Prof. Dr. Md. Nazrul Islam

REPORT
ON
NATURAL RESOURCE MANAGEMENT PLAN (FLORA AND FAUNA)

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By
Professor Dr. Md. Nazrul Islam
Consultant
Forest Resource Management Expert
Preparation of Payra-Kuakata Comprehensive Plan Focusing on Eco-Tourism Project
&
Forestry and Wood Technology Discipline, Khulna University, Khulna

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Declaration

I, Dr. Md. Nazrul Islam, declare that all materials included in this report is the end result of my own work and that due acknowledgement have been given in the bibliography and references to ALL sources be they printed, electronic or personal.

(Professor Dr. Md Narul Islam)
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Abstract

Inventory of forest resources and the management of forested land is an important venture. As a society in the present day, we are expecting that forest land managers will meet our current needs for forest-related goods and services and sustain the resources so that our future generations will be able to enjoy the various outcomes from the forests that we enjoy today. The ability to meet this expectation is often expressed through a plan, which might include statements that reflect our beliefs of what the management of the land may provide. The proposed project area includes 7 Upazillas, viz. Patharghata, Barguna Sadar, Amtali, Taltali, Kala Para, Galachipa, and Rangabali under two administrative districts, i.e., Barguna and Patuakhali. Erosion and deposition of soil are regular natural phenomenon in the area. Different types of grasses grow quite extensively on chars during the early period of vegetation which ended with a mangrove forests either by plantation or by natural process. The mangrove forest area is distributed in 6 upazillas out of the 7 upazillas of the project area. The top canopy in the mangrove forest is occupied by *Sonneratia apetala*, *S. caselaoris*, *Avicennia officinalis*, *Excoecaria agallocha* and *Bruguiera gymnorrhiza*. Besides few representations of *Heritiera fomes* and *Ceriops decandra* are also detected in the park of the area. The forest ground is covered mainly by the seedlings of *E. agallocha*, *S. apetala* and *A. officinalis*. These mangroves are also home to numerous birds, fish, sharks, corals, crustaceans, crocodiles, turtles, monkeys, and even support waters where bio-luminescent algae flourish. Mangroves absorb high amounts of carbon – some estimate four times more than tropical rain forests – making them an indispensable ally in the fight against climate change. It is also a good attraction for the tourists. These tourists provide an income and livelihoods for local communities who financially benefit from preserving the mangroves rather than destroying them. Thus, make a plan for managing the mangrove forest along with other plan is very important for the area.

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1. Introduction

Patuakhali and Barguna districts are coastal districts of Barisal Division and is located at the fringe of the Bay of Bengal. The land elevation differences are typically less than 1 meter and hence are vulnerable to natural disasters such as cyclones, tidal surges, floods and sea level rise due to its coastal location and low elevation (Brammer, 2014). The Meghna, Brahmaputra, and Ganges rivers have collectively shaped the landscape. The sediments are mainly non-calcareous clays, but they are silty and slightly calcareous on riverbanks and in a transitional zone in the east adjoining the lower Meghna. Usually, silty and clay deposits are finely stratified, and sandy deposits, as well as mixed sandy and silty deposits are coarsely stratified. It includes recent accretions as well as the young and old Meander floodplain deposits. The soils of these areas are slightly saline (0.5-9.9 ds/m) and the pH values range from 5.8-7.8 and soil organic matter varies between 1.2 and 3.6%. The climate is humid with temperatures range from 18 to 32 degrees Celsius and annual rainfall between 2000-3000 (Siddiqi and Khan 2004). The principal rivers traversing the districts are the Andharmanik, Agunmukha, Payra, Lohalia, Patuakhali, and Tentulia in Patuakhali and the Payra, Bishkhali, Khagdum, and Baleshwar in Barguna.

The distribution of land areas upazila-by-upazila is illustrated in Table 1. Among the seven Upazilas, Amtali upazila has the reserve forest area that constitutes the highest proportion (53,14%) of the total area. Galachipa Upazila contains the least amount of reserve forest.

Table 1. Distribution of Reserve Forest in the Project area

Upazila	Land Area	(%)	Reserve Forest	(%)
Galachipa	463.06	(51.79)	29.68	(3.32)
Kalapara	467.11	(94.96)	21.05	(4.28)
Rangabali	260.4	(69.57)	20.6	(5.5)
Patharghata	234.11	(17.54)	37.29	(38.37)
Barguna Sadar	311.67	(23.36)	8.26	(8.5)
Amtali	539.3	(40.42)	51.64	(53.14)

Coastal ecosystems are extremely diverse and robust, and include aquatic and terrestrial ecosystems comprising saline, brackish, and fresh water arenas. The littoral zone's land area consists of mud flats, sandy beaches and sand dunes, flatlands, and undulating terrain that are home to a variety of ecosystems and habitats. In the coastal zone, at least ten distinct agro-ecological zones have been identified, each of which contains multiple bio-ecological zones. This diversity

of ecosystems supports a broad range of flora and fauna, including genetically diverse species. Consequently, all levels of biodiversity (genetic, species, and ecosystem) are exceptionally high in the coastal zone.

It is well known that the high level of human exploitation and destruction of habitats in the coastal zone disrupts the integrity of ecosystems and contributes to natural degradation well below the threshold levels for recovery, resulting in irreversible degradation. Besides, as a low-lying nation, Bangladesh is among the most vulnerable nations in the world to the earliest effects of climate change (MoEF, 2008). The observed and anticipated effects of climate change and vulnerability include sea level rise, increasing salinity trends, growing drainage congestions, greater monsoonal rains and reduced dry season precipitation, increasing frequency and intensity of tropical cyclones and storm surges, erosion of soil and coastal embankments, and deteriorating coastal ecosystems (MoEF, 2005; Alam, 2010). Consequently, the protection of the ecosystem becomes an essential component of any integrated coastal zone management.

