Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(2): 529 – 548 (2022)
www.ejabf.journals.ekb.eg

Climate Change Impacts and Ongoing Adaptation Measures in the Bangladesh Sundarbans

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ARTICLE INFO

Article History:
Received: Aug. 2, 2021
Accepted: March 15, 2022
Online: April 19, 2022

Keywords:
Sundarbans,
Fisheries,
Natural disasters,
Occupational changes,
Climate change

ABSTRACT

The climate of Bangladesh has changed drastically which may put considerable adverse impacts on mangrove fishers; however, very few studies focused on this professional group. An attempt was made to perceive the impact and adaptation measures of the Sundarbans mangrove resource users, employing interviews and focus group discussions. A total of 150 respondents were randomly selected from the Sundarbans west under Shyamnagar Upazila of Satkhira District. It was revealed that the abundance of fishes, fuel woods, honey, golpata (*Nypa fruticans*), and shrimp post-larvae (PL) witnessed considerable reduction. The resource users have adapted themselves by changing their occupation, becoming jobless and depending on the other family members. PL collection, honey collection, shrimp culture, and wood collection were found professional adapting strategies to adopt cyclone, flood, salinity intrusion, river erosion and drought. Several recommendations are elicited, the implementation of which is important to ensure livelihood sustainability of the mangrove communities.

INTRODUCTION

The Sundarbans is a part of the world's largest delta formed by the rivers the Ganges, Brahmaputra, and Meghna, covering about 4.2% of the total Bangladesh; whereas, forests cover only 10.2% of the land area **(Alexandar, 2014; Sunny, 2017a)**. It is the largest single block of tidal halophytic mangrove forest in the world which is situated in the South-West area (21º 31′-22º 38′N and 89 º 00′- 89º55′ E) of Bangladesh

and has been a Ramsar site since 1992, and world heritage of UNESCO from 1997 **(FAO, 2007)**.

It covers approximately 10,000 km^2, among which 60 percent remains in Bangladesh and the rest is situated in India **(Hossain & Dearing, 2015; Mondal, 2015)**. The Sundarbans covers approximately 6,017 km^2 in Bangladesh, where an area of 4143 km^2 is landmass and the remaining area is 1874 km^2, forming water bodies of a network of rivers, canals and creeks **(DoF, 2010)**. Sathkhira, Khulna, and Bagherhat districts cover approximately 99% of the Sundarbans in our country, and the remaining areas are in Patuakhali and Barguna districts **(Rahman & Asaduzzaman, 2010)**. Three types of ecosystem services are primarily derived from the Sundarbans of Bangladesh. These include provisioning services (benefits that people directly obtain, e.g., timber and food products such as fish), cultural services (non-material benefits, e.g., mangrove tourism), and regulatory services (benefits obtained from the regulation of ecosystem processes, e.g., carbon sequestration and protection from cyclones) **(Sunny, 2017b)**. The Sundarbans mangrove forest is rich with its natural floral and faunal diversity, including 334 species of plants, 425 species of wildlife, viz. 40 species of mammals, 300 species of birds and 35 species of reptiles, 177 species of fish, 24 species of shrimp, and 7 species of crabs, etc. **(DoF, 2010, Swapan & Gavin, 2011**). About 5 million people are engaged directly and indirectly in services, depending on the Sundarbans for their livelihoods where 69% are engaged in the aquatic resources, 22% people are working in the collection of wood resources; 5% are involved with the non-timber forest product, and 4% are involved with other purposes **(Chowdhury *et al*., 2014)**.

The Sunderbans provides a wonderful aesthetic attraction for local and foreign tourists. The vegetated tidal lands of the Sundarbans function as an essential habitat that produces nutrients and purifies water. In addition, the forest traps nutrients and sediment, acts as a storm barrier, a shore stabilizer and an energy storage unit. Mangrove wetlands act as a barrier against natural climates, avoid coastal erosion and provide nursery grounds for a number of commercially important fish, prawns and crabs. Some of these mangrove wetlands play an important role in enhancing the fishery production of the adjacent neritic waters by exporting organic and inorganic nutrients **(Alongi, *et al*., 2004)**. The environmental setting of this multiple-use ecosystem is governed by physical forces, such as geomorphology of the coast, climate, tidal amplitude and duration, in addition to the quantity of freshwater inflow **(Blasco *et al*., 1996; Islam *et al*., 2016; Sunny *et al*., 2020a; Sunny *et al*., 2020b)**.

Categorized as "Reserved Forest" the Sundarbans is radical for being the source of forestry products and fish that enrich the local and national economy, as well as for being the protector from the heavy ravages of periodical cyclones and tidal surges originating from the sea **(Islam *et al*., 2017; Sunny *et al*., 2020c)**. At present, four major types of livelihood activities are practiced in the coastal areas including mangrove forests; namely, agriculture, fishery, wood collection and honey collection **(Ahmed & Neelormi,**

2008; Ahmed *et al*., 2012; Sunny *et al*., 2019). Approximately, 65% of the total population is dependent on agriculture-based economy. Fishing activities are prevalent at various scales in the Sundarbans catering to livelihoods amongst 15% of the population. Organized large scale fishing activity occurs in the sea and deep water, with a small scale fishing activity in the delta region (half of them are illegal) **(Rahman & Asaduzzaman, 2013; Alam & Laurel, 2014)**. Microscale fishing activity in the shallow river bed is operated mainly to collect the prawns/shrimps post-larvae **(Mizan & Bijoy, 2009; Barua *et al*., 2010)**.

Climate change due to global warming is predicted to cause an annual temperature rise of 0.4 celsius degrees in Bangladesh, resulting in an annual predicted rise of the sea level by 4 millimeters **(Lönnqvist, 2010; Giri, 2014; Payo *et al*., 2016)**. These phenomena would cause an increase in salinity and a decrease in the sweet water flow in the Sundarbans, and subsequent destruction of major forest resources **(Allison, 2005; Chowdhury *et al*., 2007; Haq, 2009)**. Climate change creates resource shortages and unreliable job markets, leading to an increase in migration **(Agrawala *et al*., 2003; Barua *et al*., 2010; Islam *et al*., 2018a)**. Several studies were conducted on Sundarbans mangrove forest; nevertheless, limited work focused on the climate change impact on Sundarbans. Thus, the present study was organized to identify the impact of climate change on the Sundarbans mangrove forest and assess the adaptation measures taken by resource users of Sundarbans.

