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**Ecosystem Based Disaster Risk Reduction at Indian Sundarbans: A Lesson Learned from
AMPHAN Supercyclone**

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Abstract

Ecosystem based Disaster Risk reduction is the sustainable, green method to minimize cyclone damages at tropical coasts. As a part of a climate change resilience project initiated in 2012, 102 hectare of multispecies mangrove plantation was established at eastern corner of Indian Sundarbans. The AMPHAN supercyclone, have caused immeasurable destruction in the region, between 16th - 21st May, 2020. This research brings forward the field observations on effectiveness of community managed mangrove plantation in ameliorating disaster impacts. Study revealed that mangrove bio-shield minimized property damage during the cyclone by reducing flooding through earthen embankment stabilization and managing the wind speed, direction.

Key words

Super cyclone; Natural disaster; Mangrove; Community managed plantation; Ecosystem services; Ecosystem based Disaster Risk reduction



1. Introduction

Sundarban biosphere reserve, India (9630 sq km) is situated at the largest delta of the world, dominated by the largest contiguous mangrove forest of the globe and is the only abode of mangrove tigers. It has been designated as the Ramsar wetland conservation site with an area of 4,23,000 hectare, which is the largest amongst all other wetland conservation sites in the nation. It is a UNESCO world heritage site. The south- eastern part of the forest has been designated as a National Park with nearby buffer area as sanctuaries (Sajnekhali Wildlife Sanctuary, Lothian Wildlife Sanctuary and Haliday Wildlife Sanctuary) [1-3]. It is also a Tiger Reserve and the forested region along with human settled villages comprises the Sundarban Biosphere Reserve. Alongside these ecological treasures, Indian part of Sundarbans also supports a staggeringly high, 4.6 million people. Government of India has enforced various conservation measures to protect this largest contiguous mangrove patch of the world, an enormous reserve of 'blue carbon' and its enigmatic tigers [4]. Most of the populations of this region are subsistence farmers. Although there are agricultural land available for growing seasonal vegetables and crops, but the frequent cyclone hit, intrusion of saltwater, flooding and erosion are the major challenges of farmers. Data showed a consistent increase in total agricultural land of Indian Sundarbans, from 1990 to 2006 (16.9% to 20.9%), but there is a sharp decline to 16.3% in 2013 due to climate change- sea level rise problems [5,6]. About 34% of people residing in 54 out of 102 islands of the Indian Sundarbans are under life-threatening poverty [7]. Ecotourism is also gaining popularity as an alternative livelihood options amongst these socio-economically marginalized population and this is improving their view on conservation measures enforced in this unique eco- region. There is a drastic 101% rise of tourists' influx in the delta during 2003 to 2009 [7]. Seasonal migration of labors from the areas of Sundarbans is also a major source of income to the locals after the economic pressure generated due to drop in agricultural produce in the region because of salt water intrusion during AILA cyclone in 2009. Approximately, one member from each 75% of families must have migrate and working in inter and intra states of India [6,7].

Sundarbans has to bear the brunt of natural disasters which is ever increasing due to the vagaries of climate change and sea level rise impacts at the Ganges- Brahmaputra- Meghna delta. Measures have been taken to limit the impact of cyclones on the lives and livelihood of the socio-economically marginalized population of the delta. Ecosystem based disaster risk

reduction is a popular initiative adopted across the globe to limit damage to resources [8,9]. In this context, mangroves are proven to have enormous ecosystem services. One of the foremost of which is to save the vulnerable coastline from furies of cyclones, storm surges and tsunami by acting as a natural bio-shield [10-13]. As part of a social work and climate change resilience venture mangrove plantation activities were initiated through community participation in 2012, at Satjelia Island located in the remote corner of Indian Sundarbans (Figure 1).

