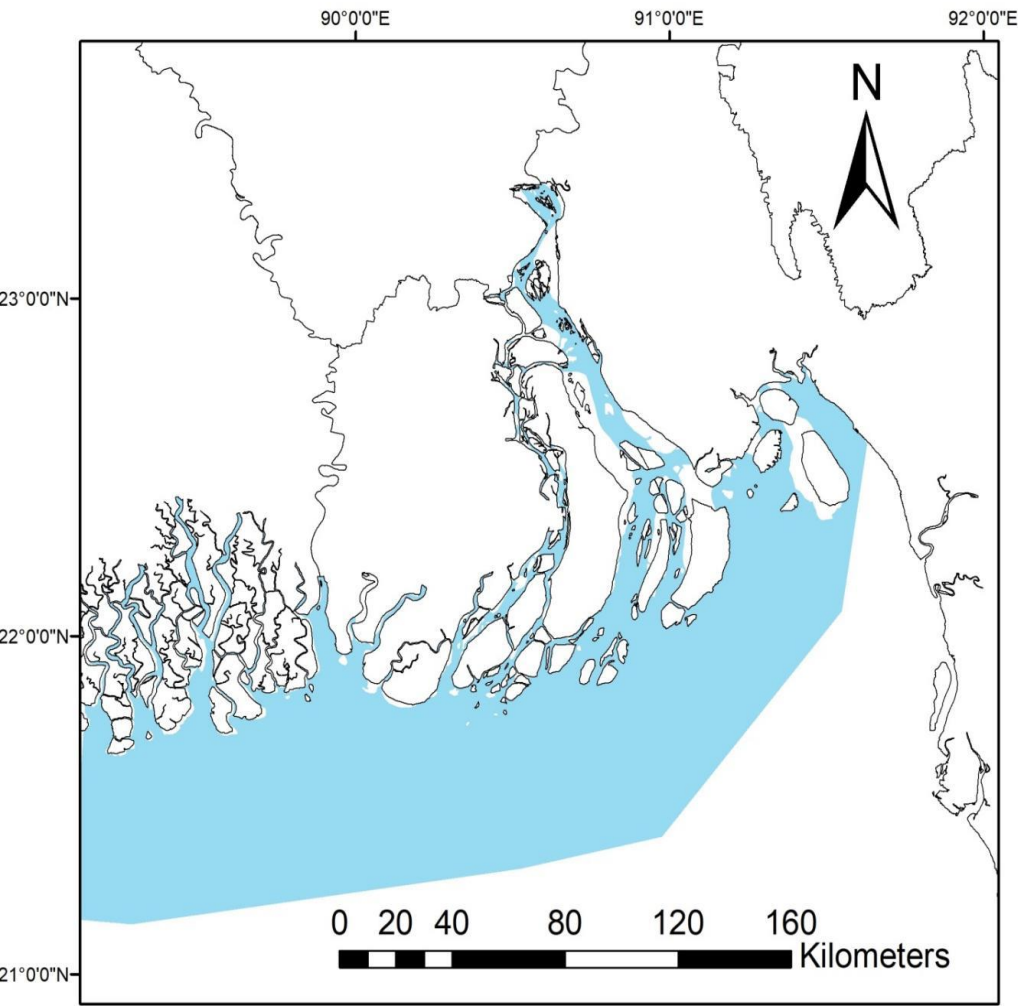### 3.1.3 Estuaries ecosystem in the coastal ecosystem of Bangladesh

Figure 6: Spatial distribution of estuary in the coastal area of Bangladesh

An estuary is the tidal mouth of a large river formed by an interaction of sea, land and freshwater forming a transition zone between freshwater and marine environment. Figure 6 shows how the coast of Bangladesh is comprised of a network of twenty complex estuarine systems.