MATERIALS AND METHODS

The study area covered Sundarbans west in Shyamnagar Upazila of Satkhira district. A total of 150 respondents from different socio-economic and operational groups were investigated (fishermen, honey collectors, golpata collectors, wood-cutter and resource harvesters). For a successful interview, the respondents were interviewed with semi-structured questionnaires designed for these purposes. The purpose of the survey was to gather information related to demography (e.g., basic information of community), depression and cyclones (duration, types of disaster, frequency/wind speed, storm surge height and casualty) and mortality rate. The survey method was followed for collecting both quantitative and qualitative primary data from each spot using a well defines and pre-tested questionnaire following the objectives of the study. Secondary data were collected from different GO's such as the Bangladesh Bureau of statistics (BBS), Upazila Fisheries Officer (Shyamnagar), Bangladesh forest department, NGO's like BRAC, Prodipan, DSK, Practical Action, Shushilon, and DFID (Department for International Development). Descriptive statistics were derived to summarize the property of the data set, and the analysis was conducted through the usage of SPSS version 16.0 (statistical package for social science) and MS Excel.

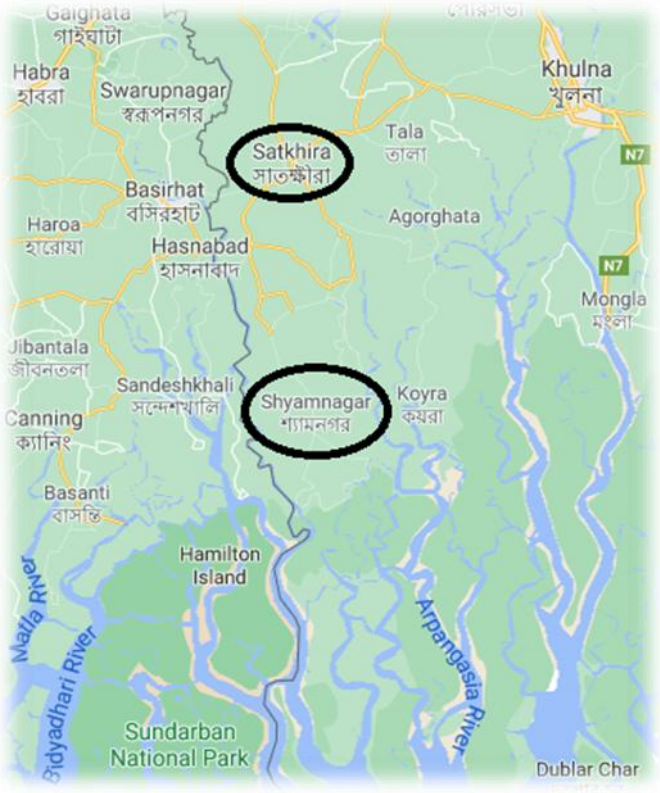

Fig. 1. Location of the study areas

RESULTS AND DISSCUSION

3.1. Climate changing hazards

The respondents were interviewed to know about 30 year's climate-changing hazards which are shown in Fig. (2). Respondents faced cyclone (34%), flood (6%), drought (1%), river erosion (2%), salinity intrusion (5%), and 52% faced multiple hazards (such as cyclone, flood, salinity intrusion etc.). The majority faced cyclones, floods, salinity intrusion, drought, river erosion etc. A study revealed that most of the respondents faced tidal surges, floods, and cyclones (91.67%, 66.67%, and 50%, respectively). River erosion, tsunami, and excessive rainfall were the other disasters faced by the respondents. The natural disaster was the constant company of the coastal population. They were faced more than one disaster every year **(Islam *et al*., 2018a)** . The disaster was considered to be a great constraint for sustainable development in Bangladesh. Cyclone, tidal surge, flood, river bank erosion were some of the worst types disasters which have adverse effects on the livelihood of our people, especially in the coastal zone. Coastal areas put the coastal peoples at high risks since they are susceptible to numerous natural hazards, such as cyclones, tidal surges, salinity intrusion, riverbank erosion, shoreline recession, tsunami etc **(Islam *et al*., 2018a)**. The risks from tropical cyclones, storm surges, floods, and other climatic hazards are geographically concentrated in specific regions of the Sundarban.