COVID 19 outbreak caused a huge public health crisis throughout the globe. Eventually it leads to nationwide lockdown to contain the disease but has also resulted in huge unplanned migration of mostly unorganized labor population [14,15]. During this COVID-19 pandemic, between 16-21st May 2020, the region was hit by a devastating super cyclone, AMPHAN having the highest wind speed of 260 km/h. This resulted in untold destruction and official report suggests that 28% of the Sundarban area was devastated by this cyclone and 1200 sq km of mangrove reserve forest impacted out of 4263 sq km [6]. This perspective gives an outlook on how a social work venture facilitating community based mangrove plantation has saved around 3000 families at Satjelia island from after effects of the AMPHAN cyclone.

2. Community based mangrove plantation

As a social work initiative a mangrove restoration activity was started at Satjelia island of Indian Sundarbans in January, 2012 [4]. Green livelihood promotion, disaster management and degraded mudflat restoration are the three most important focus of the project implemented due to participation of 2100 socio- economically marginalized families. 1050 members constituted the female only self help groups whereas another 1050 members were in the Primary Committee for Forest Conservation (PCFC) groups. The later was responsible for protection, plantation of mangroves in the degraded mudflats along the river banks. It has been proven by scientific literatures that mangroves consolidate soil, and act as a natural defense against any disaster like cyclones, flood events as well as sequester 'blue carbon' [2,13,16]. Hence, as a part of the disaster mitigation plan, 102.4 ha of naked mudflats were reforested by mangrove plantation with help of PCFC group members in 2012. *Avicennia marina* (Acanthaceae), *Bruguiera sexangula* (Rhizophoraceae), *Ceriops tagal* (Rhizophoraceae), *Rhizophora mucronata* (Rhizophoraceae) and *Xylocarpus moluccensis* (Meliaceae) are chosen to be representative species for this mangrove restoration initiative [2,4].