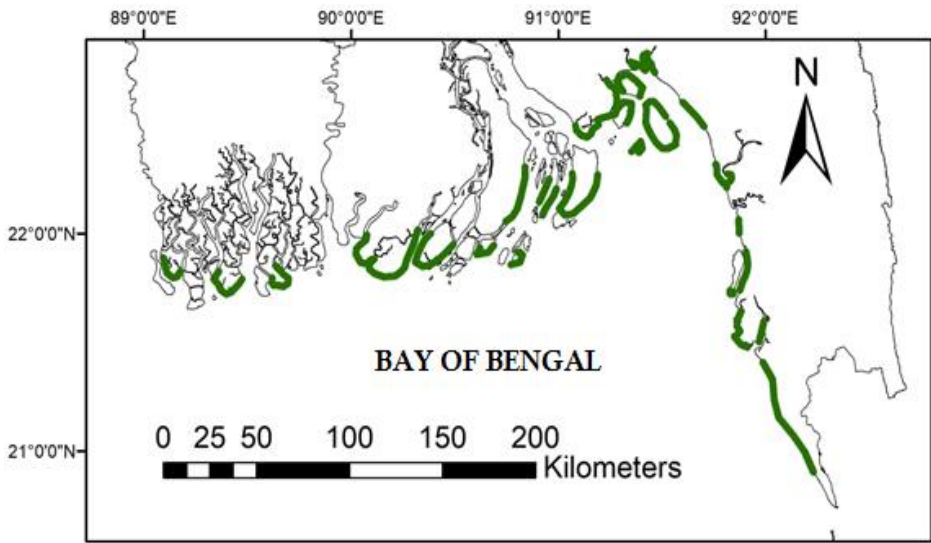### *3.1.4 Saltmarsh ecosystem in the coastal ecosystem of Bangladesh*

Figure 7: Spatial distribution of salt marsh ecosystem in the coastal area of Bangladesh

Salt marshes tend to grow in chars or islands of estuaries (5-7 years after birth) in the coastal areas. From figure 7 it can be seen that salt marsh ecosystems can be found at Cox's Bazar, Saint Martin's island, Char Kukri-Mukri, and Nijhum dip in Bangladesh.

3.1.5 Turtle nesting ground in the coastal ecosystem of Bangladesh
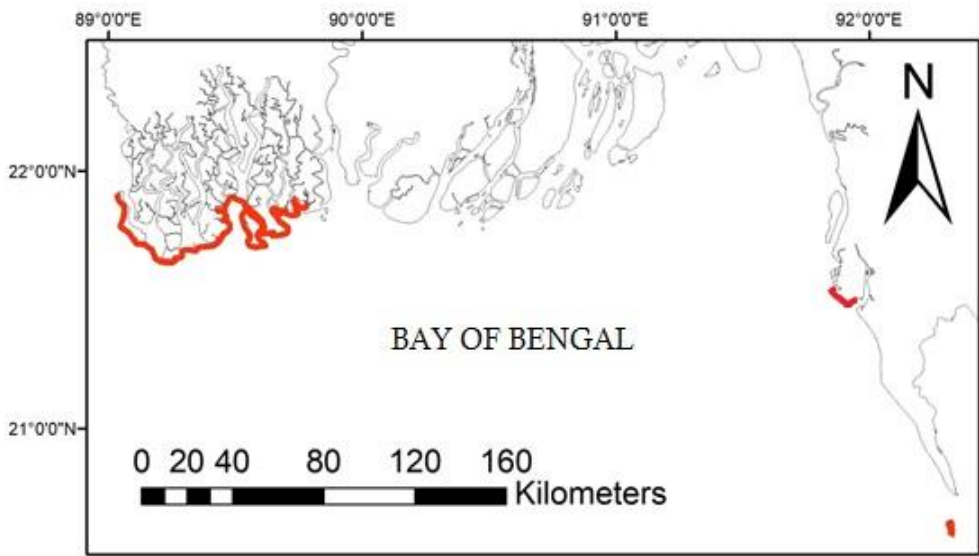

Figure 8: Spatial distribution of turtle nesting ground in the coastal area of Bangladesh

Sea turtle habitat can be found in the sandy beaches of the Sundarban area (e.g Dublar Char) and Saint Martin's island. Figure 8 shows the natural sea turtle habitat in the coastal zone of Bangladesh.