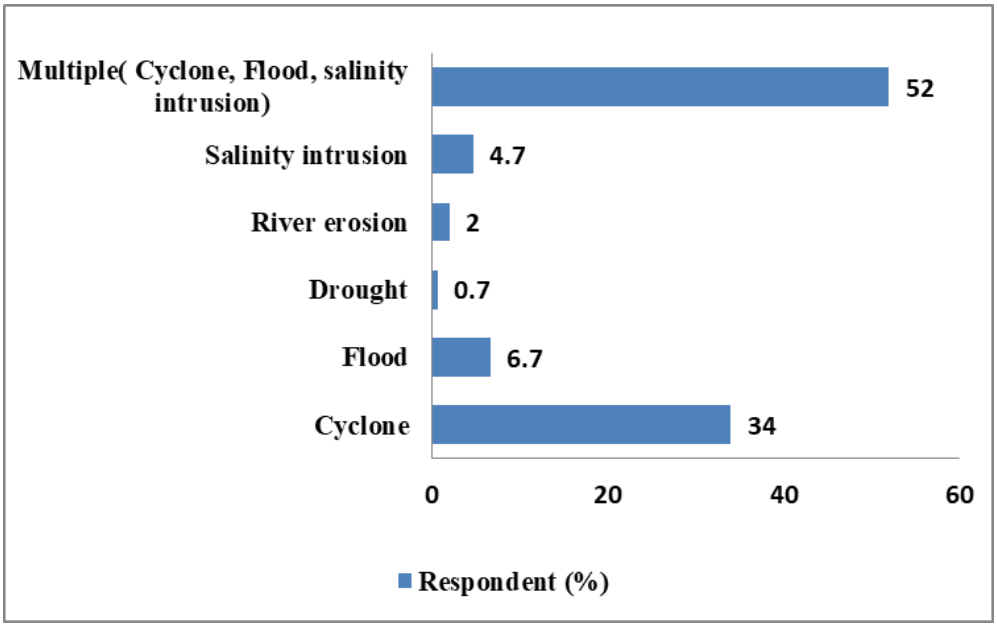

Fig. 2. Climate change hazards of Sundarban

3.2. Devastating natural disasters

The frequent occurrence of extreme events such as cyclones, strong wind, and wave, current and tidal surges made the livelihood of the fishers more vulnerable. The major adverse climatic condition included flood and the tidal surge in 1985, a devastating cyclone in 1991, flood in 1987, 1998, 2004, and 2007, cyclone Sidr in 2007, Rashmi in 2008, Aila, Nargis and Bijli in 2009, Mahasen in 2013 and Gorki in 2016 that put adverse impact on the communities by destroying their residence and fishing utensils, and they allured to illegal fishing to compensate the loss **(Islam *et al*., 2018a)**.

The disasters mostly affecting are represented in Table (1). Most of the respondents (39.3%) reported that Aila of 2009 was more dangerous, 22% reported Sidr of 2007, 18% reported cyclone of 1988, 15% reported a flood of 1998, 4.7% reported cyclone of 1996 and 1% reported cyclone of 1991. Respondents mentioned that cyclone Aila was hitting at night; the majority of people had no news about this disaster, and thus disastrous damages took place in a large scale including man, animals and birds. During 1991-2000, 93 major disasters were recorded in Bangladesh **(Mizan & Bijoy, 2009)**. The impacts of climate change affected the coastal community dreadfully. The coastal community of Bangladesh first received this impact in 1970 and 1991, when two super cyclones hit the country and caused the death of about 500,000 and 138,000 people, respectively **(Islam *et al*., 2018c; Sunny *et al*., 2021a)**. In Bangladesh, the south-west part of the country was affected by category 4 Cyclone, Cyclone Sidr, in November 2007. Cyclone Aila began as a disturbance on 21 May in the Bay of Bengal, strengthened as a category 1 cyclone,

causing the death of about 200 people, and left hundreds of thousands more homeless **(Sunny *et al*., 2021b)**.

Table 1. Experience of the people with dangerous disasters

Year of disaster occurrence	**No. of respondents**	**Respondents (%)**
24-27 November, 1988	27	18.0
April, 1991	1	1
1996	7	4.7
19-22 November, 1998	23	15
15 November, 2007 (Sidr)	33	22
27 May, 2009 (Aila)	59	39.3
Total	150	100.0

3.3. Damages of natural disasters

The present study found that respondents experienced the death of people (2%), house damage and death of domestic animals (35%), damage of crop (15%), damages of fisheries (23%), death of man, animal, and house damage (13%), and 12% formed the damage in fish and crops (Fig. 3). Natural disasters drastically destroyed houses, trees, roads, dams, causing the death of man, animals, birds, and the damage of fish farms and croplands. Koyra, Dacope, and Shymnagar Upazila of the south-west coastal belt of Bangladesh were among the sites receiving the hardest hit of the cyclone Aila. The storm surge washed away all the houses, crops and agricultural land, homestead garden, and livestock, and thereby the area experienced huge toll damages to lives and livelihoods. Aila not only broke down the overall social harmonization but also resulted in a chaotic situation in those areas. One-fourth of the Sundarbans forest area was damaged by the cyclone Sidr **(Mizan & Bijoy, 2009)**. Precisely, eight to ten percent of the forest was completely damaged, leaving fifteen percent partly damaged.