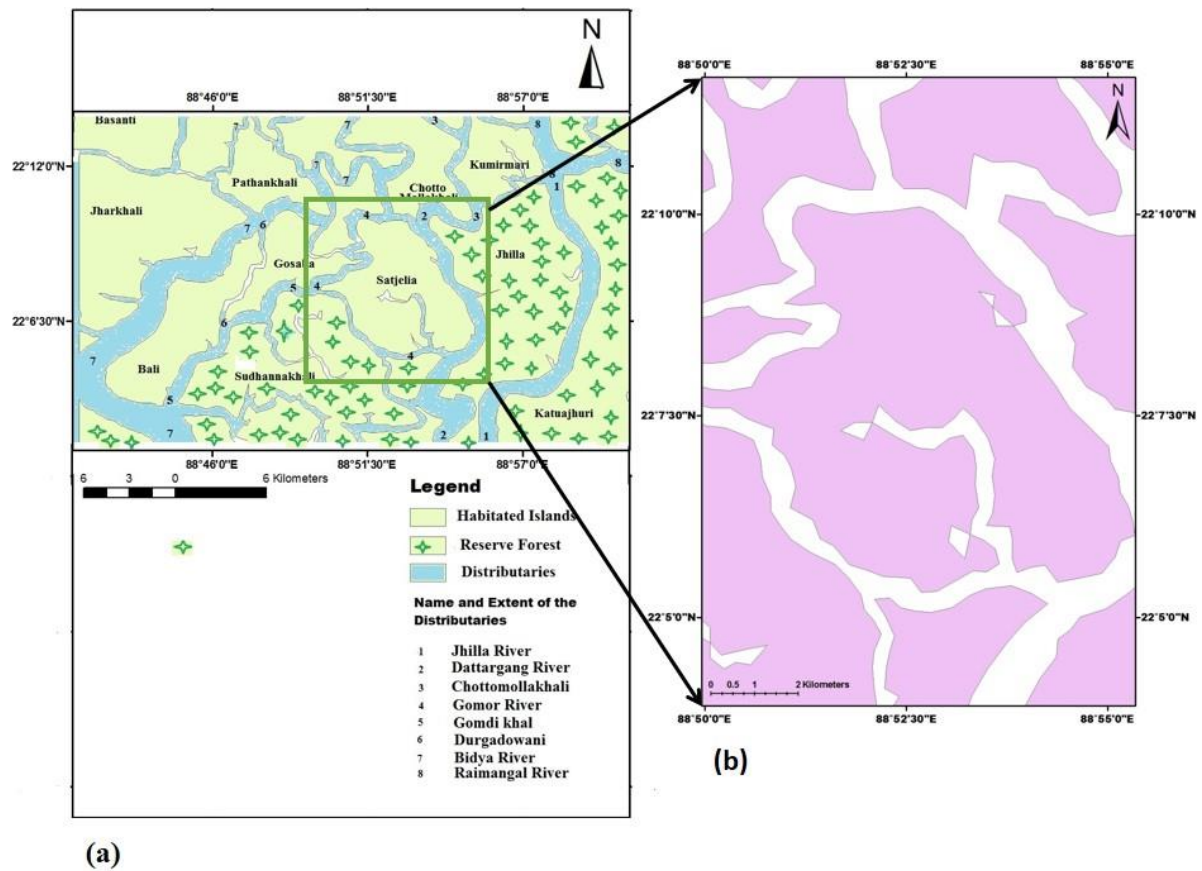


Figure 1: (a) The left hand side shows the area of Indian Sundarbans which is the largest contiguous mangrove forest and only abode of mangrove dwelling tigers. (b) The project area is zoomed out showing Satjelia island where through community based plantation 102 Ha or mangroves has been planted in 2012 and has shown resilience against AMPHAN cyclone in 2020.

Community and PCFC members have actively participated in the plantation activities and were paid from project fund as per the labor rate in 2012 [1,2,4]. Resource conservation and disaster management trainings were conducted in the project period (2012- 2016) to impart the importance of mangrove in any possible future disaster events. The PCFC members were also responsible for protecting the restored mudflats till 2016-17, from illegal logging or goat rearing activities. This has given the beneficiaries', a sense of participation in both plantation and protection of the mangrove bio- shield. Because of these project activities and community mobilization models employed in the restoration initiative, 39- 100% survival rate of the plants have seen varying with the different planted species till 2016. Research on 'Blue carbon'

sequestration dynamics also suggested about 85% increment on organic carbon density in the mudflats restored via mangrove plantation [2,17].

3. Case selection and research methodology

In the current AMPHAN super cyclone, the parts of Satjelia and Lahiripur Gram panchayet (Village) sheltered by these mangrove plantations have saved from flood and the flooding intensity also have reduced in comparison to the non mangrove mudflats. This mangrove shelter has saved around 3000 families across the island. The devastation incurred by the storm has been depicted in figure 2.



Figure 2: The devastation caused by AMPHAN cyclone at Indian Sundarbans and how mangrove plantation of 2012 acts as a barrier against the vagaries of the supercyclone. (a) The banks and mudflats not protected by mangrove cover have been breached during the cyclone causing extensive flooding across the area inundating agricultural lands. (b) Flooding after the cyclone has inundated many of the houses in the village. (c) Eight year old mangrove plantation (*Rhizophora mucronata*) along the mudflat of the river banks of Lahiripur Gram Panchayet (village). (d) Mangrove cover grown due to the plantation activity of 2012 has protected the village from AMPHAN by stabilizing the mudflats.

Mangroves have physiological and anatomical adaptations to survive in the saline environment and generally exist between land and sea (Table 1a). They can consolidate the mudflat soil and hinder erosion activity during tidal regimes or storm surges [12]. In case of AMPHAN eight year old mangrove plantation cover has resisted the wind speed of the cyclone and also protected the mudflat from caving in, resulting in a barrier against the storm. Mangroves are a group of salt-tolerant trees or shrubs that grow in water, with their roots emerging from the water. Mangrove ecosystems provide important ecosystem services for flood protection in coastal areas and also benefit the region economically.

