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Indigenous and ecosystem-based solutions in SEPLS management amid overlapping predicaments in the Sundarbans, Bangladesh

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1. Introduction

The Sundarbans mangrove forest, identified as a world heritage site by the UNESCO, is the largest single track contiguous mangrove forest in the world, totaling around 140,000 hectares. It is situated on the delta formed by the convergence of the Ganges, Brahmaputra, and Meghna rivers, which is located on the Bay of Bengal. The overall land area is an estimated 10,000 square kilometres, with approximately two-thirds of this region being within the borders of Bangladesh and the remaining one-third situated in the state of West Bengal, India. The Sundarbans, located in Bangladesh, correspond to latitude 21°38'10.18" North and 22°29'51.65" North, and longitudes 89°02'22.87" East and 89°53'13.93" East. The geographical region under consideration extends from the *Harinbhanga* and *Raimangal Rivers* in the Western boundary to the *Baleswar River* in the Eastern boundary (Mondal et al., 2018).

The Sundarabans is a unique Socio Ecological Production Landscapes and Seascapes (SEPLS) with a composite ecosystem combining forest, marine, coastal, and wetland environments (Titumir & Paran, 2022a). However, it is losing resources due to anthropogonic pressures and climatic changes. Multiple crises like COVID-19 pandemic, cost of living is also posing unprecedented challenges to the wellbeing of both the Sundarbans and IPLCs dependent on it (Titumir & Paran, 2022a; Titumir et al. 2019). IPLCs in the Sundarbans have adopted various innovative and participatory local approaches and actions to manage the SEPLS sustainably (Titumir et al. 2022b).

This multiple-evidence-based (MEB) participatory research aims to capture indigenous and ecosystem-based solutions in SEPLS management amid overlapping crises of COVID-19, climate change and increased cost of living. It is conducted in collaboration with Indigenous People and Local Communities (IPLCs) in the Sundarbans—drawing Indigenous and Local Knowledge (ILC) and traditional practices of two cooperatives - *Koyra Bonojibi Bohumukhi Unnayan Samity* and *Munda Adivasi Bonojibi Bohumukhi Unnayan Samity*. The two cooperatives have faced a plethora of challenges due to overlapping crises and in response, they have taken various actions to adapt to and mitigate these challenges. This study aims to explore whether indigenous and ecosystem-based solutions in SEPLS management amid multiple crises lead to increased regenerative capacity and well-being of ecosystems, increased income and standard of living, low-impact lifestyles, and sustainable production and consumption by IPLCs. Based on the findings, this study also provides an analysis presenting how indigenous and ecosystem-based solutions could contribute to Global Biodiversity Framework (GBF) and Sustainable Development Goals (SDGs).

2. Methodology

This study is designed adopting MEB approach. The researchers have carried out systematic consultations to develop a methodological toolbox to identify vulnerability, regenerative capacity, status of income and standard of living, low-impact lifestyles, and sustainable production and consumption practices through workshops involving 30 IPLCs. The methodological toolbox

identified includes participatory vulnerability assessment, preparing inventory of indigenous and ecosystem-based solutions, identifying ILK-based best practices, and conducting validation exercises. Throughout the chapters this study utilized situation analysis, analysis of the causes of vulnerability, analysis of community action and capacity, and drawing action plans from analysis (Table 1).

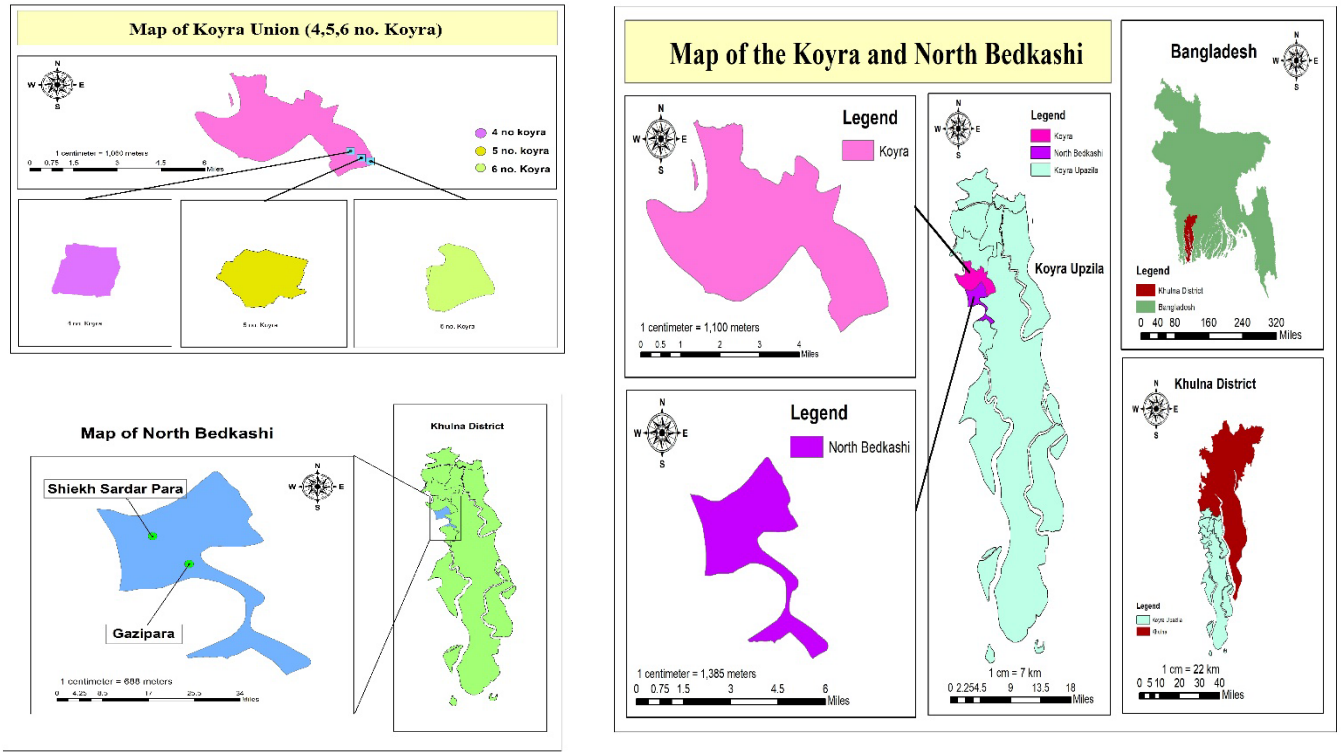
Consultative workshops were conducted in two forest peoples 'cooperatives- namely- *Bonojibi Bohumukhi Unnayan Samity* and *Munda Adivasi Bonojibi Bohumukhi Unnayan Samity.* The methodological toolbox identified in the consultations was utilized through one-on-one survey with semi structured questionnaire and focus group discussions (FGDs). The FGDs was conducted in separate groups while male and female participants attended and provided their opinions based on their experiences. The study utilized ILK collected through consultation with forest people and used data reservoir of *Unnayan Onneshan* (UO)- a multi-disciplinary research organization working with IPLCS in the Sundarbans for more than decades. The participants of the study perform their livelihood activities through wood collection *(Bawalis)*, fishing *(Jele)*, honey and wax collection *(Mouals),* and crab collection.