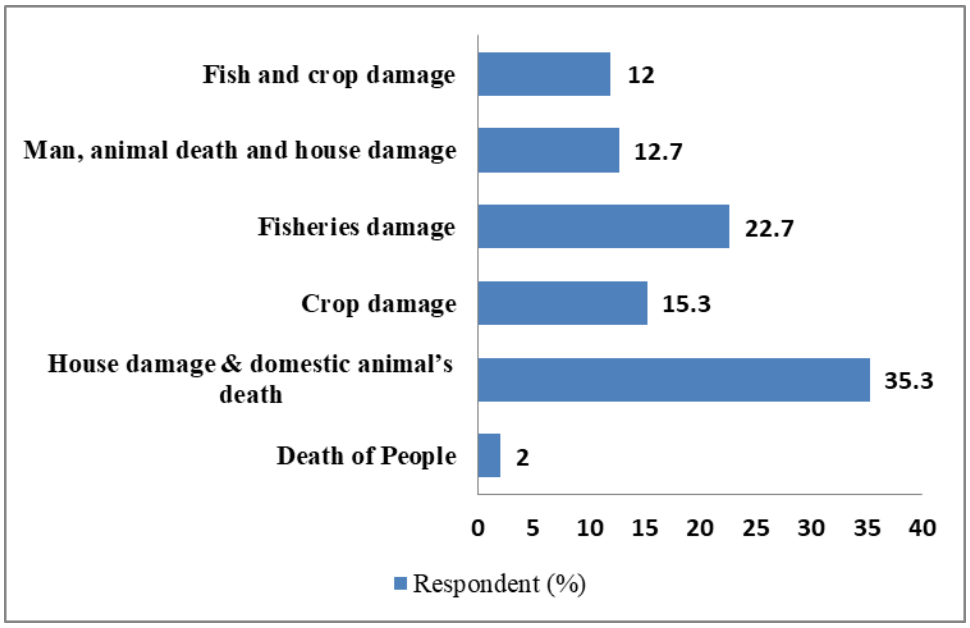

Fig. 3. Damages of natural disasters in the coastal regions

3.4. Resources of the Sundarbans before frequent occurrence of natural calamities

In the present study, it was found that 34% of resource users remarked plenty of fish, crab, and shrimp; 21% remarked plenty of fruits, 12% remarked plenty of livestock and wild animals, 4% remarked plenty of river and canal, 11% remarked availability of honey and wax, and 18% remarked plenty of golpata (Fig. 4). Sundarbans, the largest mangrove forest was teeming with natural resources, served as a diverse habitat for many species, including fish, birds, reptiles, amphibians, mollusks, crustaceans, and many other invertebrates. It was full of Sundari trees (*Heritiera fomes*). The leaves of golpata (*Nipa fruticans*) were harvested by the local community for thatching purposes. Mangroves were a good source of wood, timber, and housing materials, firewood, charcoal, and poles for fish traps. Mangrove was a source of honey and wax, which had high economic value. Moreover, the vegetated tidal lands of the Sundarbans functioned as an essential habitat that produces nutrients and purifies water. In addition, the forest traps nutrients and sediment, acts as a storm barrier, shore stabilizer, and energy storage unit. The Sundarbans ecosystem supported rich fisheries diversity **(Islam *et al.*, 2018a)**.

This ecosystem supported 27 families and 53 species of pelagic fish, 49 families and 124 species of demersal fish, 5 families and 24 species of shrimps, 3 families and 7 species of crabs and 8 species of lobster. A total of 334 plants, 165 algal, 13 special orchids, 17 ferns, 87 monocotyledons, and 230 dicotyledons, belonging to 245 genera and 75 families from the Sundarbans and adjacent area were found available **(Rahman & Asaduzzaman, 2013)**. The principal tree species was Sundry (*Heritiera fomes*), which covers about 73% of the total landmass, and the second species was Gewa (*Excoecaria agallocha*), covering about 16% of the total forest area. The plant species included 35 legumes, 29 grasses, 19 sedges and 18 euphorbias. Among 50 true mangrove plant

species recorded throughout the world, the Sundarbans alone contain 35 species. The magnificent animals on land were: the Royal Bengal Tiger, spotted deer, barking deer, and wild bears were there in plenty. Besides those jungle cats, fishing cats, civet cat, monkey, bengal fox, jackle, water monitor, monitor lizard and snakes were important faunal spp. Moreover, abundant in the Sundarbans were purple heron, pond heron, cattle egret, little egret, open billed stork, smaller adjutant stork, brahmini kite, spotted dove, rose-ringed parakeet, crow pheasant, woodpecker, bee-eater, drongo, pide myna, jungle myna, bulbul, tailorbird, magpie robin, sparrow etc. It was recorded that wild Buffalo, 2 species of deer, javan rhinoceros extinct and presently 2 species of amphibians, 14 species of reptiles 25 species of birds and 5 species of mammals were considered as endangered species. This paper aimed to produce a new assessment of the ecology of the mangrove of Sundarbans **(Rahman & Asaduzzaman, 2013)**.

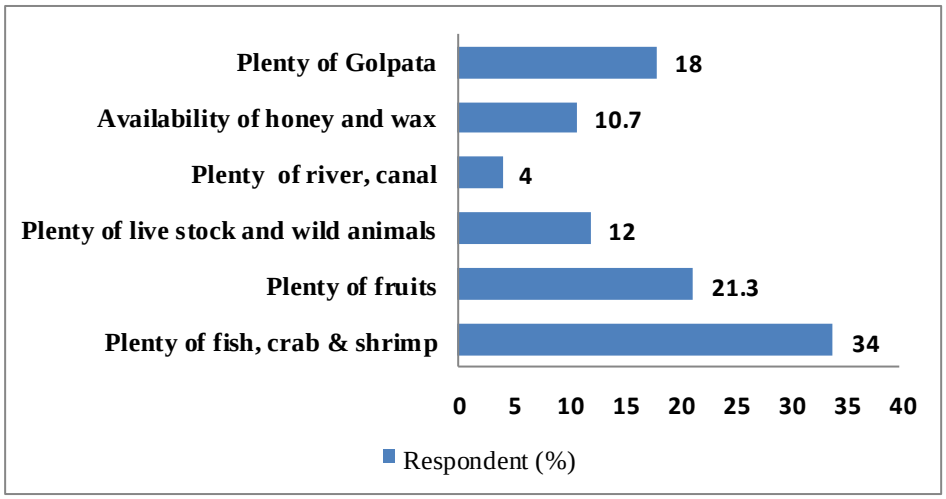

Fig. 4. Resources of the Sundarbans with less impact of climate change

3.5. Resources of the Sundarbans after frequent occurrence of natural calamities

The resource users mentioned inadequacy of fish, crab, and shrimp (29%), scarcity of wooden tree (23%), scarcity of animals (13%), reduction of honey and wax (9%), and 26% found scarcity of golpata (Fig. 5). Climate change reduced the stock of resources. Saline water increased with the sea level rising, and hence, freshwater fishes lost their habitat. One calculation showed that a 25cm of sea level rise would result in a 40% mangrove loss **(Romañach *et al*., 2018)**. The local community remarked that excessive heat reduced the water retention capacity of the land, and trees died from the lack of water. The area did not receive the usual timing rainfall; thus animals, fishes couldn't breed, and fishes were decreasing day by day. The tree couldn't survive due to lack of rainfall, excess salinity and heat; hence honey was decreasing day by day. River, canals were losing depth due to siltation, as a result, breeding and feeding ground was hampered. The prevalence of higher poverty in these areas might also be connected to poor livelihood patterns associated with the higher environmental adversity **(Giri, 2014)**.

Livelihoods in these areas were mainly based on local resources (e.g. forest) and their extraction (e.g. agriculture, fishing).