During the years 1960-1980, a coastal embankment was constructed in an effort to preserve agricultural land and increase rice production in the coastal region. In the coastal region, a total of 5017 km of embankments were constructed against nature's will (Rahman and Rahman, 2015). However, the embankments are threatened by rising sea levels and cyclonic storm surges. To mitigate the effects of climate change, Bangladesh must cultivate sustainable forests along its coastline. Consequently, Bangladesh Forest Department (BFD) began afforestation in the coastal belt in 1966 with the primary goal of protecting the lives and property of coastal residents from cyclones and tidal bores (Das and Siddiqi, 1985). Until 2010, approximately 190,000 hectares of accreted land were planted with coastal mangroves (Islam et al., 2013) where the most successful species were *Sonneratia apetala* (keora) and *Avicennia officinalis* (baen) (Siddiqi, 2001). Presently, S. apetala accounts for approximately 94.4 % of all established mangrove plantations, while A. officinalis accounts for only 4.8 % (Siddiqi and Khan, 2004). Other important mangrove species, such as *Heritiera fomes* (sundri), *Excoecaria agallocha* (gewa), *Xylocarpus mekongensis* (passur), *Aegiceras corniculatum* (khalshi), *Nypa fruticans* (golpata), etc., were found to be promising as experimental trials within S. apetala plantations (Siddiqi et al., 1992). Some mainland tree species, such as *Samanea saman* (rain tree), *Casuarina equisetifolia* (jhao), *Pithecilobium dulce* (payra), and *Acacia nilotica* (babla), were discovered to be suitable for planting on the elevated coastal lands after a lengthy investigation (Siddiqi, 2002; Islam et al., 2014).

Management plans for coastal plantations have been made with the following goals in mind: (1) to continue planting coastal forest plantations and to start managing existing ones for their timber value; (2) to protect and preserve areas of environmental value related to the conservation of biodiversity resources; (3) to combine people's participation and development; and (4) to increase and promote recreational and tourism potential. To reach the goals, programs like 1) management of forest plantations, 2) operation of continuous forest inventory system, 3) participatory forestry, 4) forest leisure and tourism, 5) management of protected areas, and 6) environmental services are put in place (Canonizado 1999).

In some areas of mangrove plantations, deer and monkey species have been brought in and are doing well. Some areas have now been set aside as wildlife reserves. Some parts of the mangrove forest and farms have also been set aside as protected areas with different names, such as National Parks, Wildlife Sanctuaries, and Ecologically Critical Areas. A people-oriented participatory forestry program, the Coastal Greenbelt Project (CGP), aimed to improve the socio-economic condition of the rural poor, improve the role and status of women in rural enterprises, diversify and supplement farm income, substitute locally produced coconut for improved oil, and improve environmental quality, including the restoration and/or protection of critical mangrove habitat (Canonizado 1999). Participatory plantation on government fallow land, embankment, roads, and trains reduces poverty (Khan et al. 2004). The Embankment Settler Group leases khash lands for embankment upkeep under the CERP. There are a variety of non-governmental organizations that have programs designed to establish plantations in homesteads, institutions, along roadsides, in khas, and on recently accreted char land as well as fallow land.

2. The Need for Forest Management Plans

Forest plans are descriptions of the activities that should be implemented to achieve a property owner's objectives. Forest management without a plan may be governed by short-term operational considerations, but this may have undesirable or unforeseen long-term consequences for the landowner (Demers et al., 2001). Consequently, planning is an essential aspect of forest management. If a forest management plan is not prepared with care and forethought, the activities implemented in the near future may not produce the results desired by the landowner over the long term. The majority of significant natural resource management organizations in North America have formulated an action plan for the land they manage. Nevertheless, many modest forest

landowners do (Joshi et al., 2015; Butler et al., 2004). The Food and Agriculture Organization of the United Nations (2010) estimates that management plans have been established for 52 percent of the world's forests.

Some form of planning is typically employed, whether it is a traditional process that uses mathematical tools such as linear programming to allocate activities to forest strata, an elaborate process that uses heuristic methods to develop a spatially explicit harvest schedule, or a seat-of-the-pants (back of the envelope, scratch-your-head) method to determine what to do next. In many instances, quantitative relationships are used to distinguish superior plans from mediocre or subpar plans.

3. Creating Natural Resource Management Plans

Forest planning organizations typically want plans that help them (1) implement activities, (2) predict future harvest levels, (3) optimize resource use, and (4) maintain or develop habitat areas, possibly while balancing several other concerns (budgets, personnel, etc.). In many parts of the globe, natural resource management prioritizes ecological and social concerns over economic or commodity production. Natural resource managers must efficiently use their resources to achieve their aims. Many college students dislike mathematical methods for decision-making. Economic, biometric, and operations research studies are used. Modern simulation and optimization methods may be needed to create forest plans and effectively manage multiple objectives and constraints. Thus, students must learn how to use these tools and how the results can help them plan.

Natural resource managers have a duty to address natural resource management issues that make headlines. If we manage land scientifically and aim to meet our landowners' goals, we must be able to boldly and effectively assess current and future forests, range, and wildlife habitat. If this is not feasible and we cannot communicate the trade-offs well, we will struggle to persuade our clients (the landowner, supervisor, stockholder, or general public) that their goals are met. Natural resource managers will also struggle to persuade the public of our expertise. Land managers must show that economic, ecological, and social goals are addressed in management plans to build trust among natural resource management groups. Systematic, organized, and quantitative planning methods may help plans endure scrutiny. This book should help you develop some of these tools or comprehend the concepts you may encounter as natural resource managers.

4. Status of the Natural Resources of the Area

4.1. Homestead tree diversity[1]

Homestead is the most significant natural resource base in Bangladesh and is home to a wide variety of plant species (Table 2). Some of these plant species in rural homesteads are dubbed "life-supporting species" because they help people survive food shortages and natural disasters. In a study, Atikullah et al. (2016) observed a total of 189 growing plant species in Patuakhali and Barguna districts. Chambol (Albizia richardiana) and Mahogany (Swietenia mahagoni) dominated fewer saline areas, while Raintree (Samanea saman) dominated moderately and heavily saline areas. Mango (Mangifera indica) was dominant in highly salty areas, while Coconut (Cocos nucifera) was almost equally dominant in all saline zones. Date palm (Phoenix sylvestris) was less common in highly saline areas. Tamarind (Tamarindus indica) thrived in moderate and highly saline areas. Due to salinity, species adaptation ranged greatly. Thus, actively growing mango, coconut, and tamarind in coastal saline areas would boost household income (Fig. 1).