Table 1. Methods, tools, and analyses adopted in the study.

Method	**Tools**	**Analysis**
Consultation for methodological toolbox	• Participatory vulnerability assessment • Preparing inventory of indigenous and ecosystem-based solutions • Categorizing ILK-based best practices • Validation exercise	• Situation analysis • Analysis of causes of vulnerability • Analysis of community action and capacity • Drawing action plan from analysis

(Source: Compiled by authors)

The study focused on two specific unions (the lowest tier of the local government body) namely Koyra and North Bedkashi which is in Koya sub-district of Khulna district, Bangladesh. Three specific villages namely 4 no. Koyra, 5 no. Koyra, and 6 no. Koyra were selected from Koyra union while, Sheikh Sardar Para (Ward No. 3), and Gazi Para (Ward No. 7) villages were purposively selected from North Bedkash Union for data collection.



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Map 1. Study area- Koyra Sub-district, Khulna district, Bangladesh

(Source: Authors)

3. Vulnerability Analysis: Livelihood Stress and Biodiversity Loss

This chapter illustrates the livelihood stress and vulnerability of the community people as well as the vulnerability in the Sundarbans' ecosystem- resulting to biodiversity loss. COVID -19, climate change and cost of living has added extra burden to their livelihood. This chapter, using some indicators, will shed light on how their livelihood get strained due to multiple crises.

3.1 State of lives and livelihood

The impact of COVID-19 pandemic, associated with other challenges, caused livelihood distress for IPLCs. Reduced income of the IPLCS led them to borrow loans with high interest rate- plunging them into a vicious cycle of debt. IPLCs were not even able to bear their subsistence during this period, which had multiple impacts including health and livelihood distress.

Dependency on loans for family expenses

The study found that above 90 per cent people were bound to take loan during COVID-19 to bear their family expenses (Figure 1), which indicates their dependency on daily labor and limited savings for emergency need. In other word, the livelihood resiliency of IPLCs in the Sundarbans

is meagre. It is also found that IPLCs in the two cooperatives were borrowing loans mostly to meet their subsistence. Most of the borrowers took a loan ranging from BDT 5-15 thousand (Figure 2). This scenario implies that during COVID period majority of the IPLCS were not able to bear even the subsistence level of income for their families.

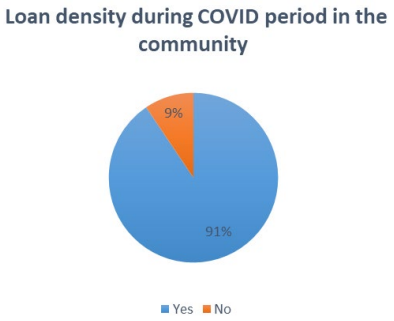

Figure 1. Taking Loan during COVID-19. (Source: Authors)

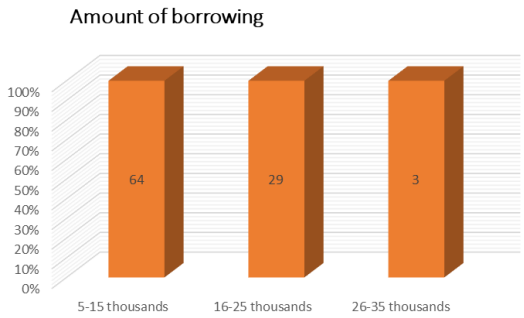

Figure 2. Amount of money borrowed.

The popular sources of loans were non-governmental organizations (NGOs). A substantial amount of loans was also borrowed from government organizations and local moneylenders (Figure 3). It is observed that the interest rate provided by NGOs and moneylenders were very high. Often IPLCs have been found getting into vicious cycle of debt, which has multiplying and long impact on their livelihood security.

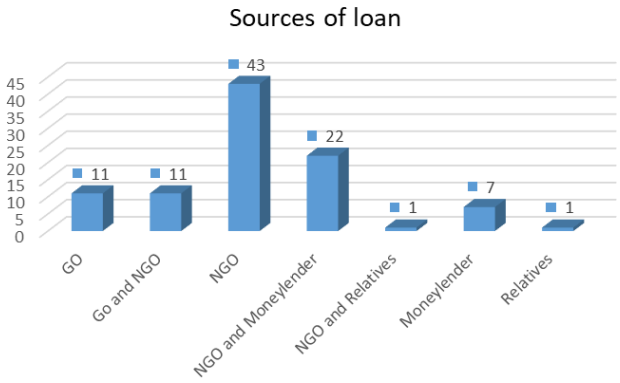

Figure 3. Source of loans. (Source: Authors)

Reduced expenditure during and after COVID-19

The affordability of IPLCs to buy new clothes is low. Many respondents cannot even buy new clothing even once a year. Most of them can buy new clothes only once a year and a considerable number of them can buy new clothing twice a year, presumably during festivals (Figure 4).