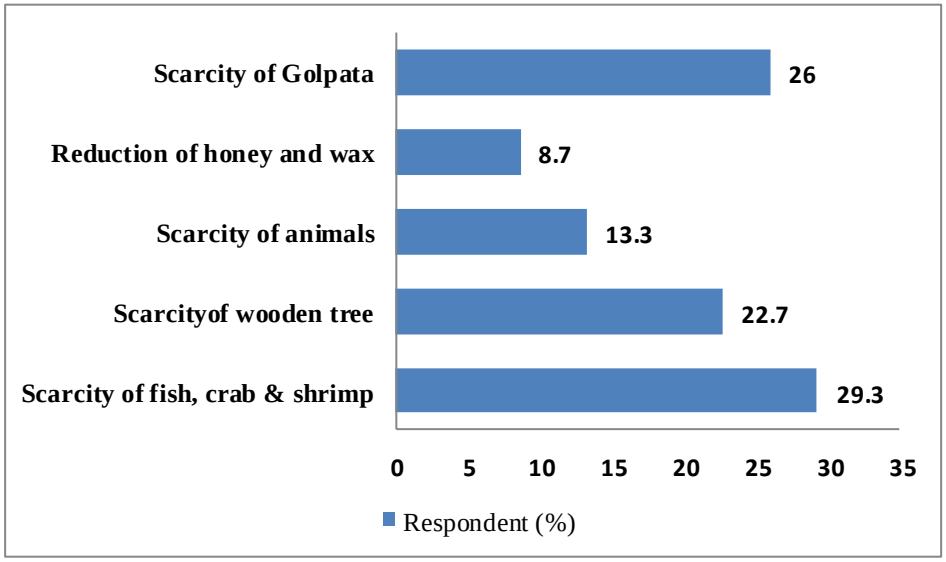

Fig. 5. Resources of the Sundarbans with increasing impact of climate change

3.6. Impact of climate change on water body

Most of the people (37%) cited the scarcity of fish; 37% opined siltation; 17% mentioned the increase of salinity, and 9% reported reduction of current as of the climate change impact (Fig. 6). Rivers, canals, swamps lost their flow, and day by day fish and other aquatic animals lost their number and abundance significantly. Saline water entered into the freshwater canals. Siltation was a great problem for rivers, canals, swamps which caused floods during the rainy season. Flowing water in the rivers, canals, etc. through and around the Sundarbans flushed out saline water intrusion from the sea. Increasing salinity intrusion due to anticipated sea-level rise was one of the major threats to the Sundari trees, which were already under threat due to increased salinity levels **(Payo, 2016)**.

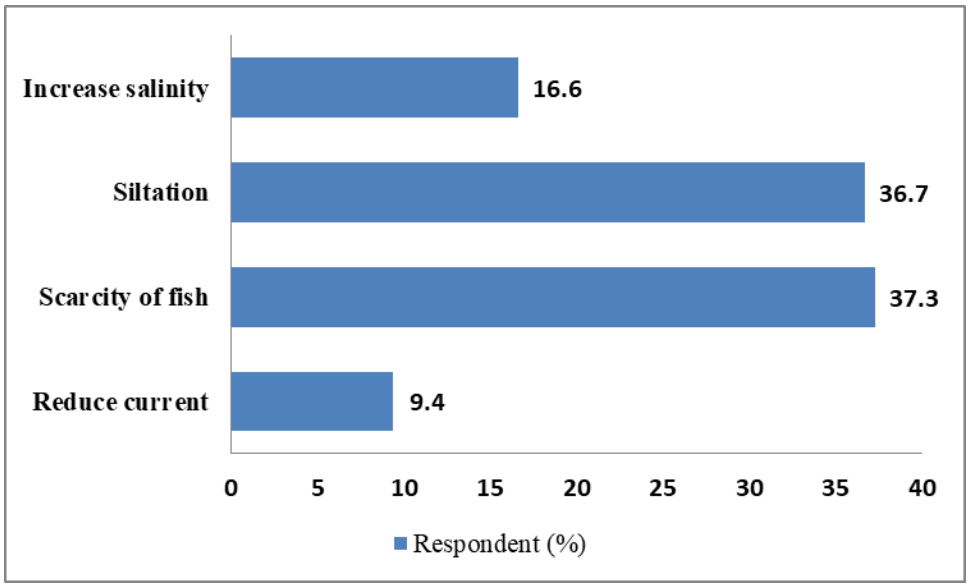

Fig. 6. Impact of climate change on the waterbody

3.7. Climate change impact on agriculture

The study showed that 38% of people mentioned reduced yield compared to the quantity recorded before; 33% people said that agricultural crops were more affected by disease, and 29% recorded increased soil salinity (Fig. 7). At present, salinity in river water had exacerbated the inundation problems from Cyclone Aila. The tidal surge during the cyclone rushed over or broke rivers' embankments and covered farmland in saline water. This means that even after the water was subsided and the land was dry, salinity will continue to harm crop cultivation, grazing, tree growth, etc. for years **(Lönnqvist, 2010)**. Agricultural crops were attacked by disease, pesticides, and insecticide used at high doges to prevent disease; these chemicals are mixed with water causing the pollution of the water body.