The growth and type of mangrove forests depend on: hydrological connectivity and topographical features. Hydrological connectivity consists of the quality, quantity and timing of freshwater and sediment inflow. This is responsible for deciding the height of the mangroves. Tidal conditions, coastal landscapes and marshes decide the path of the mangroves, *i.e.*, their growth in the horizontal direction [18]. Therefore, mangroves can adapt to rising sea levels and changing land use because of the ability to move horizontally and vertical accretion.

Mangroves are connected to each other and form an integrated system linking the coast and the ocean. Though they thrive in saline conditions, the deltas where mangroves are found also depend on freshwater supply. Deltas have been shrinking in areas where freshwater is scarce, leading to loss of mangrove forests. These ecosystems are being threatened by unsustainable human activities for development.

A qualitative exploratory case study, using in-depth interviews, official documents, and literature review has been used to understand the role of community-managed mangrove plantations in saving families from problems resulting after a natural disaster. Verbal interviews were conducted with the villagers residing along the mangrove protected river banks also indicated the role of mature mangrove strands in ameliorating flooding and cyclone intensities. The interviewees were selected from the island in consultation with local Non- Governmental Organization (NGO) who was residing along the mangrove plantation cover and without the same. A total of 65 respondents expressed their views during the month of June 2020, after the damages due to the cyclone (Table 1b). Respondents from 25 families reside in houses protected by the mangrove cover while another 25 families were from different parts of the nearby islands without mangrove cover. Sixteen members of a (NGO) working on the relief activity just after

the cyclone, were also interviewed to get an qualitative outlook on the extent of damage incurred and influence of a 8 year old community managed mangrove plantation in ameliorating the extent of the damage.

Table 1a- Different mangrove communities seen across the globe

Place/ region	Type of Mangrove	Ecological function/ livelihood impacts	Reference
Most common variety of mangroves, found in almost all mangrove ecosystems in.	Red Mangrove (<i>Rhizophora mangle</i>)	Found on coastlines and low-lying land. This species has aerial roots (prop roots) that are emerge from water. This helps to host aquatic and coastal wildlife and prevent soil erosion at the coastline. These are the tallest mangroves, so they provide the best protection against cyclones and storm surges. Most suitable for aquaculture due to fish and shrimp found among the roots.	[21]
Central America, Southeast Asia	Black Mangroves (<i>Avicennia spp</i>)	Located inland, after red mangroves. It gets its name from the bark of the trees, which are black. The wood is used as charcoal, fuel and harvested for construction purposes. This variety of mangroves has pneumatophores, <i>i.e.</i> , roots originating upwards from the roots in the soil. These help the plants and underwater root systems receive oxygen.	[21]
Central America	White Mangroves (<i>Laguncular Racemosa</i>)	These are located at higher elevations, near inland water bodies. They do not have aerial roots, but produce flowers and fruits. The leaves have pores which transpire saline water. Therefore, white mangroves play an important role in preventing inland water sources from becoming saline.	[21]
Southeast Asia	<i>Sonneratia spp.</i> (Locally known as Firefly Mangrove, Mangrove Apple)	This variety is found in coastal swamps and slow-moving water. Apart from numerous ecological benefits, these mangroves are important to coastal communities and livelihoods. The small fruits are either cooked or used in beverages. <i>Sonneratia alba</i> produces fruits that resemble small, green apples, which are pickled. Leaves can also be	[22,23]

Southeast Asia	Nipa Palm (<i>Nypa fruticans</i>)	<p>consumed and have medicinal properties to treat cough, small pox, applied on cuts and bruises, etc. Like black mangroves, wood can be used for construction. Fish and shrimp can be found at the roots.</p> <p>The Nipa Palm grown in swampy lands and aids other mangroves in protecting the coast. It requires moderately saline conditions. The only palm species that is considered a mangrove.</p> <p>The seeds of some fruits can be eaten. The leaves are used for thatching roofs. A sweet syrup or sugar can be extracted from the sap, which is an important traditional livelihood of coastal communities in Indonesia, Thailand, etc. It has been used in traditional medicine- various parts are used to treat ulcers, centipede bites, headaches, etc.</p>	[24,25]
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Table 1b: The stakeholders