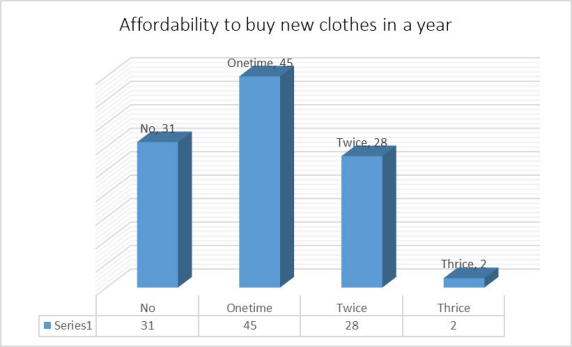

Figure 4. Affordability to purchase new clothes in a year. (Source: Authors)

The study found that there had been has been a steep decline in the allocation of budget for clothing following the COVID-19 pandemic (Figure 5). Almost all the respondents indicated that budget allocation for clothes were declined after the pandemic.

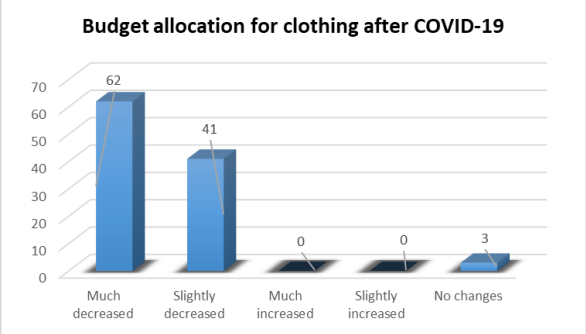

Figure 5. Budget allocation for clothing after COVID-19. (Source: Authors)

IPLCs also lowered their expenses for entertainment purpose during COVID-19 period (Figure 6). Most of the respondents reported a large decrease in entertainment expenses during the pandemic, which can be attributed to the fact that people were unable to travel to places due to lockdown that kept the expenses low. But they argued reduced income during COVID-19 period had negative impact on the overall expenses.

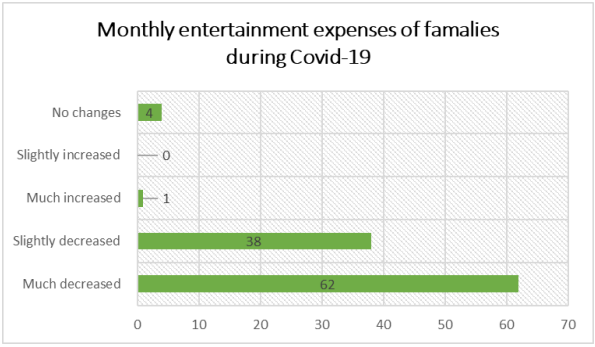

Figure 6. Entertainment expenses during COVID-19. (Source: Authors)

Health-related difficulties and diseases burden

Almost all respondents argued that they had been suffering from various diseases (Figure 7), indicating increased disease burden in the community as a common memory. The impact of COVID-19 pandemic on their livelihood negatively affects their ability to seek healthcare services. The COVID-19 and associated health difficulties may also be responsible for this (Titumir & Paran, 2022a).

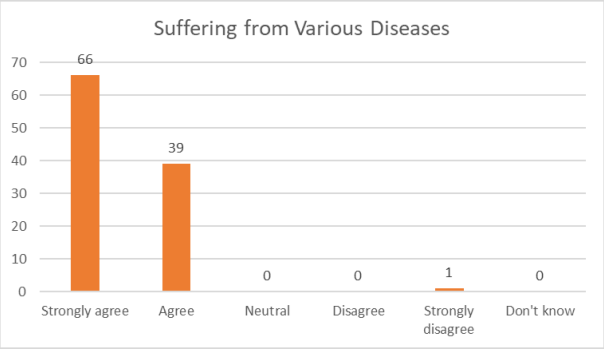

Figure 7. Opinion poll on diseases suffering. (Source: Authors)

3.2 State of biodiversity and ecosystem

The Sundarbans has undergone negative changes due to both human intervention and natural calamities. Biodiversity loss induced by fragile ecosystem has far-reaching consequences on life and livelihood of IPLCs.

Decreasing trend of fish available in rivers

Availability of fish in the water bodies of Sundarbans has decreased (Titumir & Paran, 2022b). Above half of the respondents agreed with the statement that the number of fish in rivers and canals is less than before. Only 2 respondents strongly disagree about any noticeable change (Figure 8).

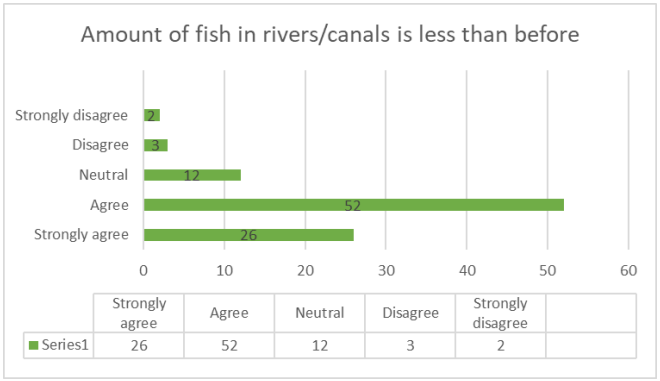

Figure 8. Decreasing trend of fish available in rivers than before. (Source: Authors)

Decreasing trend of various trees available in forest

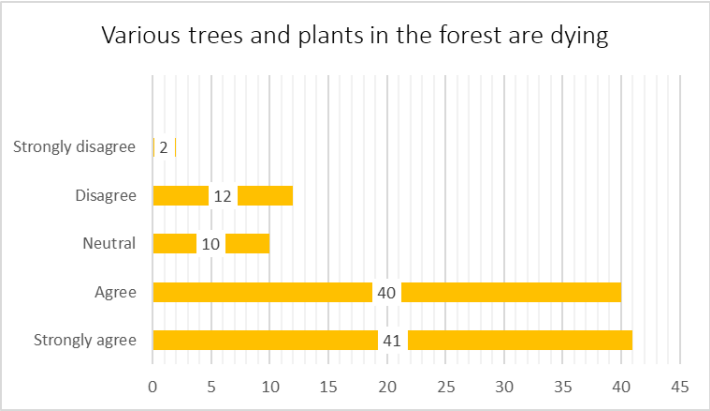

Figure 9. Decreasing trend of various trees available in forest. (Source: Authors)

Most of the respondents agree with the statement that various plants and trees are dying in the Sundarbans (Figure 9). Availability different floral species has decreased over the years. As a result, many parts inside the forest are becoming empty fallow lands.