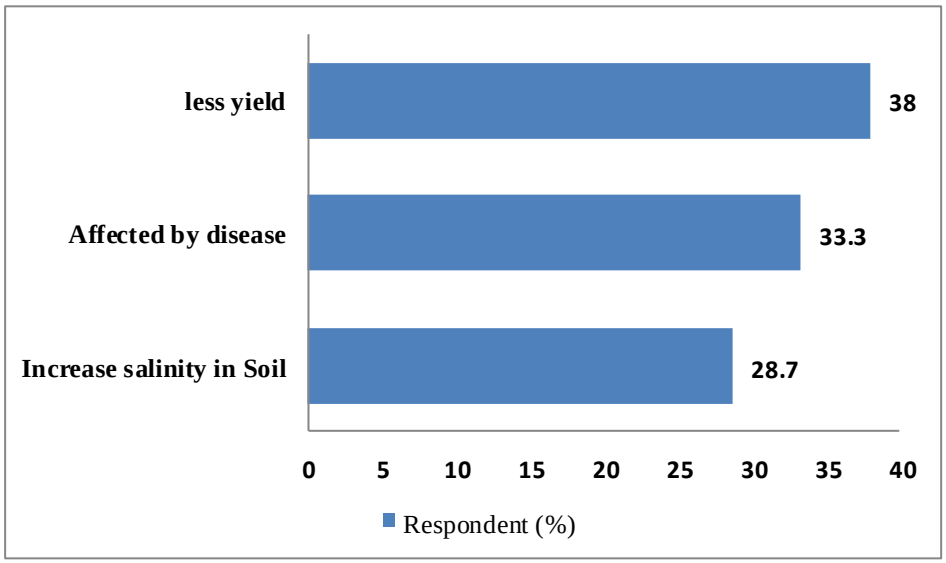

Fig. 7. Impact of climate change on agriculture

3.8. Climate change impact on fisheries

The present study revealed that, 32% of people mentioned less production; 28% cited the effect of disease; 24% marked the damage of fish farm; 9% stated the loss of breeding ground, and 7% noted the loss of fishing ground (Fig. 8). Climate change has remarkably affected the productivity and distribution of fishery resources of marine waters in various ways. Changes in water temperature and precipitation affect the dynamics of ocean currents, the flow of rivers and the area covered by wetlands **(Islam *et al.*, 2018a)**. This would have effects on the ecosystem structure and function and the distribution and production of fish stocks. Increased incidence of extreme events, such as floods, droughts, and storms would affect the safety and efficiency of fishing operations and increase damage and disruption of coastal and riparian homes, services and infrastructure **(Allison, 2005)**. Increased water temperature might likely advance the sexual maturation and the timing of spawning of adult hilsha population, this might upset the timing of spawning migration into the freshwater rivers and estuarine areas **(Agrawala, 2003)**.

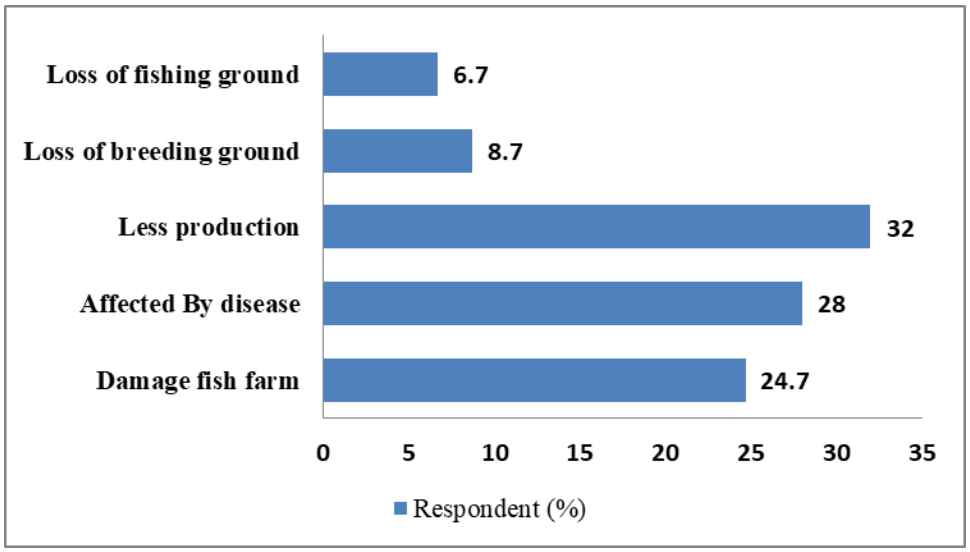

Fig. 8. Impact of climate change in fisheries

3.9. Status of fisherman of Sundarban

The Sundarban dependent fishermen were decreasing (57%); some were newly added and were counted as the increase of fishermen (27%) and 16% remained unchanged (Fig. 9). Fish availability reduced significantly due to climate change and consequently fishers were decreasing day by day. Vulnerability, due to climate change, was influenced by the status of the community and its geographical position. As an extreme case, one fisherman mentioned during an oral history interview ‘‘*during Sidr, the water [surge] suddenly came and washed away my children and my house.*” Fishermen mentioned in FGD that “*We, the fishers, are more vulnerable to natural calamities as we become helpless in sudden calamities during fishing; we just remember God, and our*

families are the worst victims as they have to live in the coastal areas". On the other hand, some fishermen were engaged in fishing because they had no alternative livelihood options. A study depicted that 85% of the women in the coastal area were engaged in various works of shrimp farming **(Sunny *et al*., 2021b)**. Most of them were engaged in the collection of shrimp larvae from nearby coastal rivers and marshes. The increasing salinity of river water threatened the traditional way of living in such communities **(Chowdhury *et al*., 2007)**.