3.2 Ecosystem services

The ecosystem services and their threats were identified based on the interviews and consultations with local stakeholders, experts on the south-western, south-central, and south-eastern coastal zone of Bangladesh. Figure 14 summarizes the ecosystem services of the ecosystems in the coastal zone.

3.2.1 Mangrove in the coastal ecosystem of Bangladesh

The mangrove accommodates a large number of aquatic species of fishes, shrimps, crabs, planktons, snails, shells, etc as habitat. They also serve as the breeding, nesting, and spawning ground for fish. The mangroves also serve as their breeding ground for the terrestrial species as well. People in the mangrove region not only depend on fishery but also shrimp farming, crabbing, etc. for livelihood. The news-print paper industries are largely dependent on the mangroves in the southwestern coastal zones. Tourism, world heritage site, education, ethnic festivals and worshipping by local people, etc are cultural services of the mangroves. Mangroves also reduce the impact of such natural calamities by reducing the loss of properties and lives on the local communities. The breathing roots of mangroves penetrates the ground and help to bind and build soil. The above-ground roots slow down water flow which helps to the deposition of sediments and reduction of soil erosion in the coastal zones. The mangroves in Bangladesh can also be identified as the world's largest carbon sink as they stock carbon in the woody biomass and the anaerobic sediments as organic matter by the carbon sequestration. Tidal waves and the accumulation of litter from the dead leaves helps to form the fertile topsoil in the mangrove ecosystem. These litters are also a great source to the zooplanktons and maintain a healthy food chain in coastal water.

3.2.2 Coral in the coastal ecosystem of Bangladesh

In Bangladesh, the coral ecosystem supports 50% of the fish species and other marine fauna as it provides a good nursing and breeding ground and natural habitat for them. It is a good supplier of nutrients for the primary production in the marine food cycle. There is an estimated amount of 1500 MT red seaweed available around St. Martin's Island. Turtles and turtle eggs found in the dune environments of the island are sold to the local Rakhain community. Some people collect corals for indoor household decorations or aquariums and souvenirs. Saint Martin's island is one of the popular tourist spots of this country. Besides, most of the corals and sponges (also known as filter feeders) consume particulate matter suspended in the water column and help in the purification or filtration of coastal air and water. It also plays a role in carbon and nitrogen-fixing and nutrition cycling. Coral ecosystems protect the shorelines and beaches by changing the direction and slowing down the ocean waves and currents. By this process, they slow down the erosion of shorelines and beaches. Coral ecosystems also protect coastlines from the damaging effects of natural disasters like tropical storms and water surges.

3.2.3 Estuaries in the coastal ecosystem of Bangladesh

The estuaries in the coastal zone of Bangladesh are the biggest natural habitat for large fish species including both migratory and permanent, crustaceans and mollusks, and other species with high economic and commercial value. It is also the largest nesting and breeding ground for fish. The large range of diverse fish species attracts migratory birds from foreign countries. Seaweed production in the estuaries has immense medicinal value and is used as food. It is also used as an ingredient for the biochemical, pharmaceutical, and cosmetics industries. Cox's Bazar, Noakhali, Chittagong, and Bagerhat districts of Bangladesh are well known for the habitats of seaweed. Saltmarsh and mangroves can form and are found near the estuaries. As mangroves and estuary both act as a natural buffer zone between fresh and saline water they provide combinedly a diverse range of habitats for unique species.