Table 2. Homestead plant species in different salinity zones of the studied south-central coastal areas of Bangladesh

Homestead plant species	Different saline zones of the study areas		
	Less saline	Moderately saline	Strongly saline
Timber and fuel-yielding	32	36	34
Fruits-yielding	39	40	40
Medicinal and spices	15	17	14
Ornamental	16	20	13
Naturally-growing	13	14	14
Woody,nonwoody (herbs/shrubs/climbers)	58	62	52
Total	173	189	167

[1] This section heavily depends on Atikullah et al. 2016

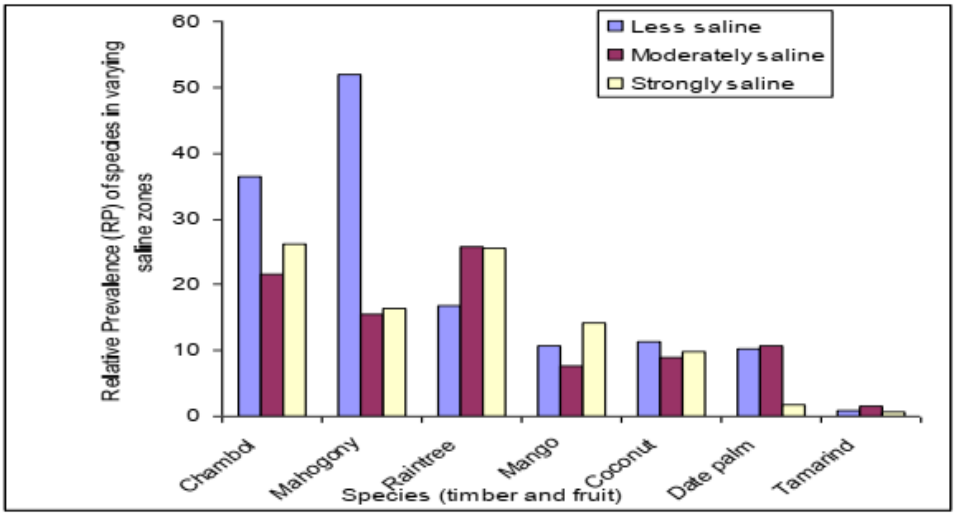

Fig. 1. Relative prevalence of major timber-and fruit-yielding species in different saline areas of the studied south-central coastal zones of Bangladesh

On average, approximately 181 individual trees of various ages existed per homestead. Less saline homesteads had 201 trees, followed by 176 in highly saline and 164 in fairly saline (Table 3). Because they were suited, multipurpose trees dominated the less-saline zone. Some fruit- and timber-producing species thrived in less salty areas. Besides naturally forming trees, less saline areas have more species. Fruit and timber output in saline-affected coastal areas may benefit from a uniform tree species distribution.

Table 3. Relative prevalence of dominant tree species in varying saline zones of the south-central coastal region of the study of Bangladesh.

Species/Scientific name	English/ Common name	Relative prevalence			Total		
		Lees saline	Moderately saline	Strongly saline	Average trees	% of homesteads with the species	RP all farm
1) Timber-yielding							
Albizia richardiana	Chapalish	36.516	21.595	26.130	31.56	0.89	28.01
Swietenia mahagoni	Mahogany	51.989	15.397	16.350	32.33	0.83	26.67
Samanea saman	Rain tree	16.718	25.686	25.547	24.41	0.93	22.68
2) Fruit-yielding							
Mangifera indica	Mango	10.620	7.678	14.144	11.92	0.91	10.88
Cocos nucifera	Coconut	11.282	8.892	9.901	11.08	0.91	10.06
Phoenix sylvestris	Date palm	10.199	10.766	1.740	8.92	0.78	6.98
3) Medicine-yielding							
Terminalia arjuna	Malabar nut	0.030	0.002	0.021	0.16	0.10	0.015
Calotropis gigantea	Swallow wort	0.020	0.007	0.000	0.10	0.06	0.006
Azadirachta indica	Neem	1.478	2.040	0.065	1.91	0.49	0.938
4) Ornamental species							
Hibiscus rosa-sinensis	China rose	0.0183	0.0506	0.0600	0.23	0.18	0.0411
Delonix regia	Gulmohur	0.0127	0.0077		0.07	0.07	0.0044
Nyctanthes arbor-tristis	Jasmine	0.0002	0.0025	0.0025	0.04	0.04	0.0014
5) Naturally growing							
Streblus asper	Rough bush	0.152	0.005	0.425	0.61	0.23	0.138
Barringtonia acutangula	Indian oak	0.011	0.001	0.069	0.19	0.09	0.018
Hydnocarpus kurzii	Chaulmoogra	0.040	0.017	0.038	0.23	0.13	0.031

Locals identified salt-tolerant tree species, which are enumerated in two parts: those that survived in moderate to strong saline conditions and those that survived in less saline conditions (Table 4).

Table 4. Species grown in moderate to strongly saline tolerant and less saline areas of the study sites of the south-central coastal region of Bangladesh.