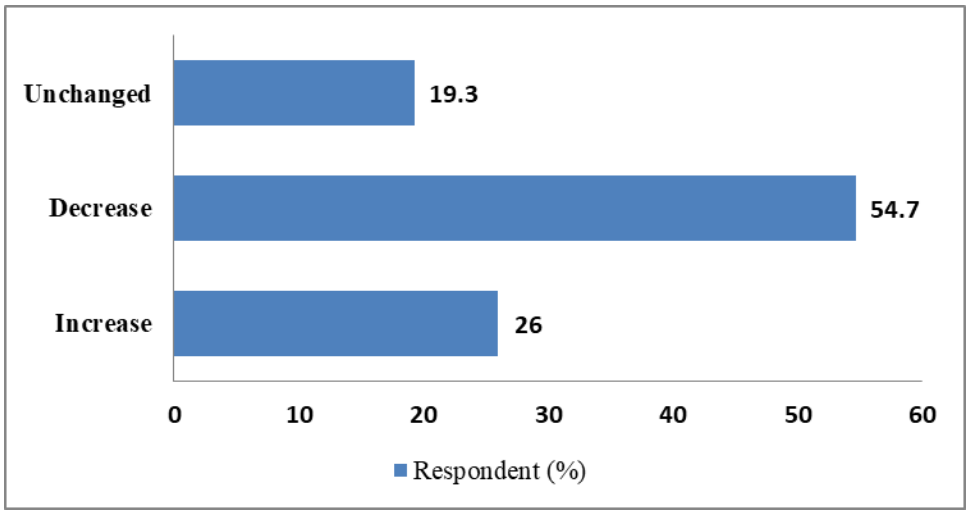

Fig. 9. Status of the fishers in the Sundarbans

3.10. Effect of climate change on salinity intrusion

Among the interviewed respondents, 38% mentioned the damage of water source; 33% reported damage of cultivated land, and 29% related the losses of freshwater fishes to salinity intrusion (Fig. 10). Notably, sea-level rise would have adverse impacts on the forest directly through enhancing inundation and indirectly by enhancing saline intrusion in river systems. Reduced freshwater flows coupled with sea-level rise would consequently further enhance the dry season salinity levels in the Sundarbans. The effects of climate change on the Sundarbans would be considerably more critical during the dry season that extends from November to April **(Sunny *et al*., 2021c)**.

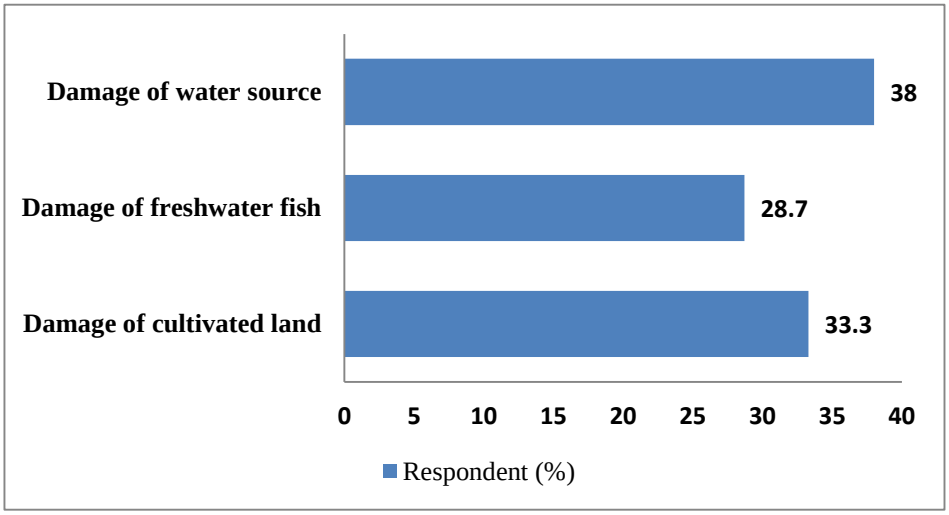

Fig. 10. Effect of climate change on salinity intrusion

3.11. Occupational changes of resource users

It was found that 14% of fishermen changed their occupation and 30% fishermen remained unchanged; 6% honey collector changed their occupation, and 21% remained unchanged; 15% PL (Post-larvae) collectors changed their occupation, and 20% remained unchanged; 6% golpata collector changed their occupation, and 13% remained unchanged; 3% woodcutters changed their occupation, and 17% unchanged their occupation (Fig. 11). In addition, 7% respondents changed to the brick worker; 10% changed to day labor; 6% became motorcycle driver, 4% changed to be construction worker; 4% became carpenter; 5% changed to patty businessman; 5% became building maker; 3% became fish farmer; 5% turned unemployed, and 101% remained unchanged. Mangrove resource users changed their occupations on a large scale, though some remained unchanged. Besides these, some were newly added. The mangrove forests have been shown to sustain more than 70 direct human activities, ranging from fuel-wood collection to fisheries **(Barua *et al*., 2010)**.

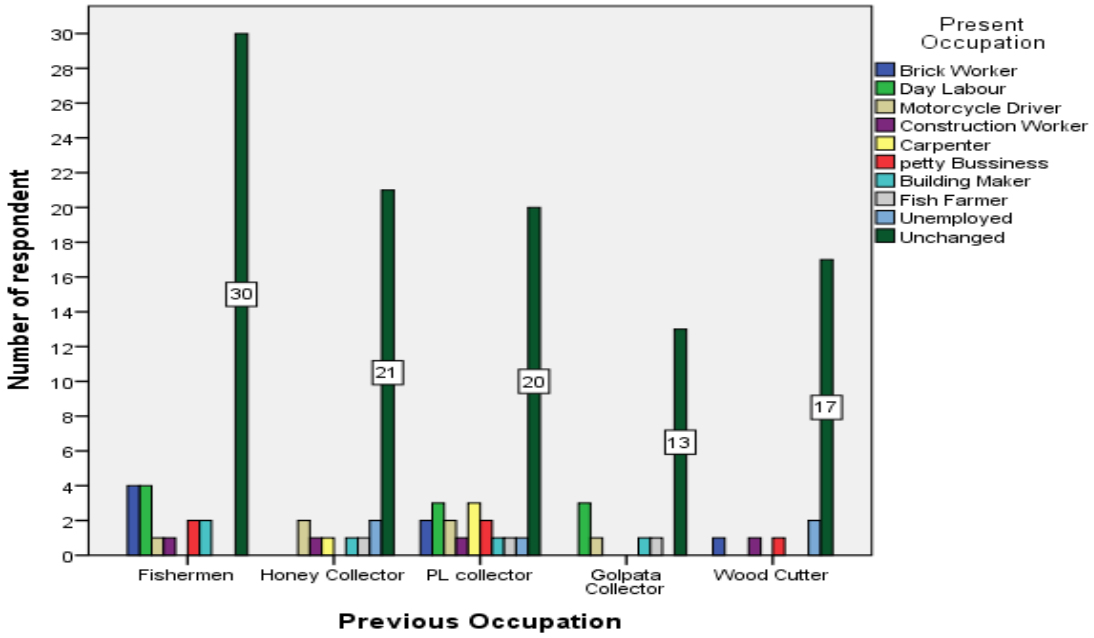

Fig. 11. Occupational changes of resource users.