3.2.4 Saltmarsh in the coastal ecosystem of Bangladesh

Salt marshes provide shelter and serve as the breeding and nursing ground for many commercially important species such as fish, insects, crabs, shrimp, oysters, etc. Some plant species in salt marshes are often used as medicine in medical and pharmaceuticals. Saltmarsh also plays a very important role in storing blue carbon (carbon captured and sequestered in the living organisms of the coastal ecosystems such as mangrove forests, seagrass, or intertidal saltmarshes). Some plant species in the salt marsh ecosystem can reduce and filter water excess pollutants, toxins, and suspended sediments and maintain the quality of the water. Salt marshes also act as a barrier and create a 'buffer' which helps to reduce the wave energy, current velocity, and trap sediments, and protects upland areas and private property from flooding and erosion during storms. The plants in the saltmarsh ecosystem mainly flourish in the spring-summer season and start to decay in the fall-winter. Some of the decaying plants become the primary food source to worms, fishes, crabs, and shrimps and the rest of them develop as fertilizers for the next season's plants. Thus, salt marsh plants contribute to the food web and add nutrients to the ecosystem.

3.2.5 Turtle nesting ground in the coastal ecosystem of Bangladesh

Sea turtles are known as herbivorous grazers. They graze seagrasses which help to maintain the health of seagrass beds. It is very beneficial to other commercial marine species such as fish, shrimp for which seagrass bed provides a healthy environment to breed. Local people and communities use the turtle as food and sell it to other communities in some parts of the coastal zone of Bangladesh. Sea turtles use degradable marine debris like food and cleanse the marine water which helps to maintain a healthy marine environment. Sea turtles have a role to play in the dune environment. During full moon and new moon, turtles dig several roots under the ground to protect their eggs from predators. The unhatched eggs provide nutrients to the beaches and dune vegetation. Thus, the roots of these plants can hold the soil better and reduce soil erosion.
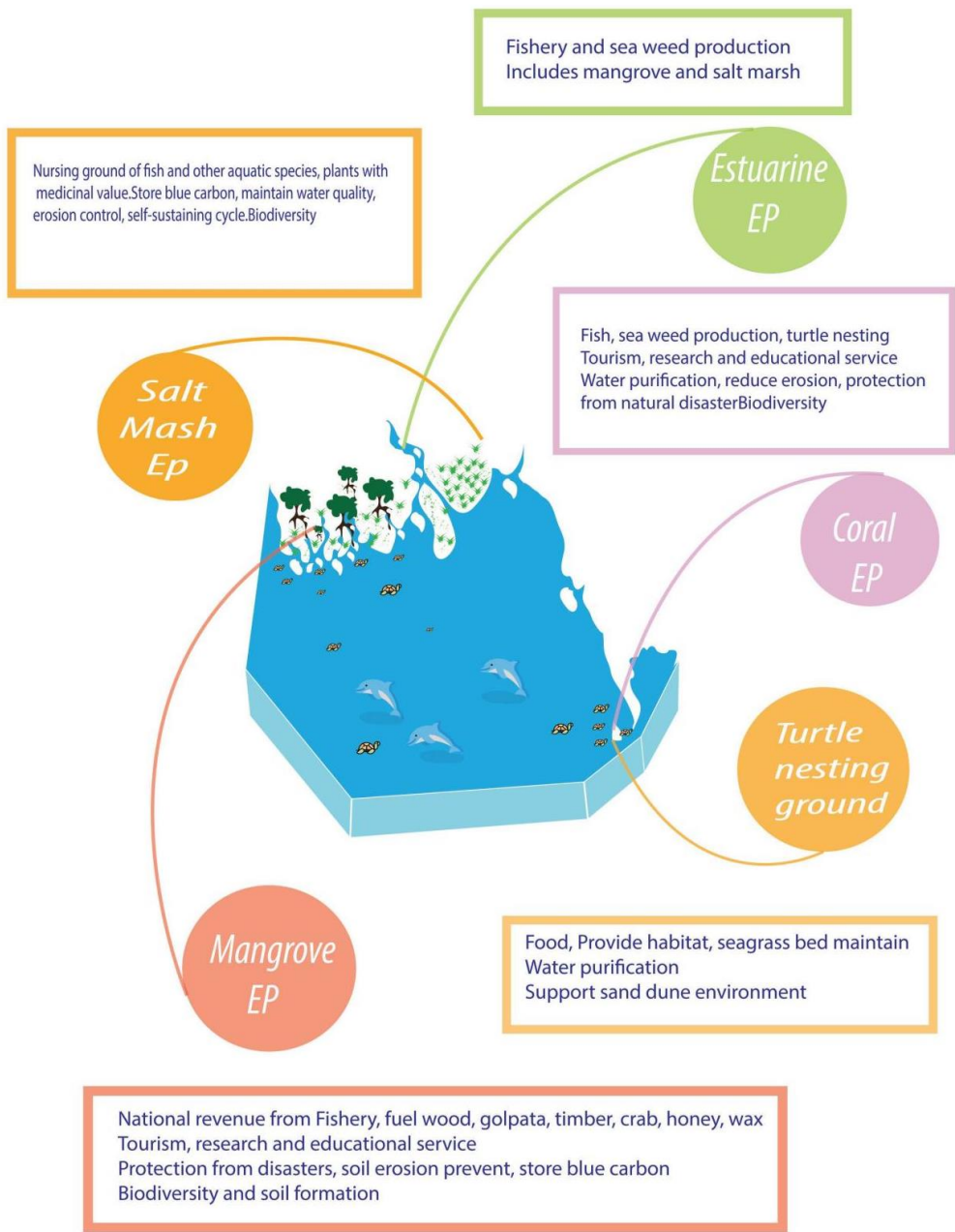
Fishery and sea weed production
Includes mangrove and salt marsh