Serial Number	Stakeholders	Respondents
1	Families residing near the planted mangrove cover	25
2	Families residing in opposite side of the island away from the mangrove cover	25
3	Non- Governmental Organization representatives working in the relief effort post cyclone	15
	Total	65

4. Result and Discussion

The interview sessions and on- site visits clearly suggest that the flooding during the aftermath of the cyclone was considerably low in the houses along the vicinity of the mangrove plantation cover. The mangrove bio-shield not only has checked the breaching of earthen embankment by 60% but has also resulted in lesser flooding. The tube wells near the mangrove cover were one of the only sources of local fresh water for more than a month, following the disaster. The area was not flooded during the storm because of the mangrove bio-shield. Most of the respondents (23

out of 25), residing away from the mangrove cover reported massive damage of their houses and ponds during the cyclone incident. 14 out of 25 of these respondents reported their roofs been blown away or house infrastructure damaged during the cyclone. Only 5 respondents from the mangrove sheltered region reported of such damage. Mangrove cover has acted as a bio-shield against the strong winds and has reduced the wind speed during this disaster. Similar evidences also suggests that mangrove patch has the capacity to reduce the wind speed by acting as wind breaker [10,11].

All the 25 responded from part of the island not protected by mangrove cover have responded that the embankment was breached during the cyclone resulting in massive flooding of agricultural land and houses in contrast to the respondents in the vicinity of the mangrove cover. All the 25 respondents use to be part of training programs conducted during 2012- 2016 as part of the plantation initiative and has taken strides in protecting the mangrove plantations in the area. This also proves the importance of the awareness camps along with plantation initiatives to enlist the support of the local stake holders in conservation or eco- restoration initiatives. None of the agricultural land near the mangrove plots were damaged due to the adult mangrove covers mainly because of the fact that it has protected the embankment from getting breached.

The respondents from NGO working in AMPHAN relief efforts has also stressed upon the importance of this mangrove patch in saving the embankments' during the cyclone and reducing flooding losses. Mangroves have a elaborate root system that consolidate the soil, loose sediments and a mature mangrove patch act as a barrier against the cyclones and storm surges [10,11]. The major reason of the devastation across Sundarbans is the fact that the earthen banks caved in during the cyclone as evident from Figure 2(a). It also imparts other ecological services in the region like more fish catches are reported by the respondents in the part of the river fringed by the newly established mangroves. Literature review also enlists this kind of ecological services by mangroves [19,20]. As the part of the community based plantation program the residents near to the mangrove patch were given incentives on their protection and they imparted paid labor in the plantation process which has instilled their sense of ownership on these plantations. This has resulted in nurturing of the plants till the present day and reduced poaching activities. The NGO respondents stressed upon this fact during explaining the reason behind

success of this plantation project. So, community managed mangrove plantation acts as a successful Ecosystem based Disaster Risk reduction model in case of AMPHAN disaster.

Currently, rainfall patterns are changing and the frequency of cyclones has increased due to climate change. The role of a mangrove ecosystem in providing resilience and risk management to coastal communities is rising. Bangladesh, India and Vietnam rely on mangroves to protect them from annual floods and cyclones, while the United States, China, Mexico and India also reap economic benefits [13]. Past researches also focused on how mangroves have proved effective in managing or ameliorating disaster impacts during several disaster events across the globe (Table- 2) and same trend has been also noticed during AMPHAN supercyclone at Indian Sundarbans.