Moderately to strongly saline tolerant species		RP	Less saline tolerant species		RP
Scientific name	English name		Scientific name	English name	
Acacia nilotica	Arabic gum	0.079[3]	*Alstonia scholaris*	Devils tree	0.008[1]
Aegle marmelos	Wood apple	0.168[3]	*Borassus flabellifer*	Palmyra palm	6.439[1]
Annona reticulata	Bullocks heart	0.0016[3]	*Cassia fistula*	Indian laburnum	0.063
Azadirachta indica	Country neem	2.040[2]	*Citrus maxima*	Pummelo	0.094[1]
Bambusa tulda	Bamboo	0.068[3]	*Cocos nucifera*	Coconut	11.282[1]
Casuarina littorea	Seef wood	0.014[3]	*Embelica officinalis*	Indian gooseberry	0.038[1]
Citrus aurantifolia	Lemon	0.019[3]	*Erythrin fusca*	Coral tree	0.158
Diospyros blancoi	Wood nut	2.1452[3]	*Limonia acidissima*	Elephant apple	0.001[1]
Ficus hispida	Country fig	0.047[3]	*Manikara*	Sapota	0.137[1]
Garcinia cowa	Cowea	0.009[3]	*Neolamarckia cdamba*	Wild cinchona	0.041[1]
Pithecellobium dulce	Jilapi	2.423 [2]	*Psidium guajava*	Guava	3.716[1]
Pongamia pinnata	Indian buch	0.670[3]	*Phoenix sylvestris*	Date palm	10.199[1]
Pithecellobium dulce	Jilapi	2.423[2]	*Syzygium fruticosum*	Jamun	0.963[1]
Sonneratia caseolaris	*Chaila*	0.004[3]	*Terminalia arjuna*	Malabar nut	0.030[1]
Tamarindus indica	Tamarind	1.458[2]	*Zizyphus mauritiana*	Jujube	2.086[1]

RP- Relative prevalence of species in coastal saline zones.

-Less saline area[1], -Moderate saline area[2], -Highly saline area[3].

Table 5. Threatened and rare species need to be conserved and immediate action in this region

Local name	English name	Scientific name
Abeti	Cane	*Calamus rotung*
Atafal	Custard apple	*Annona reticulate*
Bantula	----	*Hibicus moschatus*
Buno Karol	Teasle gourd	*Momordica cochinchinensis*
Cawaphal	Cowa	*Garcinia cowa*
Chatian	Devils tree	*Alstonia scholaris*
Hijal	Indian oak	*barringtonia acutangula*
Kamranga sheem	Winged bean	*Psophocarpus tetragonolobus*
Mewa kathal/Ata	*Annona muricata*	
Mouseem	Sword bean	*Canavalia gladiata*
Nagmani	----	*Wissadula periploci folia*
Pechigab	----	*Diospyros embryopteris*
Royna	Rohina	*Aphamixis polystachya*
Urigab/Bangab	----	*Diospyros Montana*
Shimul		*Bombax ceiba*
Karanch/sitesora		*Pongamia pinnata*
Khoi		*Streblus asper*
Bora		*Typha elephantiana*
Pani ghas		*Lindernia anagallis*

4.2 Coastal plantation and its diversity

Since the 1960s, the Bangladesh Forest Department (BFD) has implemented programs of coastal afforestation along the 710 kilometers of coastline by planting mangroves on coastal embankments, newly accreted coastal char lands, and offshore islands. Compared to unplanted areas, mangrove plantations in coastal Bangladesh have promoted accretion and reduced erosion, according to Chow (2017). Between 1973 and 1989, plantation areas experienced 37,2 times more accretion than erosion, whereas non-planted areas experienced only 1.6 times more accretion than erosion. Man-made mangrove forests cover more than 170,000 hectares of embankments, chars, and islands and constitute a unique coastal greenbelt.

Afforestation of foreshore and tidal areas outside embankments proved to be a cost-effective method of dissipating wave energy and reducing embankment flooding during storm surges. Cyclone Sidr in 2007 and Cyclone Aila in 2009, for example, caused less property damage and fewer fatalities in Chokoria and surrounding areas than the devastating cyclone in 1991. This was due to foreshore afforestation on embankments, which significantly reduced storm surge velocity (GoB 2008).

In the coastal areas, a total of 1,92,395 ha mangrove, 8,690 ha non-mangrove, 2,873 ha Nypa, and 12,127 km strip plantations were planted as of 2013 (Hasan, 2013). Among the early mangrove plantations, about 80% of the area was *S. apetala*, 15% was *A. officinalis*, and the remaining percentage was *E. agallocha, Bruguiera sexangula* (kankra), *Ceriops dacandra* (goran), *H. forms*, and *X. mekongensis*, which are more valuable species for timber, fuel wood, and paper pulp production (Table 6). The most successful planting species, *S. apetala*, demonstrated promising survival and growth performance all along the coastal belt. *A. officinalis* is the eastern coastal belt's second most successful species. These two species dominate the overall mangrove plantations along the coast. Other valuable mangrove species, on the other hand, did not survive in the accreted lands, most likely due to a lack of planting experience and scientific knowledge. However, a few trees of other mangrove species can be found sporadically along the coastline, in addition to the existing *S. apetala* and *A. officinalis* plantations. As a result, *S. apetala* has been widely planted in almost all development projects due to its success in newly accreted char lands. However, due to continuous siltation on the forest floor, a lack of seed sources from other mangrove species, and grazing by cows and buffalos, no regeneration has been found in S. apetala forests. Plantations of

37 different non-mangrove species have been established, primarily on the slop of a coastal embankment, along roadsides, and on raised coastal lands (Nandy et al., 2002).