Nursing ground of fish and other aquatic species, plants with medicinal value.Store blue carbon, maintain water quality, erosion control, self-sustaining cycle.Biodiversity

Estuarine EP

Fish, sea weed production, turtle nesting
Tourism, research and educational service
Water purification, reduce erosion, protection from natural disasterBiodiversity

Salt Mash Ep

Coral EP

Turtle nesting ground

Food, Provide habitat, seagrass bed maintain
Water purification
Support sand dune environment

Mangrove EP

National revenue from Fishery, fuel wood, golpata, timber, crab, honey, wax
Tourism, research and educational service
Protection from disasters, soil erosion prevent, store blue carbon
Biodiversity and soil formation

Figure 14: Major coastal ecological provinces of Bangladesh and their ecosystem services.

	Ecosystem services	Threats
Mangrove	- Breeding, nursing, and nesting ground for different species - Cultural services - Protection from the natural disaster - Reduce soil erosion - Store carbon dioxide - Biodiversity - Soil formation	- Deforestation - Illegal encroachment - Shrimp farming - Pollution - Canal use - Salt production - Sea level rise - Natural hazards
Coral	- Fish production and marine habitat - Tourism - Cleanses water - Reduce erosion - Protection from the natural disaster	- Pollution - Fishing - Tourism - Global warming
Estuarine	- Fishery - Production of seaweed - Combines with Salt-marsh and mangrove	- Fishing sector - Pollution - Natural salinity increase - River erosion and sedimentation
Saltmarsh	- The nursing ground of different species - Medicinal value - Carbon sequestration - Maintaining water quality - Erosion control - Self-sustaining cycle	- Fishing - Sea level rise - Animal grazing
Turtle nesting ground	- Seagrass ecosystem - Turtle can be used as a food - Water cleanser - Support dune environment	- Construction of development projects - Domestic animals - Fishing net - Tourism - Plastic pollution

Table 1: List of Ecosystem services and threats of the coastal ecological provinces of Bangladesh.

3.3 Threats to the ecosystems

The main threats that impose stress in the coastal ecosystems were identified throughout the study. Table 1 has a list of ecosystem services and threats of the coastal ecological provinces of Bangladesh.