Change in Sea levels

Most of the respondents have found noticeable rise in sea levels in recent years (Figure 10). Climate change effects, such as sea-level rise and increased turbidity, may cause habitat loss and fragmentation in the Sundarbans. The intensity and frequency of these extreme weather events are exacerbated by climate change, increasing the vulnerability of the local population (Titumir et al., 2022a). The destruction caused by these events necessitates significant investments for reconstruction and recovery, further straining the cost of living.

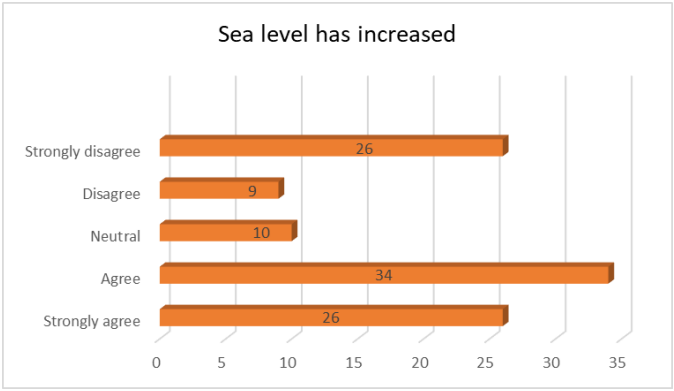

Figure 10. Change in Sea Levels. (Source: Authors)

Increasing salinity in rivers and ponds

Most of the respondents found increased salinity in rivers and ponds (Figure 11). 40 respondents strongly agreed with the statement that the salinity of rivers has increased. At the same time, 30 respondents simply agreed to the statement, and only one respondent disagreed. Almost all respondents unanimously agree that salinity of pond water has increased.

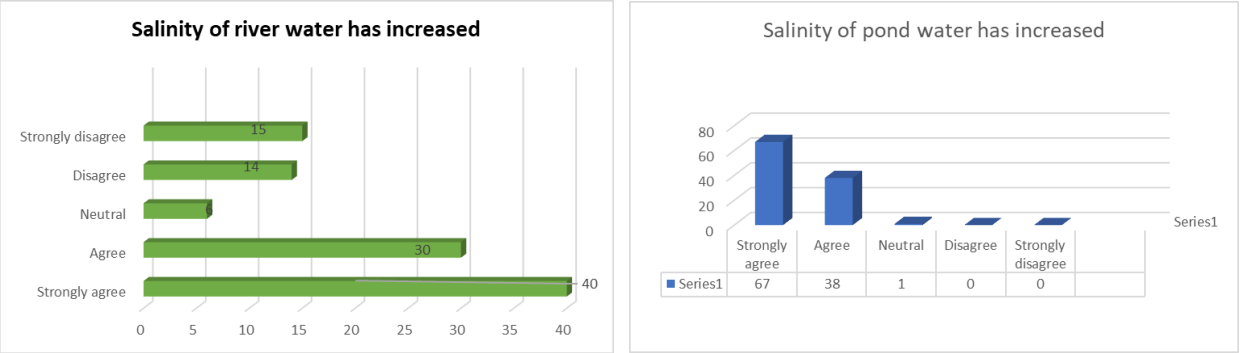

Figure 11. Increased salinity in rivers and ponds. (Source: Authors)

Migration or displacement during lifespan

The livelihood insecurity of IPLCs caused by double burden of climate change, bio-diversity loss, and COVID-19 resulted in number of impacts. IPLCs in the Sundarbans experienced displacement and migrated to one place to another place for living (Figure 12).

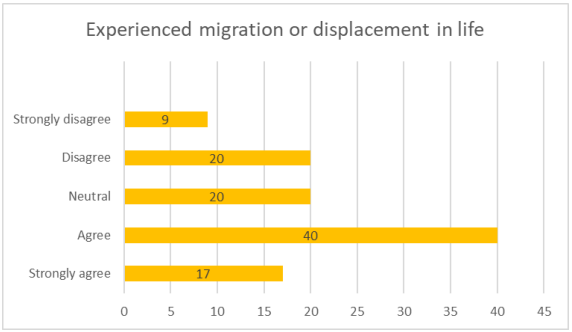

Figure 12: Displacement during lifespan (Source: Authors)

Change in lives and livelihoods

The lives and livelihoods of millions of people were adversely affected by numerous natural disasters caused by climate change. Most of the respondents agreed that there has been a change in their livelihoods and or they faced difficulties in earning an income (Figure 13). The agricultural

productivity in the region can be affected by climate change, resulting in reduced crop yields and limited availability of food, thereby leading to an increase in food prices (Titumir & Paran, 2022a). This situation poses a challenge for the local population in affording an adequate diet.

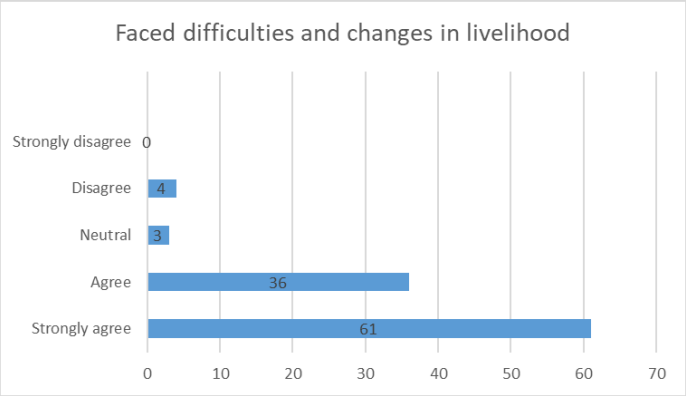

Figure 13. Changes in livelihoods. (Source: Authors)

In the forthcoming years, the alterations in climate variables are predicted to have catastrophic consequences. The displacement of communities residing in the Sundarbans due to climate change-induced events such as sea-level rise and increased cyclone frequency can disrupt their traditional livelihoods, such as fishing and agriculture, leading to economic hardships and a rise in the cost of living.

Limited options for alternative work

Above 90 per cent of the respondents reported that they have no alternative work other than collecting honey, fish, wood, leaves, crabs from the forest (Figure 14). Shrinking livelihoods and income are caused by limited options for alternative works.