Table 6. Reserve forest adjacent to the port of Pyra and its biodiversity

Name of the Reserve	Biodiversity
Fatrar Ban	Sundri, Keora, Baen, Golpata Deer, monkey, wild boars, fishing cats, python, cobra, monitor lizard and crocodiles
Gangamati Reserve Forest	Akashmoni, keora Forest Rooster
Lebur Bon	Keora, Gewa, Goran, Golpata Red crab
Sonar Char	Chaila, Keora, Babla, Nypa Palm, Karamcha, Phragmites, and Berry. Deer, monkey, forest cat, wild boars, buffalo, and forest rooster
Haringhata Forest, Barguna	Keora, Goran, Gewa, Ora, Passur, Golpata, Hogla etc Spotted Deers, Monkeys, Wild cats, Boars, Monitor lizard, forest rooster, red crab

5. Uses of the Coastal Forest Resources in the Area

Coastal plantations provide local communities and the environment with numerous benefits. Here are some local applications of coastal plantations:

- Plantations along the coast function as natural barriers against coastal erosion, storm surges, and tsunamis (Mukherjee et al., 2013). These plantations absorb wave energy, reduce littoral erosion, and provide shoreline stabilization.
- Mangrove plantation provides timber for construction of houses and boat, the main communication transport, fuel, and other non-timber forest products, such as fish, crab and honey (Kairo et al., 2001). Kusumadewi et al. (2015) and (Ngumbi et al. 2016) observed that the coastal communities depend heavily on mangrove forests for their livelihoods, with mangrove-based fisheries providing the main source of income.
- Coastal plantations can attract tourists and generate income for local communities. In Indonesia, the Karimunjawa Islands have become a popular tourist destination due to their picturesque mangrove forests (Kurniawan et al., 2019).
- Coastal plantations provide habitats for various plant and animal species, including endangered species. In Ghana, for instance, the mangrove forests in the Muni Pomadze

Ramsar site provide habitats for several bird species, including the endangered, white-bellied heron (Kingsford et al., 2009).

- Coastal plantations sequester carbon from the atmosphere and help mitigate climate change. In the Philippines, for example, the Bohol Island State University established a mangrove plantation that sequesters carbon and provides various ecosystem services to local communities (Rönnbäck et al., 2007).

As can be seen from the information presented above, coastal plantations not only supply the most in-demand form of timber for the construction of their homes and vessels, but they also offer additional revenue-generating possibilities in the form of tourism and fishing.

6. Integrated Resource Management Plan

6.1. Importance of special planning in the coastal areas

The coastal zone accounts for 20% of the country's land area and 28% of Bangladesh's population (Islam, 2004). This region has a population of 36.8 million people, with more than half of them (52%) living in poverty (Islam, 2008). The poor are particularly exposed to the negative consequences of climate change since they are concentrated in coastal regions. Climate change is making natural disasters more often in Bangladesh, especially in the coastal regions and on the char islands. In coastal areas, there are weak facilities for roads, electricity, housing, sanitation, transportation, and coastal protection. The rural coastal population constructed their homes utilizing native building resources including wood, bamboo, CI sheet (tin), and other thatching materials. Due to natural disasters, particularly cyclones and windstorms, they consequently lose their homes every year. In addition to sea level rise, the coastal region of Bangladesh is vulnerable to a variety of natural and man-made hazards, including flood (Chowdhmy and Karim, 1996; Islam and Sado, 2000; Paul and Rasid, 1993), salinity intrusion (Alexander et al., 1998; Haque, 2006; Miah et al., 2007; Mondal et al., 2001; Potten, 1994), cyclone (Alam et al., 2003; Islam and Peterson, 2009), subsidence (Stanley and Hait, 2000; Worm et al., 1998) and land transformation (Bala and Hossain, 2009; Iftekhar, 2006; Rahman et al., 2009). Bangladesh has already started to lose a sizable portion of its land mass as a result of the coastal region's rising sea level (Rahman, 2009). One of the countries most impacted by deadly tropical cyclones is Bangladesh (GoB, 2008). When cyclones make landfall, the northern Bay of Bengal, which resembles a funnel, causes tidal bores that have impacted thousands of coastal residents. Tropical cyclones that struck the area that

is now Bangladesh were among the deadliest natural disasters in recorded history (GoB, 2008). Around 17 percent of the 508 cyclones that have originated in the Bay of Bengal over the past 100 years that have hit Bangladesh have been severe, or nearly every three years on average. Tropical cyclones and the storm surges they cause have a significant negative impact on life, property, and the economy of coastal Bangladesh, particularly on the agriculture and fishing industries and, consequently, on the way of life for those who live there. This effect will be enormous in the future due to cyclones and storm surges brought on by climate change, which will occur more frequently and intensely (Quadir and Iqbal 2008).

6.2. Rationale for an integrated coastal resource management plan

Integrated Coastal Resource Management, also known as ICRM, is a holistic strategy that encourages the responsible utilization and growth of coastal environments through integrated management of coastal resources. ICRM is an acronym that stands for Integrated Coastal Resource Management. The realization that coastal resources are interconnected and interdependent serves as the foundation for the reasoning behind the development of an ICRM plan. In order to achieve sustainable development and prevent environmental degradation, a holistic approach must be taken to the management of coastal resources. Coordination between various economic sectors and interested parties is necessary for the efficient administration of coastal resources. The ICRM plan can serve as a forum for the participation and cooperation of various stakeholders, which will ultimately result in the more efficient and equitable administration of coastal resources (Douvere, 2008). ICRM plans are necessary to provide a framework for managing coastal resources in a sustainable manner (Huang et al., 2015). This is necessary to ensure both conservation and development in a way that is equitable and sustainable, providing benefits to current and future generations. Coastal areas are under increasing threat from human activities such as overfishing, pollution, and habitat destruction. ICRM plans are necessary to provide a framework for managing coastal resources in a sustainable manner (Das et al., 2018). In addition to this, it guarantees that none of the activities involved in maintaining the balance cause any damage to the natural world (Talwar et al., 2019). Through the promotion of a comprehension of the interconnections between ecological, social, and economic factors, the ecosystem-based management approach, which is a central component of ICRM, has the potential to improve the efficiency and effectiveness of coastal management (Costanza et al. 2008). By incorporating adaptation measures into coastal management, it is possible to contribute to the building of resilience to the effects (Nicholls et al.,

2015) In conclusion, an Integrated Coastal Resource Management plan is an essential instrument for attaining sustainable development in coastal areas, as it strikes a balance between the ecological, social, and economic dimensions of coastal resources. An Integrated Coastal Resource Management (ICRM) plan can help to ensure that coastal resources are managed in a way that is beneficial to both current and future generations by reducing threats to coastal resources, promoting equitable and sustainable use of resources, striking a balance between the needs of various stakeholders, building resilience to the impacts of climate change, and promoting stakeholder engagement and collaboration.