3.3.1 Mangrove in the coastal ecosystem of Bangladesh

The overexploitation of some species (Goran, Gewa, Sundri, Golpata, etc) without giving any concern to the degradation of mangrove ecosystem and destruction of the habitat of the species which are dependent on them is a very common issue in the coastal areas. Besides, illegal encroachment, poaching, and killing of wildlife and valuable species are threatening for the mangroves. Some species cannot survive without their natural habitat and displacing them from their natural habitat and poaching or murdering illegally at a high rate can destroy the mangrove ecosystem. On the other hand, the shrimp farming industry is another major threat in the coastal areas which causes environmental pollution, disease outbreak, salinization to the underground water, potable water and soil, introduction of exotic species, loss in capture fisheries and biodiversity, etc which can cause severe degradation in the mangrove ecosystem without proper management. River pollution in the mangroves occurs when plastics, fertilizers, pesticides other man-made toxic chemicals carried by upstream rivers can harm and kill mangrove species. Reckless and illegal use of the rivers and canals inside the protected areas of mangroves for navigation and transportation of large ships and cargos carrying toxic chemicals, oil, etc can be dangerous for the mangroves. The existence of new Chars or islands nearby the natural mangrove ecosystems can influence large scale removal of mangroves and deforestation. Local salt production industries are also causing rapid degradation to the mangrove ecosystems. Climate change influences flooding, drainage, tides, wave pattern, discharge and load carrying, and other characteristics of the rivers at the mangrove ecosystems which can have adverse impacts on mangroves.

3.3.2 Coral in the coastal ecosystem of Bangladesh

Household waste, runoff of sewages fertilizers from hotels and the local community, crude oil and heavy waste from boats, ferries and ship industries, sediments from construction sites, plastics and other non-degradable wastes and products, etc are dumped into the sea which leads to the severe pollution to the coral ecosystem in Saint Martin's Island. The supply of electricity in Saint Martin's island is completely dependent on generators which lead to heavy sound pollution and threaten marine life. Moreover, overfishing and destructive fishing practices without giving any concern to the degradation of ecosystems threaten the coral community. The practice of using fishing nets has a negative impact as it sometimes catches marine turtles and other valuable species from the sea. Tourism leads to severe environmental problems like different types of pollution (e.g. water pollution, noise pollution), removal, extraction, and destruction of natural resources, habitats of species, and features (e.g. fish, mangroves, dunes, hills) which have adverse impacts on the coral ecosystem. The

emission of greenhouse gas by anthropogenic activities caused global warming which created environmental problems such as coral bleaching and ocean acidification.

3.3.3 Estuary in the coastal ecosystem of Bangladesh

Overfishing in estuaries imposes serious threats to the breeding of fishes. Overfishing also decreases the juvenile or young population of certain species. Pollution of the estuaries of the Bangladesh coast can be occurred by land run-off and dumping of industrial, agricultural, and domestic waste. Estuaries are also in constant danger of man-made eutrophication. Large and small boats, ferries, launches, ships, and other modes of transportation by rivers and seas dump a huge amount of dumps and oil which also can degrade the estuarine ecosystem. On the other hand, the decrease in the upstream course of Farakka barrage, climate change and sea-level rise, shrimp farming, coastal embankment project, and other factors have a huge influence on the saline water intrusion. The input of sediments in the rivers and estuaries has been increased for several years as river erosion increased caused by the destruction of forest and vegetation, degradation of soil and river beds, removal of rocks, sand, and soil from river beds, increase in construction work due to expansion of urban areas which may cause turbidity and resuspension of coastal water.

3.3.4 Saltmarsh in the coastal ecosystem of Bangladesh

Overfishing in the saltmarsh ecosystem to reduce the population of some commercially and recreationally important species before they can reproduce. Saltmarsh is extremely vulnerable to sea-level rise caused by global warming as a result of extreme emission of greenhouse gases into the atmosphere. Animal grazing of domestic animals of the local community such as cows, goats, etc is common in the saltmarsh ecosystem in Bangladesh. Besides, some of the plants are often used as food for the domestic animals of the local community. Both of these can be harmful to the growth of plants in the saltmarsh ecosystem.