3.12. Adaptation of Sundarban resource users

The current study found that 29% of people changed their occupation to adopt the professional loss in changing climate (Fig. 12). About 3% of people mentioned that their family members migrated towards town, while 10% tried to practice climate resilience culture techniques of rice, fish and crops. About 7% of women participated in work; homestead gardening (4%) and salt cultivation (3%). Traditional lifestyles were reasonably well adapted to these unique characteristics of the Sundarbans. Human dwellings were built on raised platforms, and farmers cultivated salinity and flood-tolerant rice during the monsoon in land protected by temporary dykes when the abundance of freshwater heavily reduced salinity levels **(Kuddus *et al*., 2020)**.

The dykes were dismantled post-harvest, opening the land to tidal movements. Meanwhile, fishing of salt-tolerant varieties was the principal source of livelihood during the dry season when salinity levels were high. People also cultivated betel leaf as their cash crop, and it was profitable. But the betel vines were extremely vulnerable to flood and storm. Due to climate change, betel leaves were affected by diseases and pests **(Kuddus *et al*., 2021)**. Consequently, farmers were in danger and became loosers. Women were aware that a certain species grows well in saline conditions. They planted palm, betel nut, sofada, etc. sapling which provided little cash for the family. Women also engaged themselves in handicraft, based on their individual skill.

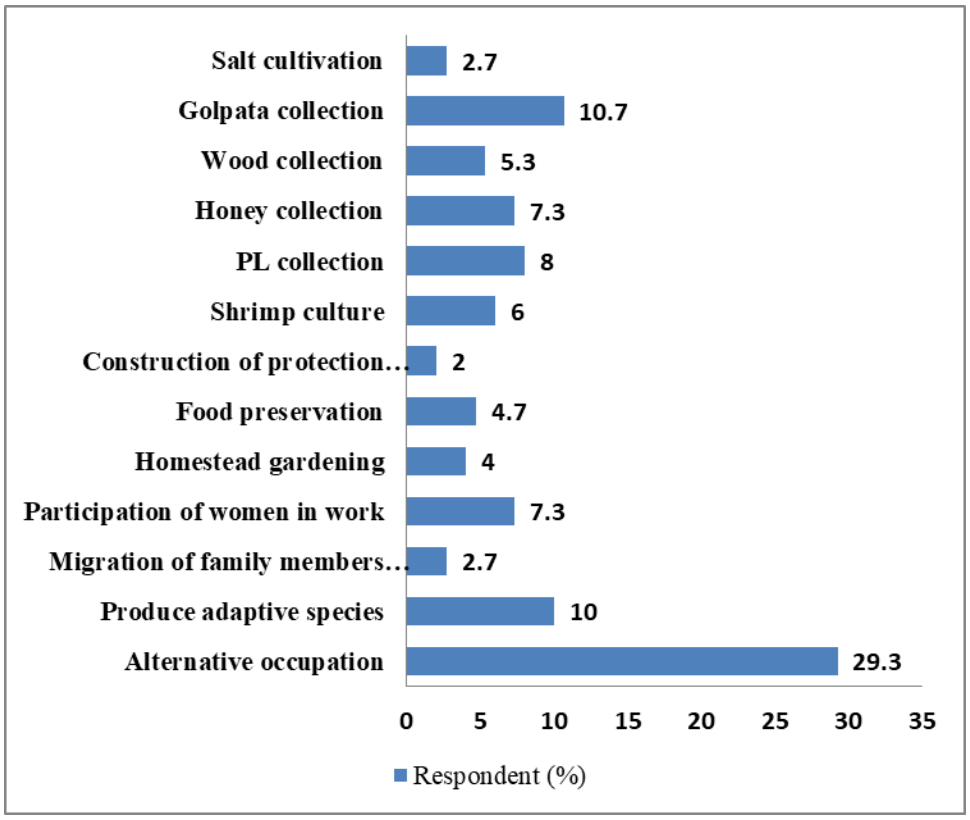

Fig.12. Adaptation mechanisms of resource users

3.13. Adaptation measures against climate change

It was found that 36% of peoples followed adaptation measures to cope with cyclone; 33.3% with a flood; 2% with drought; 11.3% with river erosion, and 17.4% with salinity intrusion. Flood resilient housing, raising plinth of the house was done by the flood-prone people to adapt against flood. Farmers produce saline tolerant rice such as BARI dhan 40,41, BINA Dhan 7. Additionally, chilis, carrot, sugar beet, and barley were cultivated by the resource users as alternative cultivation **(Mizan & Bijoy, 2009)**.

CONCLUSION

Sundarbans is one of the largest mangrove forests in the world. The Sundarbans has great importance in the economy of Bangladesh; however, frequent occurrence of natural calamities had adverse impacts on its natural resources and day-to-day life of the dependent communities. A gradual rise was daily noted in the sea level aligned with a rapid increase in salinity, causing a remarkable change in cropping pattern, methods of cultivation and variety. The breeding of fish, birds, animals was hampered and the mortality rate become high. The resource users of the Sundarbans became jobless, and their livelihood was in notable danger. Thus, it is evident that the impact of climate change is incredibly destructive in coastal mangrove areas. Hence, the climate-associated

loss should be mitigated and the rehabilitation process should follow the perceptions of the local community. Community-based resource management could improve the situation with the help of different government organizations, NGOs, and donor organizations. The findings of the study could become a guideline for better planning regarding the climate-vulnerable Sundarbans and the development of the livelihood of dependent communities. The following specific recommendations could play an important role to improve the climate resilience of the resource users of the Sundarbans mangrove forest.

- Awareness on climate change should be increased among the resource users by enhancing coordination between private and public organizations.
- Expansion of indigenous knowledge on adaptation among the climate-vulnerable communities.
- More pragmatic participation of GO's and NGO's in disaster-prone area should be ensured.
- The social security of local people should be strengthened.
- The sustainable harvest of resources should be monitored.
- More cyclone shelters, medical centers, embankments should be constructed for the security of the local people.
- Ban of Pl collection and alternative livelihood programs should be introduced.
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