6.3. Strategic goals and objectives of forest resource management plan

As a long-term vision for the sustainable administration of the coastal plantations and reserve forest and its interface landscape, the following vision statements are proposed:

- The forest resources will continue to provide protection to the locals' life and livelihoods.
- Afforestation in newly developed char areas, vacant areas, and reforestation in degraded coastal areas.
- Co-managing resources will raise awareness, shared responsibility, and financial benefits for traditional users, who will preserve them.
- In coastal resource management, FD will improve its infrastructure, logistics, and technical capacities and seek technical help.
- Local communities can adapt to climate change by developing and efficiently operating alternative income businesses.
- Wildlife preserves and wetlands will protect fish and wildlife.
- The Forest Department will seek public-private partnerships in accordance with GOB guidelines to enhance ecotourism services and facilities to capitalize on nature tourism.
- To maintain ecosystem goods and services, climate change impacts will be recognized and mitigation and adaptive management strategies implemented.
- Ecological duties like streamflow restoration will be acknowledged.

6.3.1. Management strategies

Over the ten-year Plan, the following management strategies are recommended to attain the desired condition:

- FD as an agency that can plan, execute, and oversee a biodiversity and wetlands conservation and resource management program that includes subsistence use.
- Afforestation in newly developed areas and reforestation in degraded areas with the participation of locals through a system of co-management.
- To a framework that supports participatory governance and fair sharing of benefits by making it easier for concerned parties to act responsibly as stewards.
- Participatory, collaborative management with increased coordination and cooperation with key government agencies like DOF, DOE, Coast Guard, other agencies, local government, private sector, local communities, tour operators, etc.
- To mobilize sustainable conservation funding through innovative methods and alliances that address new opportunities and needs in eco-tourism, recreation, biodiversity conservation, sustainable livelihood, food security, carbon sequestration, and other ecosystem services.
- Strong monitoring and evaluations by co-management team.
- Creation of awareness to sustainable resource use.

6.3.2. Strategic goals and outcomes

The refinements and shifts in strategic management outlined above are anticipated to contribute to the accomplishment of the following objectives and outcomes for the sustainable management of the coastal resources and its surrounding landscape:

- Goal 1: Protect, restore, afforest, support, and improve coastal forest (plantation and reserved forest) resources and interface landscape biodiversity.
    - Outcome: Forests, terrestrial resources, wetlands, and aquatic resources that can retain their health, productivity, variety, and resilience to unnaturally severe disturbance.
- Goal 2: Provide resilience-based food security through fisheries, values, benefits, products, and services while assuring the sustainable flow of these resources for future generations.
    - Outcome: Through the consultation of best available science and stakeholders, resource use is managed on the premise of sustainability and co-management.

- Goal 3: Promote ecotourism and recreational activities.
    - Outcome: Increased eco-tourism revenues boost alternative incomes and biodiversity protection and visitor control.
- Goal 4: Promote community-based co-management of coastal endeavors and their surroundings.
    - Outcome: The FD helps landscape groups and stakeholders determine co-management and benefits sharing.
- Goal 5: Develop and execute climate change mitigation and adaptation strategies.
    - Outcome: The FD maintains the coastal forests as a carbon sink (both green and blue carbon in forests and wetlands) and improves ecosystem resilience to help local people adapt to climate change effects like cyclones and storms.

7. Strategic Programs for the Sustainable Coastal Forest Resources

7.1. Coastal afforestation/reforestation program to protect habitat and livelihoods

Coastal forests, according to many researchers, lower wind speeds and significantly contribute to reducing damage from oceanic disasters in coastal areas (Zhu et al. 2000; Takle et al. 2006; Santiago et al. 2007; de Zoysa 2008). According to Zhu et al. (2000), the topography, wind direction, and distance from the forest belt's edge all have an impact on the relative wind speed within the forest belt. Mangrove species offer a promising opportunity to improve the social and ecological conditions in the coastal environment (Nandy and Ahammad, 2012). Vegetated coastal habitats are another alternative for an eco-engineering strategy (Duarte et al., 2013). In order to reduce the vulnerability of coastal residents, coastal ecosystems might be extremely important (Ahsan, 2014; Parvin and Ahsan, 2013; Touhiduzzaman and Rahman, 2017).

Coastal afforestation is a more affordable and environmentally sound choice than other options to safeguard Bangladesh's coastal areas and offshore islands, notably from the effects of cyclones and storm surges, given the adaptation and mitigation measures of climate change impacts (Siddiqi, 2008). First, plantations provide a wide range of advantages that enable coastal communities become more able to adapt, e.g., accelerated the sedimentation process. Therefore, we propose:

- Continuous reforestation of riverbanks and coastal zones with mangrove species. If the soil is clayey and the site is newly accreted char lands in a low saline zone, Keora will be preferred. However, if the soil is slightly saline and sandy, Baen will be preferred.
- Due to high mortality, monospecific plantations of S. apetala are confronted with a serious problem that has produced enormous voids within the forests. Even, after several years, the Baen is also create natural gaps. There is an immediate need to restore these gaps through reforestation, establishing a second rotation mangrove plantation by introducing recommended mangrove species (*H. fomes, E. agallocha, X. mekongensis, A. corniculatum, Cynometra ramiflora* (shingra), *Phoenix paludosa* (hantal), and *N. fruticans* at river/canal side) with adaptive capabilities for a long-term, sustainable coastal shelterbelt. A successful underplanting will also produce mixed and multi-story forests and will give a natural look.
- During the several phases, some main land species such as *S. saman, C. equesetifolia, P. dulce, A. nilotica, Albizia lebbeck* (kalo koroi), and *A. procera* can be mingled with mangroves, as their growth in a study by Islam et al. (2004) was deemed promising. Other palm species found to be suitable in Bangladesh's foreshore coastal areas include Cocos nucifera (coconut), Phoenix sylvestris (date palm), and Borassus flabellifer (palmyra palm) (Islam et al., 2014).
- Reforest in degraded coastal areas with secondary seral mangrove species (*E. agallocha, X. mekongensis, A. corniculatum, Cynometra ramiflora* (shingra), *Aglaia cucullata* (Amoor), *N. fruticans* (golpata) etc.
- Poa annua (samna) grass can be grown along the embankment site to reduce the shortage of fodder.
- Use a high starting density when planting mangroves as a form of defense. When designing triangles, wind direction can be taken into account.

