

Unraveling Livelihood Interactions in the Mangrove Sundarban: Evidence from Koyra Upazila using PRA and Geospatial Analysis

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Abstract: The Sundarban is one of the largest mangroves in the world and it is facing a lot of difficulties due to the global climate change. The event of Climate change is not only hampering the wildlife and marine resources but also impacting the livelihood of the surrounding people. The aim of this study is to develop and evaluate the Livelihood Vulnerability Index (LVI), a multi-component index that measures household livelihoods' susceptibility to climate variability and change in the two unions -Uttar Bedkashi and Dakshin Bedkashi in the Koyra Upazila under Khulna division, in order to clarify the disparate effects of climate change on communities living in the vicinity of the Sundarbans. The overall result of LVI-IPCC is -0.192 which shows that the study area has moderate level of vulnerability. Besides, the people of the study area have high levels of vulnerability in sensitivity, moderate level of vulnerability in adaptive capacity and less vulnerability in exposure with the score of 0.604, 0.449, and 0.123 respectively. However, the dynamic mystiques of mangrove shows that there is a gradual decrease of vegetation and agricultural practices but an increasing trend of the bare land is visible in the Koyra Upazila surrounding the Sundarban mangrove areas.

Introduction:

Mangroves are significant global forest resources for people living along the coast because they offer a variety of advantages to people that support their livelihood activities on an ecological, cultural, and economic level (Ewel et al., 1998). According to the annual report of The Global Mangrove Alliance (GMA) published by International Coral Reef Initiative (ICRI), the total amount of world's remaining mangrove is near about 147,000 square kilometer which is almost similar to the size of the country Bangladesh (Dallison, 2022). Regretfully, over the past two decades, the mangrove area has drastically decreased by 35%, and this decline is continuing at a pace of 2.1% year (Cornforth et al., 2013). There are over 635,586 hectares of mangroves in Bangladesh overall, of which 618,586 hectares are growing naturally (Hoque & Datta, 2005). However, the situation is worse in Bangladesh since 29% of the country's population, more than 35 million people live in the coastal regions (Ahmad, 2019) and almost 52% of the people living along the shore directly depend on forest resources for their livelihoods (Islam & Rahman, 2015). Besides, the mangrove provides with the major sources of livelihood for those community residing near the Sundarban area in this country and serve as a buffer zone during unanticipated shortage or as fills during normal shortage

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(Angelsen & Wunder, 2003) by protecting the area working as a natural shield. Livelihood analysis is a crucial task that helps to ensure sustainable management of biodiversity by involving people in the management process and reducing dependence on forests (Fikir et al., 2016). But it is a matter of great regret that because of the current climate change and other anthropogenic factors the livelihoods of the Sundarban areas are being impacted negatively and thus, contributing to the increase in dependency on the forest resources as well as vulnerability in case of livelihood diversification.

The study area Koyra is severely vulnerable in case of livelihood diversification due to the changing climate globally and the causes of diversifications within this area have been explored within this study. Koyra is a coastal and the second largest Upazila of Khulna district in Bangladesh. The approximate size of this upazila is 263.12 square kilometers when the Sundarbans are excluded and 1,775.41 square kilometers when they are included (Sadik et al., 2018). So, this research justifies how the livelihood diversification in Koyra Upazila has been taking place gradually addressing climate vulnerability of the current situation to promote community development and contribute to the adaptation strategy. Besides, this study can provide some ways ahead for those national and international policy makers concerning the changes of climate worldwide to some extent and what solutions can fit to these environmental changes by keeping in mind that how people of this remote area are getting used to with the current situation according to their spatial context.