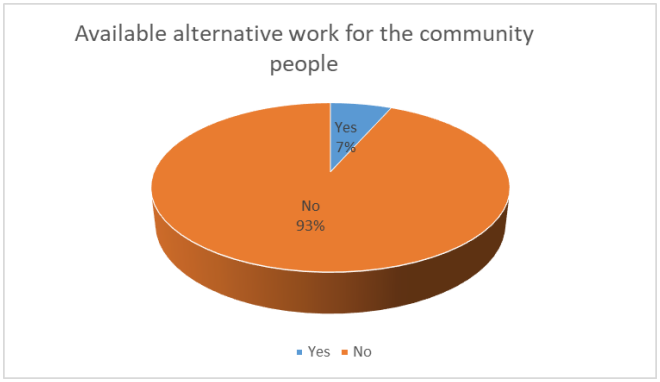

Figure 14. Available alternative work for IPLCs. (Source: Authors)

3.3 Participatory vulnerability analysis

The table 2 presents the indicators and sub-indicators for participatory vulnerability assessment conducted in the community. The indicators show the level of impacts caused by poly crises including COVID-19 stress, biodiversity loss and cost of living.

Table 2. Vulnerability indicators and sub-indicators.

Indicators of vulnerability	**COVID -19**	**Climate change**	**Biodiversity loss**	**Cost of living**	**Impacts level**
Sub-indicators	Added extra burden in basic needs	Sea level rise	Decreasing Trends of Crop & harvesting	Strain in Food expenses	
Sub-indicators	Lost means of livelihood	Change in rainfall	Decreasing Trends of Fish Availability	Strain Clothing	
Sub-indicators	No alternative work	Victim of Displacement	Decreasing Trends of Trees Availability	Strain Health cost	
Sub-indicators	Restriction to access to forest	Temperature Rising	Decreasing Trends of Forest Land Area	Spend out savings	
Sub-indicators	Compromised	High Salinity	Decreasing Trends of Vegetation Area	Unaffordability of Educational expense	

(Source: Compiled by Authors)

The assessment of vulnerable condition of community people was conducted using both vulnerability matrix and multi criteria decision aid (MCDA). This study fixed the variables into 5 (almost all= more than 60%) to 1 (Very few= below 10%) matrix and calculated the result through a survey (Table 3). After analyzing the opinions found from the survey, it measured the overall impact of three main indicators along with their sub-indicators.

Table 3. Variable matrix

Point	**Scale**	**Illustration**
5	Almost all	More than 60% participant
4	Most of them	51%-60%
3	Some of them	25%-50%
2	Small of them	10%-25%
1	Very few	Below 10%

Table 4. Heat map sign of the vulnerability assessment.

	Very few(1)	Small of them(2)	Some of them	Most of them	Almost all

			(3)	(4)	(5)
Strongly Disagree(1)	1	2	3	4	5
Disagree(2)	2	4	6	8	10
Neutral(3)	3	6	9	12	15
Agree(4)	4	8	12	16	20
Strongly Agree(5)	5	10	15	20	25

	Critically endangered
	Endangered
	Fare
	Very good

(Source: Compiled by Authors)

Heat map of the vulnerability assessment suggests that climate change, biodiversity loss, cost of living are vulnerable conditions, with an overall impact of leaving the people and the Sundarbans endangered (Table 5).

Table 5. Heat map illustrating the vulnerability assessment using both vulnerability matrix and MCDA methods, including overall three dimensions based on the field survey.

Indicator	**Sub indicator**	**Variable based on people's opinion found in field survey**					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	vulnerable condition
Climate Change	Sea level rise	15	12	6	2	3	
	Change in rainfall	10	8	3	6	2	
	Victim of Displacement	10	12	6	2	1	
	Temperature Rising	15	12	12	4	1	
	Salinity	15	12	3	6	3	
Biodiversity loss	Decreasing Trends of Crop & harvesting	20	12	9	2	1	
	Decreasing Trends of Fish Availability	15	16	6	2	1	

	Decreasing Trends of Trees Availability	15	12	12	10	1	
	Decreasing Trends of Forest Land Area	15	12	6	6	1	
	Decreasing Trends of Vegetation Area	10	12	12	8	3	
	Fooding	5	12	3	6	1	
	Clothing	10	12	9	8	1	
Cost of living	Health Issue	10	12	9	8	1	
	State of difficulty in earning	10	8	3	4	3	
	Education	10	12	9	4	1	

Indicators	**Vulnerable Condition**	**Overall Impact**
1. Climate Change		Endangered
2. Biodiversity loss		Endangered
3. Cost of living		Endangered

(Source: Compiled by Authors)

4. Community based Innovation and traditional knowledge

IPLCs in the Sundarbans were compelled to change occupations to adjust to emerging situations caused by climate change, such as nipa leaf collectors or honey hunters involved in fishing, which can lead to overexploitation of fishing resources. Again, many intruders are illegally encroaching to the forest and harm both ecological traits and livelihood options. Against vulnerability IPLCs has been taking numerous actions following ILK and traditional practices.

4.1 Promotion of Traditional Knowledge and practices

Traditional knowledge practices that are important for the Sundarbans in the face of loss of biodiversity, cost of living, and climate change include the utilization of non-timber forest products, such as golpata (*Nypa fruticans*), honey, and fish, which are used by a significant percentage of the local population (Titumir et al., 2023). Local and indigenous people have been sustainably utilizing their ILK in managing forest resources as they developed a strong harmonious relationship with forest and acquired vast understanding through long experience. And this learning continues to generation to generation leading them an expert of managing forest ecology and resources. Titumir & Afrin (2022) showed how years of knowledge, practice and numerous conventions have turned into conventional rules that people are following for generation to generation without harming the resources to grow. Different community follow their respective

community based innovative strategies and cultural beliefs to earn their breads including golpata (*Nypa fruticans*) cutters, mouals (honey/wax collectors) and bawalis (woodcutters) from the available resources in Sundarbans. Each group demonstrates unique and innovative methods to perform their activity.