7.2. Reduction of coastal erosion

Shoreline alterations caused by erosion and accretion are natural processes that occur on a spectrum of timescales. They may occur in response to smaller-scale (short-term) events, such as storms, regular wave action, tides, and winds, or large-scale (long-term) events, such as glaciation or orogenic cycles, which can significantly alter sea levels (rise/fall) and tectonic activities that cause coastal land subsidence or emergence. Consequently, the majority of coastlines are

inherently dynamic, and cycles of erosion are frequently an essential component of their ecological character. Wind, waves, and currents are natural forces that readily move the unconsolidated sand and soils in coastal areas, resulting in rapid alterations to the shoreline's position.

Development in coastal areas has raised awareness of erosion issues and spurred efforts to manage erosion and restore coastal ability to adapt to human activities, extreme events, and sea level rise. When countermeasures (hard or soft structural options) are improperly designed, built, or maintained and the effects on nearby shores are not carefully evaluated, erosion worsens. Locally, regional, or jurisdictional boundaries are used to address erosion instead of system boundaries that mirror natural processes. Insufficient awareness of coastal processes and coastal system protection causes this anomaly.

Hard structures for coastal protection are expensive, and public opposition to rock emplacements often makes the issue worse (Bray et al., 1995; Black, 1999; Clark, 1995; van der Weide, 2001). Coastal forests and trees provide some coastal protection, and clearing of coastal forests and trees has increased the vulnerability of coasts to erosion, as seen in Vietnam (Mazda et al., 1997; Cat et al., 2006), Malaysia (Othman, 1994), Indonesia (Bird and Ongkosongo, 1980; Nurkin, 1994; Tjardana, 1995), Sri Lanka (Samarayanke, 2003), India (Malini and Rao, 2004; Gopinath and Seralathan, 2005) China (Bilan, 1993) and Thailand (Thampanya *et al.*, 2006).

- Less construction of robust structural/engineering alternatives Use structures constructed on the coastline (seawalls, groynes, breakwaters/artificial headlands) or further offshore (offshore breakwaters) to influence coastal processes in order to stop or slow coastal erosion.
- More use of Soft structural/engineering options (beach nourishment/feeding, dune construction, revegetation, and other non-structural management options) to dissipate wave energy by mimicking natural forces and preserving the coastline's natural topography.
- In mudflat environments, it is essential to plant vegetation species at the appropriate elevation. Saltmarsh species are recommended for low and subtidal deltas below the high-water mark. Typically, saltmarshes are zoned according to elevation, with the zones governed by the frequency and duration of tidal flooding. Spartina, as a pioneer species within this zone, is tolerant of more frequent flooding than higher marsh species and, as a result, is frequently planted well below the intertidal zone. (French, 2001). Other saltmarsh

species that can be utilized include helophytes such as *Phragmites australis* (Cav.) Trin. ex Steudel and *Scirpus lacustre* L. Mangroves are also recommended and easy to plant in this region. If the area has a severe erosion problem already, then special seeding techniques are required.

- To reduce insect damage, a combination of species is recommended; however, the selection must be carefully considered to avoid competition. Several publications offer planting/replanting guidelines, including Hanley. (2006). The mangrove forest should have a minimum width of 300 meters, a minimum density of 0.5 meters, and a staggered planting pattern.
- In sandy beaches, seeing the presence of wider ripple marks, tool marks and mud crack, Ipomea can be planted to reduce erosion. In addition to this, other beach grass (*Acanthus ilicifolius* (Hargoza), *Acrostichum aureum* (Hudu, Tiger fern) can be combinedly used with it.
- Over time, the vegetation species will be replaced, first by pioneer mangrove species, then by seral mangrove species. This process will take place gradually. At long last, salt-resistant varieties of mainland plants will be cultivated.

7.3. Tengragiri wildlife sanctuaries management programs

The Wildlife (Preservation) Act in 1974, the Forest Policy in 1994, the Forest Act amendment in 2000, and the Social Forestry Rules in 2004 and 2010 have gradually shifted forests management from timber production to ecological requirements, conservation of biological diversity, meeting bona fide subsistence consumption needs of local people, and climate change mitigation and adaptation functions and services of forests. The main goals of the sanctuaries management program are to: i) co-manage the three animal sanctuaries as natural ecosystems and carbon sinks. ii) protect biodiversity, including wildlife and aquatic resources, from all forms of biotic interference, iii) rehabilitate, maintain, and develop good-quality forest cover and productive wetlands with natural structure and composition, iv) reduce and shift local community subsistence use of forests, wildlife, and aquatic resources to the buffer zone and interface landscape zone, and v) regulate high impact visitor use for outdoor recreation, research and educational purposes by mounting an awareness and motivation campaign.

- Co-management groups like CMCs will strengthen protection against illegal felling, fishing, and poaching. The CMCs will execute value chain and income generation activities

for the local community to motivate dependent communities to reduce their removals in exchange for conservation-linked livelihood opportunities. Honey, wax, hantal, and bark will not be harvested in sanctuaries to limit human intervention. Hiking, sightseeing, jungle boating, cruising, and wildlife watching will be allowed in the core zones, but motorized vessels and group picnics will be restricted to designated routes.

- No transient or permanent fisherman settlements will be permitted within the preserve.
- To ensure the sanctuaries as protected breeding/spawning areas for marine fish and other aquatic fauna, a complete ban on fishing will be enforced in the waters within the three sanctuaries.