Objective of the Study:

The main aim of this study is to analyze the dynamic mystiques of mangrove forest and dependent livelihood in the Sundarban using Participatory Rural Appraisal (PRA) tool and geospatial technique in Bangladesh. This study also considers different livelihood vulnerability indexes and the influencing factors which are contributing to the growth of these vulnerabilities in their various forms. The research is centered on three major portions which are- adaptive capacity, sensitivity, and exposure to identify the existing livelihood vulnerabilities using IPCC-LVI framework to examine

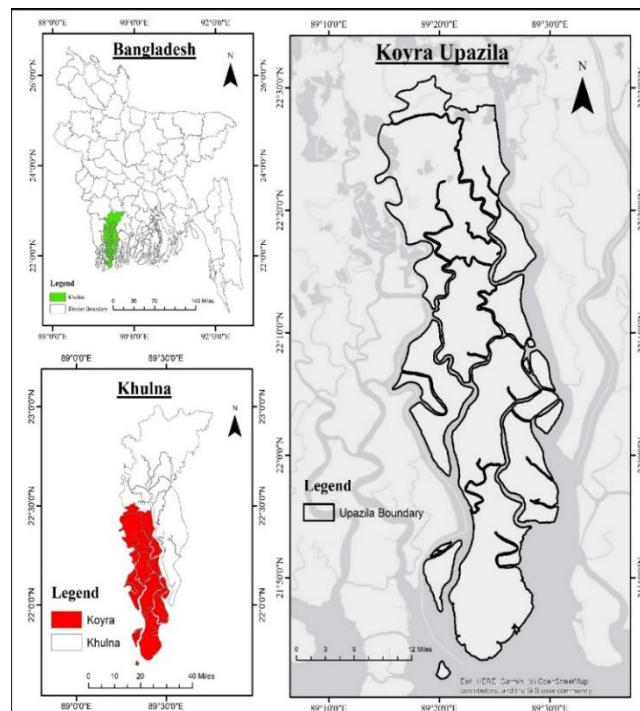


Figure 01: Administrative Boundary of Koyra

three objectives which include-

- i) to understand the livelihood dynamic mystiques by using PRA tool,
- ii) to identify the livelihood vulnerabilities of the community people by using LVI-IPCC method and
- iii) to provide LULC maps mentioning changes in the study area using geospatial techniques.

Data and Methodology

The study has been done on two unions named Uttar Bedkashi (Latitude $22^{\circ}18'13''\text{N}$; Longitude $89^{\circ}18'12''\text{E}$) and Dakshin Bedkashi (Latitude $22^{\circ}14'24''\text{N}$; Longitude $89^{\circ}19'30''\text{E}$) in Koyra Upazila under Khulna division. The Uttar Bedkashi Union is only 20 kilometers from the largest mangrove in the world, the Sundarban, and 4 km south of the Koyra Sadar

upazila. The Koyra Sadar lies to the

north of the study area, while Bedkashi Union lies to the south. The Sundarbans and Shakbaria River border the east, while the Kobadak River borders the west (Akm et al., 2015). This study took both the qualitative and quantitative approaches. Participatory Rural Appraisal tool has been used to understand the livelihood diversifications and people perceptions which emphasize engaging with communities through discussions,