Fishermen community in the Sundarbans articulated an indigenous technical knowledge (ITK) including unique fishing methods where they respect natural fish breeding during sustainably fishing. The fishermen also use indigenous knowledge and techniques for fishing, such as different types of nets and traps (Raju et al., 2016). They allocate a single specific day for fishing which is Fridays. They use locally designed tools for fishing such as locally made nets which are not harmful to carp variety of fishes. The rules that are in place traditionally prohibit the use of harmful tools like current nets, bainjaal, etc (Titumir et al, 2019). They do not use any dangerous net or chemicals while going for fishing. Again, fishermen use big-meshed nets for rivers and small-meshed nets for closed water bodies. Mouals (honey collectors) consider the issues of overexploitation and regenerative process of honey storage in the honeycombs are ensured. Mouals collect honey by cutting about two-thirds of the beehive and keeping the rest for bees to restore honey. Bawalis (wood collectors) abide by some sustainable methods to harvest of wood from the forest. They cut woods in year-round process where they always refrain to cut wood from the same compartment in same year to let the forest regrowth adequately. Golpata (*Nypa fruticans*) harvesters, as Titumir & Afrin (2022) showed in his study as well, collect golpata more than once a year and keeping the flowers and fruits undamaged. Again, the collectors cut the leaves in a way that the main leaf and the leaf next to it in each cluster are left behind for regrowth.

Table 6. Community based innovations

Community based Innovation	**Livelihood insecurity reduction**	**Regenerative capacity of Sundarbans and wellbeing**	**Bio-diverse adaptation to climate change**	**Wellbeing of nature and human being**
Innovation in agriculture: rice cultivation in high place to keep away from salinity	Plantation next to house	Sediment deposition	Cultivation of Mangrove Trees	Freedom of choice and action
Integrated farming crab and duck	Riverside plantation	Prolific plant Life	Maintenance of Mangrove Trees	Security
Community-Based Mangrove Agro Aqua Silvi (CMAAS) Culture	Working and assisting with the forest department against illegal poaching	Land restoration	Restoration of mangroves	Good social relations

Strengthening the cooperatives by increased activities	Working to stop illegal and stop logging	Erosion minimizing	Steer clear of fishing in delicate places.	Good health
Utilizing each inch land for cultivation	Working to stop illegal fishing with nets	Diverse species interactions	Maintain the ecosystem's food web	Multicultural Tapestry

(Source: Compiled by authors)

4.2 Community based innovations

IPLCs in the Sundarbans adopted several innovative practices following their ILK, which are effective to adapt to and mitigate the impact of climate change and other shocks. In the face of livelihood distress, their alternative practices are opening new windows for livelihood security.

Developing the culture of cultivation in each inch land

To cope up with the poly crises they are adopting culture of cultivation to each inch land and keep no land uncultivated. This is why they are planting vegetables around their house. They also use their rooftop of houses to grow vegetables.

Innovation in rice cultivation

Farmers cultivate rice in two steps while in one phase they sow seeds in higher areas away from the coast and after grown up the seedlings are transplanted to the main agricultural land to avoid risk of increased salinity in the soil and water of coastal areas. Again, the farmers cultivate rice at 8–12 inches high from the ground level, to save the crop from rising salinity in both soil and water (Titumir et al., 2023).

Potential of integrated farming (Crab and Duck)

Community people are adopting integrated farming where they rear ducks and crab jointly in same farmland which has been found more profitable.

Community-Based Mangrove Agro Aqua Silvi (CMAAS) Culture

CMAAS culture is innovated as a substitute to the commercial shrimp (CS) culture with and without adverse impact on the ecosystem. Titumir & Afrin (2022) also showed CMAAS culture is referred to the practice of integrated cultivation of few mangrove faunal species such as crabs, oyster, variety of fish like shrimps, bhetki (Latescal carifer), etc., and floral species like golpata (Nypa fruticans), keora (Sonerati_aapetala), goran (Ceriops_decandra), etc., at the same time on available swampy land in brackish water.

Strengthening the cooperatives by increased activities

As community people are experiencing huge external pressure from outsiders, the cooperatives and community people adopt increased cooperation and tolerance among their kins and members. They work together and achieve anything by showing solidarity. Thus, they strengthened the activities of cooperatives.

Table 7. Livelihood insecurity matrix and innovation linking to GBF and SDG.

	Business as usual	Innovation	Means/ drivers	Means of verification	Link to wellbeing	
					GBF	SDG
Cost of living	-The cost of building house is increasing -Increasing the price of food products - Crab Collection -Fishing by using engine - operated trawler -Using harmful current nets, bainjaal, etc for fishing.	-Raising house above normal flood level - Adjusting crop pattern to take advantage of floodwater -Locally designed fishing nets that protects carps	Traditional rules	-Traditional Knowledge	15,16	12
Climate change	-Displacement of people -Hotter summer and irregular rainfall -Increased frequency of natural storms	-Flood management scheme -Flood protection and drainage scheme -Coastal embankments establishment	Project oriented	-Non-traditional Knowledge	12,18,20	Indirect
Biodiversity loss	-Food insecurity -Job insecurity -Social insecurity	-Comprehensive disaster management -Coastal green belt project	Project Oriented	-Non-traditional Knowledge	2,4,10,11	15

(Source: Compiled by authors)

Adopting increased cooperation and tolerance among People as a means of risk reduction strategy

Of late, the community people are experiencing huge external pressure from outsiders who are not originally from forest and forest areas. They are the people who are encroachers and opportunist groups mostly extract more resources from forest inconsiderably. These outsiders always try to popularize the practice of *gher* (enclosures) for shrimp cultivation. They also try to disturb the long harmonious relationship among the existing cooperatives and kin groups. Community people

see such aggression as a serious threat to their social and economic well-being. To raise voice against such encroachment, the cooperatives and community people adopt increased cooperation and tolerance among their kins and members.

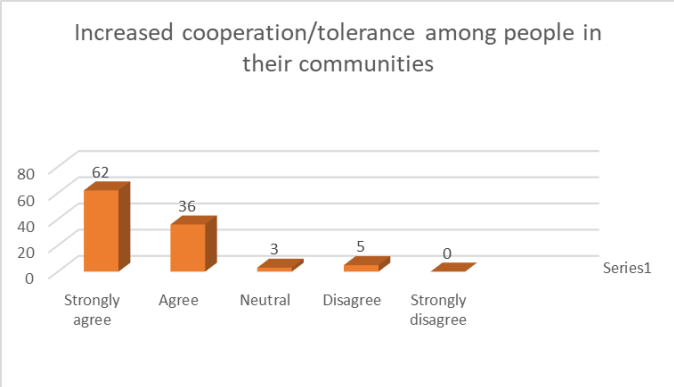

Figure 15. Cooperation and tolerance among People. (Source: Authors)

However, a positive change in the communities has been seen as there has been increased cooperation and tolerance in the community (Figure 15). Most of the respondents felt an increased cooperation/tolerance among the people in their communities, which implies that people are helping each other in difficult times.