7.4. Afforestation/Restoration of the proposed park and other areas (living and office site) in the plan

A massive redesign of the port city of Pyra is in the works, and as part of that process, the city will undergo afforestation with natural plant species that are both suitable and appropriate. This will result in the city becoming a new zero-carbon emission city. In addition to this, the damping site, which was created as a result of dredging and newly constructed char areas, will improve the environment by lowering the amount of pollution that is produced. Even the city needs some parks, curbside plantations, and residential and commercial areas that have been decorated in order to make it more appealing to visitors. rehabilitating a location that had become degraded. If plantation is done along the roadside with social forestry module, it will provide some alternation income generating opportunities to local people. For making the Pyra city as a green zero emitting city, we propose

- The utilization of native species in suitable place to facilitate rapid regeneration and guarantee the protection of biodiversity (e.g., Koroi, Karanja, Gamar, Kadam, Tal, Hijol, Tamal, Nageswar Madar etc.).
- Decorative native plants can be used in dwelling and office sites (e.g., Bokul, Kanchan, Krisnachura, Palas, Jarul, Mahua, Narikel, Supari).
- To conserve biodiversity, some native fruit tree species should be mingled with timber and decorative trees (e.g., Am, Jam, Kanthal, Lichu, Peyara, Jamrul, Tetul, Ashphal, Sofeda, Falsa, Jambura, Bel, Kothbel, Deua, Chapalis, Amloki, Arboroi, Jalpai, Gab, Chalta, Amra, Bot).

- In areas of water *Barringtonia acutangula, Crataeva magna, Erythrina fusca, Pongamia pinnata,* and *Trewia nudifolra* can be grown along water edges in low-lying areas (Alam et al., 1991).

7.5. Food security and wetlands management programs

Food security programs in coastal forests would enhance ecosystem resilience, food access and availability through wetlands and fisheries management, and equitable benefitssharing from identified NTFPs to local communities. Improved habitat protection and sustainable forests and wetlands management would help poor local communities cope with resilient Sundarbans ecosystems.

This program improves wetlands and fisheries management through co-management to assure long-term food security. Other goals include (i) providing guidelines for managing fisheries resources and implementing co-management activities for long-term sustainability of the Sundarbans fisheries by enhancing environmental preservation and conservation; (ii) rational harvesting of wetlands resources; (iii) increasing public participation and benefits from fisheries resource management; (iv) expanding the biological base; and (v) improving management performance.

Sustainable fishing management requires two steps:

a. Resource Conservation Measures: Control the number of fishers and the gears they use to maintain fisheries resources at a sustainable level.

b. Resource Improvement Measures: Manage and conserve fishing resources.

Fisheries resource conservation methods include:

a. All waterbodies in the core zone are off-limits to fishing year-round.
b. Fishing bans in fish breeding seasons.
c. Complete banning of fish gear (set bag net), limiting the use of Fash jal,
d. Fishing net mesh below 15mm/1 inch (knot to knot at stretch state) will not be allowed.
e. Insecticides and fish toxins will be banned.
f. During November–April, Ilish and Pangas below 23 cm cannot be caught, and male crabs must weigh 200gm and females 120gm.

7.6. Climate change mitigation and adaptation programs

Coastal areas with gentle topography are more susceptible to the harmful effects of hurricanes and rising sea levels than other types of coastal areas. It is suggested that a REDD+ Improved Forests Management (IFM) proposal be developed in order to attract carbon finance, while a monitoring, reporting, and validation (MRV) system is also proposed in the Plan. Besides this,

- Access to capital has been the most important factor, particularly for collectors. Specialized institutions or microfinance organizations must be established.
- Establish marketing and production cooperatives. This would enable storage, postharvest processing, refrigeration, and collective conveyance. These cooperatives will boost income, confidence, empowerment, knowledge, harvest management, and natural disaster resilience.
- Improving bottom layer socioeconomic conditions has many choices. VGD, VGF, and Food for Employment during lean seasons may help marginal collectors by limiting food.
- Since the SRF's per capita NTFP collection has plummeted, collectors should be encouraged to move to other economic activities.

7.7. Management system

All the forest resources will be managed through a collaborative management system. Here, participation from multiple stakeholders, including local communities, government agencies, non-governmental organizations, and industry will be ensured. Consequently, the emphasis of these types of plans is on meeting the requirements (economic, social, and environmental) of the community that resides in or around the forest. As in other developing countries, community interest in these programs is generally predicated on basic needs for fuel, timber, food, water, and other nontimber forest products; when these are marginally available, collaborative planning and management may lose its appeal (Matta and Kerr,2006). Successful collaborative planning programs feature quantifiable community benefits (financial and otherwise), local organizational control over natural resources, and the absence of government control (Crook and Decker, 2006). These types of management and planning systems necessitate that groups reach consensus on contentious forest-related issues and reach an understanding regarding the use of communal forest resources. To ensure greater success

- There will be clear written property rights of local people.

- Decisions will be taken by the local community without violating government policy where FD will facilitate the decisions with their scientific knowledge.
- Women group will be formed and included in co-management team.
- Long term finance will be ensured to support their activities.
- Alternative income generating opportunities will be created to reduce their forest dependency.
- Income from tourism and others will be shared with local community for their own prioritize development.
- Care will be place to address socio-vulnerability.
- Proper monitoring and evaluation through a multi-dimensional team.

8. Conclusion

A comprehensive coastal forest management plan is necessary to support coastal forest ecosystems. A good coastal forest plan should handle climate change, habitat fragmentation, invasive species, and human activity. The coastal forest ecosystem's unique flora, fauna, water resources, and soil types must be considered in management methods. Local communities, government agencies, non-governmental organizations, and business must be involved in coastal forest management plans to succeed. To meet local needs while balancing economic, social, and environmental goals, collaboration and communication are important. The management plan needs long-term commitment and careful monitoring and evaluation to assess strategy effectiveness and adjust accordingly. Stakeholder engagement and new scientific knowledge are needed to support coastal forest ecosystems for future generations. In conclusion, a complete coastal forest management plan is essential for coastal forest ecological integrity, sustainable use, and ecosystem services.

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