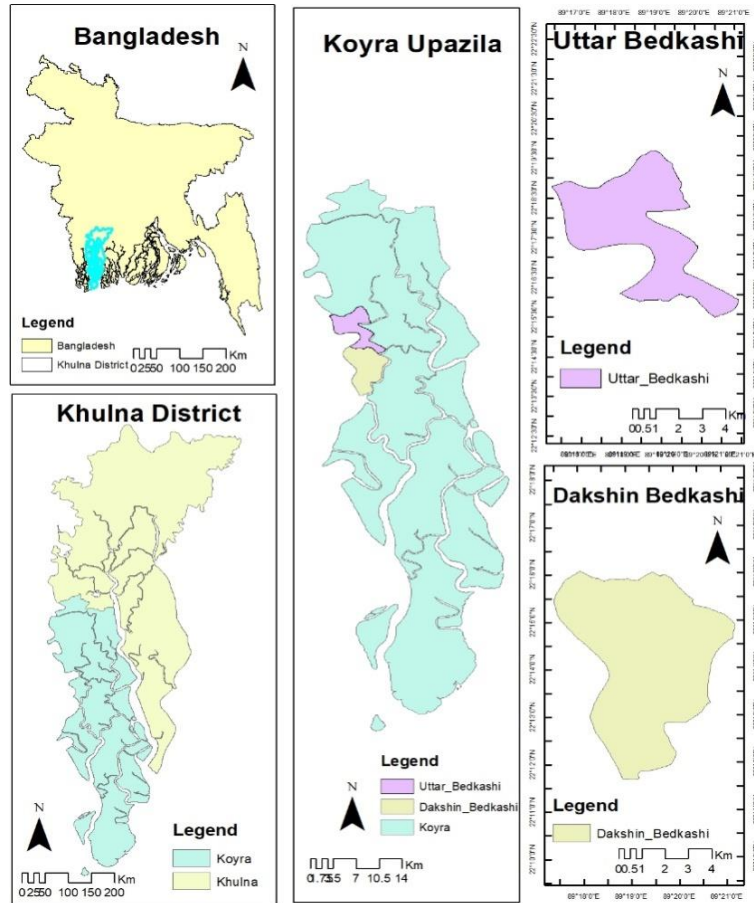


Figure 02: Locational Map of Uttar & Dakshin Bedkashi

observations, and participatory techniques to gather qualitative information. Apart from this qualitative approach, a total of 170 households' data has been collected through a questionnaire survey covering the two unions to represent the results. Verbal interviews of the community people have been documented for qualitative interpretation.

For quantitative data analysis, the conceptual framework of IPCC which is Livelihood Vulnerability Index (LVI) has been selected for the study to identify the livelihood vulnerabilities and its dimensions. The data collection part of this study is divided into two steps. Firstly, primary or field data have been collected from the study area through the PRA tool and questionnaire survey. A group of 5 people collected the questionnaire data from the local residents of the study area. For secondary data collection, various online sources have been used such as- Bangladesh Bureau of Statistics (BBS), Banglapedia, Bangladesh University of Science and Technology produced digital maps, data of Bangladesh Water Board Development (BWBD), Food and Agriculture Organization (FAO), Bangladesh Agricultural Research Council (BARC), Directorate General of Family Planning for extracting Upazila wise population data etc. Besides, the spatial data have been collected from USGS portal.

Purpose for Choosing LVI-IPCC

For this study, the LVI composite index approach has been chosen because, in order to make decisions about strategies for reducing vulnerability, public health practitioners and development organizations require information not only about the relative vulnerability of communities to climate change impacts, but also about the factors that shape that vulnerability. So, in order to ensure that every indication contributes equally to the overall index, even though each major component is represented by a different number of sub-components, the LVI uses a balanced weighted average technique (Sullivan, 2002). Besides, as this study aims to provide a livelihood vulnerability assessment tool that can be used in resource-poor settings by a wide range of users, thus, the LVI calculation approach is justified as a simple possible method of vulnerability calculation methods while giving equal weight to all important components. Moreover, since the tool is only meant to be used as a relative metric to compare vulnerability between unions in the study population, weighting schemes applied to every union in the study population would not affect the analysis as a whole, thus the decision was justified. Additionally, the secondary formula- which offers another way to compute the LVI combines the values of the primary components by means of both subtraction and multiplication. The differential impact of the two aggregation procedures on the LVI value would needlessly complicate the study and provide no additional value if weights were added to the sub-component values prior to their aggregate.

The LVI composite index method calculation

The calculation of LVI-IPCC has two parts and the first portion of the calculation is encompassing elements and sub elements together to get the composited weighted value. Eight following key elements were chosen to be encompassed in the LVI.