4.3 Regenerative capacity of Sundarbans and wellbeing: biodiversity restoration

The Sundarbans' rich biodiversity plays a crucial role in the lives of coastal communities in Bangladesh, offering a range of ecosystem services and livelihood opportunities. Sundarbans' mangrove biodiversity also manifests a physiological adaptation to saline, water-saturated soils, such as viviparous or crypto-viviparous seeds and specialized aerial roots for oxygenation (Titumir et al., 2022a). Mangrove trees disperse their propagules by water and often reproduce through vivipary or crypto-vivipary. Overall, the Sundarbans's biodiversity is essential for the well-being and economic development of coastal communities in Bangladesh. The forest's diverse species and abundance play a crucial role in ecosystem processes, such as pest regulation, pollination, timber production, and freshwater fishing, benefiting both the environment and the local community (Chakma et al., 2021).

Mangrove as buffer against tidal surges, sea level rise and coastal erosion

Mangroves provide coastal protection by acting as a buffer against tidal surges, sea level rise, coastal erosion, and saltwater intrusion (Gevaña et al., 2019). It plays a crucial role in the global carbon cycle and facilitate complex food webs and energy transfers, as confirmed by Kathiresan (2012).

Mangroves as natural carbon sequestration agent

Mangroves can be used to mitigate climate change through their ability to sequester carbon and provide coastal protection. They can trap atmospheric carbon and accumulate more organic material than other tropical forest types, making them important carbon sinks (Alongi, 2022). Mangroves sequester up to five times more carbon per hectare than tropical rainforests, making

them a significant contributor to carbon storage (Kumari et al., 2020; Ahmed et al., 2022). They also serve as breeding and nursery grounds for various species of flora and fauna.

Unique physiological, ecological, and adaptive characteristics

The unique characteristics of mangrove biodiversity include their high productivity, intense interaction with other ecosystems, and their ability to immobilize heavy metals (Mitra, 2013). Their unique three-dimensional root structure and the combination of aquatic and terrestrial environments make them an attractive habitat for a diverse arra of species, many of which perform vital functions such as pollination, seed dispersal, and nutrient recirculation, as noted by Saenger (2002). The roots, trunks, and branches of mangroves provide a habitat for epifaunal communities, including bacteria, fungi, macroalgae, and invertebrates (Kathiresan et al., 2001). Moreover, mangroves contribute to biodiversity by providing shelter, food, and breeding grounds for a diverse range of fauna, including aquatic and terrestrial vertebrates and invertebrates such as fish, amphibians, reptiles, mammals, and birds.

Sundarbans as safeguarding of community people

The Sundarbans region served as a safeguarding barrier for the coastal communities during recent cyclones namely Yaas (May 23-27, 2021), Amphan (May 15-21, 2020), Bulbul (October 28 to November 11, 2019), Fani (April 25 to May 4, 2019). Again, Bhowmik and Cabral (2013) also showed how Sundarbans played role as natural wall at the time of emergency for the people of coastal regions during Sidr (November 17, 2007) and Aila (May 25, 2009). It elucidates how this forest serves as an exemplary illustration of a natural ecosystem that acts as a protective barrier against the effects of climate change. Consequently, it serves to highlight the significance of this forest in addressing the climate-related challenges faced by Bangladesh.

Table 8. Regenerative capacity of Sundarbans and wellbeing.

			Actions taken	**Means of verification**	**Link to wellbeing of nature and human beings**	
	Loss of biodiversity	**Gain of biodiversity**			**GBF (Target)**	**SDG**
Cost of living	- Communities reliant on non-sustainable methods fish breeding sites.	- Honeybee Farming - Ecotourism	-provide alternative income sources and empower communities	Traditional Knowledge	15,16	12
Climate change	-rising temperature	-increase species that can withstand salt	- Preservation and Rehabilitation of Mangroves	Traditional Knowledge	3,4,12,18,20	Indirect

Biodiversity loss	-decrease water level -decrease trees -decrease biotic life -decrease Flora & fauna	-increase opportunistic predators -Coastal Protection -Sanctuary for Biodiversity	- -Mangrove Reforestation - Management of Sedimentation	Both Traditional Knowledge and Non-traditional Knowledge	2,4,10,11	15

(Source: Compiled by authors)

Biodiverse Adaptation to Climate Change

The restoration process of Sundarbans to address the loss of biodiversity, cost of living, and climate change involves several key actions. It is important to assess the impact of salinity on plant species and their coping capacity with increased salinity. The capability of low-income individuals to reduce climate change risks should be increased by vulnerability assessments and appropriate adaptation measures that consider local knowledge and needs. Management interventions such as co-management involving local communities can contribute to the protection and conservation of Sundarbans. To protect and manage the ecosystem, it is imperative to address the issues such as over-exploitation of resources, habitat degradation, invasive species, and pollution. Again, benefit-sharing mechanisms must be incorporated into the governance and policies of sustainability and adaptation. The restoration of the Sundarbans can be achieved through community participation and involvement in mangrove reforestation projects (Ranjan., 2019). By supporting local populations for ecological services, this strategy has the potential to have various positive effects on the environment.