3.3.5 Turtle nesting Ground in the coastal ecosystem of Bangladesh

Coastal development by constructing bridges, barrage, roads, large buildings, etc often put the existence of sea turtles at risk. Domestic animals like dogs, some wildlife like foxes often eat turtle eggs. Turtles are often captured by fishing nets, trawls, or hooks and cannot escape which is called 'bycatch'. Sometimes, fishermen in some communities see them as an omen and kill them instead of releasing them due to their local beliefs and myths. Tourism in coastal areas hampers the breeding and nesting of turtles. Sea level rise can destroy breeding, feeding, and nesting natural habitats of turtles by flooding. Change in the temperature due to climate change influences the breeding and population of sea turtles. Non-biodegradable products like plastics, fertilizers, and other chemical waste can impose a great threat to sea turtles. Normally, turtles eat marine debris and cleanse the water. When they eat non-biodegradable waste like plastic, it imbalanced their digestive system and eventually kills them.

3.4 Discussion

This study successfully identifies the ecosystem services and threats of the five most significant ecosystems of the Bangladesh coastal zone.

The mangrove ecosystem in the coastal zone is the most beneficial and economically important ecosystem of Bangladesh. The main ecosystem services of mangroves include timber, fuel woods, Goran, Gewa, fishery, honey, wax, etc. The livelihood of local people depends on these valuable goods and services. Besides, they contribute to the national economy of this country. Human intervention is the biggest threat to the mangroves in the coastal area as a large population depends on their services and benefits for livelihood. Mangrove face these threats in several aspects such as pollution, illegal encroachment, shrimp farming, agricultural activities e.g. rice production, urbanization, and many more. These anthropogenic or human-made threats can lead to severe damage and cause degradation to the ecosystems. Shrimp farming alone executes serious negative impacts on the mangrove ecosystem such as environmental degradation, saltwater intrusion in soil and water, sedimentation, pollution, and other socio-economic problems (Minar, Hossain, and Shamsuddin 2013). Mangroves in Bangladesh has the largest storage of blue carbon. About 2,088,082 tonnes of carbon is stored in the mangrove ecosystem by carbon sequestration process per year (Chowdhury, S. R., Hossain, M. S., Sharifuzzaman, S. M., Sarker 2015). This largest carbon sink of Bangladesh can become the largest source of CO_2 and contribute to climate change if the anthropogenic activity continues. The mangrove ecosystem in the coastal zone of Bangladesh is the largest coastal ecosystem as the Sundarbans itself is occupying an area of 7700 sq km. The planted mangroves in the south-central and south-eastern parts of the coastal zone are covering about 765 sq km (Centre 2004). Despite its large extent, serious degradation of the mangroves is a must without proper management and initiatives taken by the government and local people.

The one and only coral ecosystem in the coastal zone of Bangladesh is Saint Martin's Island which is about 8 km. The presence of coral habitat is very significant as it supports other valuable fish and marine species and contributes to healthy marine life by regulating and supporting services. But the coral ecosystem in Saint Martin's Island is the most vulnerable to the threats of depletion due to the tourism industry, pollution, and climate change. About 7000 people live on this island and 1500 tourists visit the island during tourist season daily which is beyond the carrying capacity of the island. This is a serious threat not only to the coral habitats but also to the other animals too. Even the Government of Bangladesh has tried to control the tourist for the past few years to protect the island's natural habitats.