Table- 2: Ecosystem Based disaster Risk Reduction by mangroves during recent disaster events across the globe

Major disaster	Year	Area	Evidence on reduction of damage of due to mangrove	References
Indian Ocean Tsunami	2004	Indian Ocean (Indonesia, Sri Lanka, Thailand, India)	This devastating event triggered the study and acceptance of mangroves as important barriers between the land and sea. A study was conducted at the Cuddalore district in Tamil Nadu. This location was ideal as it had a flat, even coastline with patches of dense mangrove forests and cleared land. Satellite images proved that a density of 30 trees per 100 sq. metres can reduce the flow of a tsunami up to 90%. These also showed that villages exposed to the coast faced maximum damage as opposed to villages behind mangroves, where damage was minimal. Also, villages that were far inland, but without mangroves were equally damaged. In Sri Lanka, it was observed that around 6,000 people were killed in a settlement that had lost mangroves whereas only 2 individuals were killed in a village that had dense mangrove forests.	[26,27]
Cyclone Bulbul	2019	Sundarbans in India and Bangladesh, Myanmar	Though this cyclone arrived with low tides, the role of mangroves was to reduce the wind speed and divert it away from the coastal cities and villages. The wind speed reached 130 km/h. It was recorded that the Sundarbans reduced the wind speed by 20km/h. The forests were severely destroyed or	[28]

			uprooted and restoration is going on.	
Sulawesi Tsunami	2018	Indonesia	This tsunami caused severe infrastructure damage and loss of many lives in Palau Bay, Indonesia. Changing land use was a major reason for exposing more areas of the coast to damage. On the western side of Palau Bay, communities that were shielded by mangroves survived the tsunami better. Field surveys show that houses that were faced the cleared parts of mangrove forests were washed away and people living in houses behind mangroves survived mostly unaffected.	[29]
Hurricane Eta and Hurricane Iota	2020	Central America	The two hurricanes arrived successively in November 2020. A patch of mangroves reduced the wind speed of 72km/h to 11km/h. These regions have lost a lot of mangroves to development activities. This is also affecting the coral reef ecosystems in the ocean nearby.	[30,31]
Cyclone Harold	2020	Solomon Islands, Vanuatu, Tonga and Fiji.	These are low-lying islands, vulnerable to climate change and extreme events. Recently, mangrove forests are being cleared in the name of development. The destruction brought by the cyclone in an already sensitive region could have been reduced if there were mangroves. During the storms, local cruising yachts sought refuge in the mangroves of Port Denarau, Fiji.	[32]

5. Conclusion

The Ecosystem based Disaster Risk reduction initiated by mangrove plantation has shown positive results in protecting the lives and livelihood of the marginalized population of Indian Sundarban during the impact of AMPHAN super cyclone. It also acts as a reservoir of fish and the area accounts for more catch particularly crustaceans than region devoid of mangrove cover. In spite of the international efforts in restoring mangroves for their 'blue carbon sequestration', plantation efforts are not gaining much momentum at The Sundarbans. This work substantiates the need of community based mangrove plantation initiative in a poverty impacted, disaster vulnerable, and densely populated region like the Ganges- Brahmaputra- Meghna Delta focusing on its ecosystem services. Community managed mangrove plantations proved to be an effective

barrier against vagaries of the disaster. Hence, mangrove plantation should not only be promoted as an initiative to sequester ‘blue carbon’ but to build disaster resilience along the coastline. Mangroves are also used for ethnobotanical purposes by local communities [33]. Further research on the mangrove patch will shed light on the mechanism by which mangroves can reduce the effect of natural disasters and how this community based mangrove plantation model can be optimized in different other tropical- sub tropical coastline impacted by mangrove loss.

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Author’s contribution

Chowdhury, A- Is responsible for initiating the multispecies plantation activity mentioned in this case study in 2012 and drafting, compiling the manuscript as well as taking part in the post-AMPHAN survey at Indian Sundarbans. **Naz, A-** As the technical consultant of Tagore Society for Rural Development (TSRD), Rangabelia. West Bengal, India, is responsible for survey conducted after the AMPHAN supercyclone and has equally contributed in organizing/ drafting the manuscript as the first author. **Iyer, A.S-** Has compiled the literature review data presented in table-1a and table-2, as a part of the winter internship project- 2020-21 with TSRD. And, **Bhattacharyya, S-** Is the coordinator of the KKS- BMZ- TSRD funded project that initiated, managed the multispecies mangrove plantation mentioned in the case study and has been the main contact person for the post AMPHAN survey on disaster impacts.

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