Table 9. Biodiverse adaptation to climate change

	Climate change vulnerability	**Actions taken**	**Means of reduction of vulnerability**	**Link to wellbeing of nature and human beings**	
				GBF	**SDG**
Cost of living	-Become homeless for natural disaster -food shortage -heath problem	-Agri and/or social forestry (in some areas) - Conversion of wetlands to crop land -Raising house above normal flood level	Traditional Approaches	2,4,10,11	15

	-problems in transportation and irrigation				
Climate change	-sea level rise -salinity intrusion -uneven rainfall	-Participatory strategy	Traditional Approaches	13,21,22	Indirect
Biodiversity loss	-loss of mangrove plant -loss fish species -extinct number of species	- Increasing species breeding sites. - biodiversity monitoring network among cooperative members -Assisting forest department to monitor vegetation management	Traditional Approaches	3,4,12,18,20	Indirect

(Source: Compiled by authors)

5. Wellbeing of nature and human being: contribution to SDGs and GBF

The various goods and services that ecosystems of Sundarbans provide, or "ecosystem services," are what make ecosystems beneficial to human well-being (Titumir et al., 2022b; Titumir et al., 2022c). Supporting services refer to products and additional services that uphold several facets of human welfare. Human well-being is impacted by regulatory functions in a variety of ways (Titumir & Paran, 2022c). For example, they can regulate the spread and range of some diseases, particularly vector-borne diseases, by purifying the air, freshwater, reducing flooding or drought, stabilizing local and regional climate, and more. The aesthetic, recreational, educational, cultural, and spiritual facets of human existence are influenced by cultural services such as sacred groves, lakes, rivers, trees, totemic species, and picturesque landscapes. However, to maintain the three additional services that have an indirect impact on people's well-being, supporting services are required (Titumir et al., 2022c).

5.1 Wellbeing of nature and human beings and cost of living

One of the best examples of the complex relationship between human well-being and the natural world is the Sundarbans, a massive mangrove forest ecosystem that borders both Bangladesh and. In addition to supporting a great biodiversity, millions of people who live on its periphery make a living. The environment of the Sundarbans is extremely important to many communities who obtain their entire means of subsistence from it. Typically, they work in wood collecting, honey

collection, and crab and shrimp farming for a living (Titumir et al., 2022b, Titumir et al., 2022c). They face numerous obstacles in their line of employment. The cost of living there is extremely detrimental to those issues. To address this, there is a model related to SDG, namely the Krunal-Montreal Global Biodiversity Framework. The goal of these assessments is to evaluate the vulnerable conditions of the people living in the Sundarbans and identify solutions using the Krunal-Montreal Global Biodiversity Framework. The table (Table 10) below shows which GBF values are suitable for the community that is considered vulnerable. Two goals (Targets 15 and 16) are provided here that are ideal for raising the standard of the Sundarbans community's stakeholders. The most crucial aspect is that these two goals are related to SDGs 12 and 15. These GBF targets support lowering the rate of livelihood insecurity reduction and increasing the community's capacity for regeneration in the Sundarbans for improving livelihood. It has numerous aims that are appropriate for solving community problems by utilizing GBF (2,4,10,11), which is related to SDG15, to control bio-diverse adaptability to climate change.

Table 10. Addressing community problem utilizing GBF and SDGs

	GBF	**SDGs**
Livelihood insecurity reduction	15, 16	12
Regenerative capacity	15, 16	12
Adaptation to climate change	2, 4, 10, 11	15

(Source: Authors)

5.2 Wellbeing of nature and human beings and climate change

The health of the natural world, human well-being, and climate change are all highly dependent upon one another. It is frequently observed in the Sundarbans that the environment treats the locals quite harshly and harms their surroundings. They must take the required steps to escape their issues and achieve a sustainable better way of life by modifying the Krunal-Montreal Global Biodiversity Framework to lead a better existence. This chart illustrates how the elimination of livelihood insecurity is achieved by working with targets 12, 18, and 20, and indirectly following the SDGs. To meet those goals, the Krunal-Montreal Global Biodiversity Framework is utilized to create knowledge, protect regions according to necessity, rebuild ecosystems, and practice sustainable production and consumption. To the Sundarbans' capacity, it collaborates with GBF 3, 4, 12, 18, and 20, and indirectly with the SDGs. For Improving Bio-diverse adaptation to climate change, it needs to follow GBF 2,4,10,11, and SDG 15.

Table 11. Improving bio-diverse adaptation to climate change.

	GBF	**SDGs**
Livelihood insecurity reduction	12, 18, 20	Indirect
Regenerative capacity	3, 4, 12, 18, 20	Indirect
Adaptation to climate change	2, 4, 10, 11	15

(Source: Authors)

5.3 Wellbeing of nature and human beings and Biodiversity Loss

The Sundarbans are losing biodiversity daily, which poses a serious threat to both the community's population and the components of biodiversity. Both land biodiversity and aquatic biodiversity are declining as a result (Titumir & Paran, 2022a). It has caused a significant shift in the biotic and abiotic living styles, which is detrimental to the state. It must adhere to GBF targets 2, 4, 10, and 11 for the decrease of livelihood insecurity to solve the issues. Additionally, it must adapt in the same way to renew the Sundarbans' capacity. The final need is to indirectly follow SDGs and targets 3, 4, 12, 18, and 20.

Table 12. Addressing bio-diversity loss utilizing GBF and SDGs.

	GBF	**SDGs**
Livelihood insecurity reduction	2, 4, 10, 11	15
Regenerative capacity	2, 4, 10, 11	15
Adaptation to climate change	3, 4, 12, 18, 20	Indirect

(Source: Authors)

6. Conclusions

The Sundarbans act as a natural wall against climate change, protecting against storms, cyclones, and other natural hazards. Protecting and restoring mangrove biodiversity can maximize their capacity for carbon storage and enhance their ability to mitigate climate change. Preserving mangroves is therefore essential for maintaining ecosystem health, protecting coastal communities, and meeting climate mitigation goals. However, the changing climate has led to a reduction in the abundance of fish, fuel woods, honey, and other resources in the Sundarbans, affecting the livelihoods of the mangrove resource users. To address these challenges, resilience-smart adaptation measures are recommended, such as vulnerability assessments and appropriate adaptation measures. Furthermore, the involvement of local communities in the management of the Sundarbans through co-management approaches is crucial for its protection and conservation. By implementing these strategies, the Sundarbans can enhance their resilience to climate change, protect its biodiversity, and improve the livelihoods of the communities dependent on its resources. The elimination of livelihood insecurity is achieved by working with targets 12, 18, and 20, and indirectly following the SDGs which also lead to achieving the targets Krunal-Montreal Global Biodiversity Framework to lead a better life in the Sundarbans.

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ANNEX

Photo: Community people are explaining how they adopted mangrove restoration strategy

Photo: Focus Group Discussion (FGD) with Koyra Bonojibi Bohumukhi Unnayan Samit

Photo: Focus Group Discussion (FGD) with Munda Adivasi Bonojibi Bohumukhi Unnayan Samity