The estuarine ecosystem is another productive ecosystem of Bangladesh as it provides breeding, feeding, and nesting ground for many commercially valuable aquatic species. The estuaries have a major contribution to the fishery sector of this country. The river and estuarine ecosystems of Bangladesh cover an area of 850,000 ha from which about 4.75% of the fishery are captured. Estuaries also were known as the habitat of seaweed. Bangladesh has 133 species of seaweed and eight of them are commercially valuable

(Ahmed and Taparhudee 2005). Estuaries are normally comprised of ecosystems such as mangroves, salt marsh, seagrass, etc (Hussain, Failler, and Al Karim 2017). Pollution, overfishing, increase in salinity, etc threats lead by anthropogenic factors are making the estuaries susceptible to be degraded. Sustainable use of natural resources given by this ecosystem and proper management plan is a crucial need to protect the estuaries.

Saltmarshes or tidal marshes are covering an area of about 110,000 ha along the low-energy coasts and estuaries of Bangladesh (Sarker et al. 2018). Saltmarsh ecosystem provides nursing ground, nutrient source, and primary food source for fishes, invertebrates, and coastal birds, add nutrients to the soil and reduce soil erosion. Saltmarsh ecosystem also serves as a 'carbon sink' as it stores carbon dioxide in the living organisms that are released into the atmosphere by anthropogenic activity and contribute to climate change. In Bangladesh, about 1,133,704 tonnes of carbon are stored in the salt marsh ecosystem by carbon sequestration process per year (Chowdhury, S. R., Hossain, M. S., Sharifuzzaman, S. M., Sarker 2015). There is a lack of availability of data, knowledge, proper research, and projects on the saltmarsh ecosystem in Bangladesh.

Turtle nesting ground contributes to the coastal and marine environment by providing natural habitat and maintaining the ocean's health and coastal waters. But fishers and local people's ignorance of sea turtles' importance is the major threat to their existence. In addition to this, constant pressure from the tourism and transportation industry, light and noise pollution impose threats towards the turtle habitats. For example, the sea turtle habitats in Cox's Bazar were in danger due to the construction of the marine drive road. However, sustainable fishing practice, monitoring the turtle population and rescue method should be introduced at the local level to conserve and protect sea turtles and their habitat. Besides, training and workshops for local volunteers and community leaders will also be beneficial for all.

4. Conclusion

The highly diversified coastal ecosystems of Bangladesh undoubtedly provide an immense amount of benefits, opportunities, and services. As the growing population is already exerting pressure on the terrestrial ecosystems, in the future, it will be dependent on the coastal and marine ecosystems. The major findings of this study are-

- Mangroves are the largest ecological region. But both human intervention and natural threats make them susceptible to degradation.

- Mangroves, estuaries, and salt marsh provide breeding, nesting, and feeding grounds for fishes and other commercially valuable species such as crab, shrimp, etc. these provinces can be very productive and earn a lot of foreign exchange by suitable sustainable management.

- Coral ecological province is the most vulnerable of all as it is very small in extent, provides a lot of services, but extreme tourist pressure causing severe threats (e.g. exceed, carrying capacity, pollution, habitat destruction, etc.).

- The mangrove and salt marsh ecosystem store a large amount of blue carbon. After decaying, they may release a lot of carbon-di-oxide and contribute to climate change as they oxidize quickly. So, management for these is urgently needed.

- Turtle nesting ground is a very unique ecosystem that is threatened due to extreme fishing practice by trawl net. Sustainable fishing practice is urgently needed for saving turtles.

However, over-exploitation and utilization of mangrove and fishery resources, pollution, and other natural aspects are already imposing serious threats to the coastal ecosystems of Bangladesh. Proper management and monitoring is an urgent need for the conservation of ecosystem services. So, the delineation of major coastal ecosystems along with the identification of their services and threats should be immediately carried out. Bangladesh's government should give more attention to monitor and plan management strategies for these ecosystem services rather than exploitation. The government should also enforce laws and regulations to control illegal practices and promote sustainable practices to raise the environmental concern of the local community and stakeholders. More baseline surveys and studies should be conducted to generate more knowledge on the ecosystem services and threats of salt marsh, estuarine and coral ecosystem of Bangladesh to properly monitor them and formulate more plans and policies to protect them.

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