Socio-demographic Profile
 Livelihood Strategies
 Social Network
 Natural Capital, Skills, and Knowledge
 Health
 Water
 Food
 Natural Hazards, Disasters, and Climate Variability

Each primary component comprises many sub-component indicators, along by a description of the methodology employed to compute the indicators, the survey question that collected data for each indicator, the initial source of inspiration for each question, and plausible causes of bias for each indicator. The indicators used for this Koyra case study has been determined by a review of prior evaluations of each of the key elements (such as studies examining the water sector in Koyra) and the viability of gathering the necessary data through household surveys. Initially, every sub-component indicator had to be standardized as an index as they are all measured on various scales. The life expectancy index, which is the ratio of the difference between the actual life expectancy and a pre-selected minimum, as well as the range of pre-determined maximum and minimum life expectancies, has been calculated using an equation borrowed from the Human Development Index (UNDP, 2007).

$$index_{sd} = \frac{S_d - S_m}{S_{max} - S_{min}}$$

The assessment aims to create a comparative vulnerability index for unions based on standardized indicators. Each sub-component's minimum and maximum values were determined from the study sample extremes. Indicators like travel time to primary water sources were standardized using these values. Variables measuring frequencies, such as conflicts over water, were standardized from 0 to 100. Some indicators, like the Agricultural Livelihood Diversity Index, were inverted to reflect higher vulnerability with fewer activities. Major components were averaged from standardized sub-component indicators, contributing to indices for socio-demographic profiles, livelihood strategies, social networks, natural capital, skills, knowledge, health, food, water, and natural disasters.

$$M_d = \frac{\sum_{i=1}^n index_{sd}^i}{n}$$

The following formula has been used to average the values for each of the eight primary components for each union, resulting in the LVI value for the study area:

$$LVI_d = \frac{\sum_{i=1}^8 w_{M_i} M_{di}}{\sum_{i=1}^8 w_{M_i}}$$

or,

$$LVI_d = \frac{w_{SDP}SDP_d + w_{LS}LS_d + w_{SN}SN_d + w_{NC}NC_d + w_HH_d + w_WW_d + w_FF_d + w_{NDCV}NDCV_d}{w_{SDP} + w_{LS} + w_{SN} + w_{NC} + w_H + w_W + w_F + w_{NDCV}}$$

where, the weighted average of the eight primary components for the study region is equivalent to LVI_d for that particular union, Koyra. The weights of every major component, w , are established based on the total number of sub-components that comprise each major component. These weights are incorporated to guarantee that every sub-component makes an equal contribution to the overall LVI. In this study, the scale for vulnerability (Suryanto & Rahman, 2019) has been categorized into the followings:

- between (-1) and (-0.4) on the LVI-IPCC scale, there is no vulnerability.
- between (-0.41) and (0.3) there is moderate vulnerability; and
- between (0.31) and (1) there is extreme vulnerability.

Computing the LVI-IPCC: Using the IPCC approach

In an effort to create a formula that would accurately reflect the IPCC definition of vulnerability, an alternative approach to incorporating the key elements into a vulnerability index was investigated. The three contributing variables to vulnerability identified by the IPCC (exposure, sensitivity, and adaptive capability) were measured in this instance using the same eight key components as in the composite index approach (Table 01).

Table 01: Showing major components from the IPCC vulnerability framework are categorized into contributing factors in order to calculate the LVI-IPCC

Contributing Factors of Vulnerability	Major Components
Adaptive Capability	Socio-demographic Profile
	Livelihood Strategy
	Social Network
	Natural Capital, Skills, and Knowledge
Sensitivity	Health
	Water
	Food
Exposure	Natural Hazards, Disasters and Climate Variability

Climate variability is assessed by the average standard deviation of the maximum and minimum monthly temperatures and monthly precipitation over a six-year period though this variable has been identified as the least affecting variables in this study particularly. The exposure of the study population is measured by the number of natural disasters that have happened in the previous six years. Adaptive capacity is measured by looking at a community's demographics (such as the proportion of young children or households headed by women), the livelihood strategies the community people use (such as farming or gathering natural resources to sell at the market), and the strength of their social networks (such as helping out neighbors with chores or borrowing money recently). Finally, the current situation of a community's food and water security as well as health status have been evaluated to determine the level of sensitivity.

When the main components are merged, the IPCC framework method deviates from the composite index approach. Instead of combining all the major components into an overall index at once, they are first combined using the same weighted average method as previously, based on the categorization in Table 02. The weights for each major component are again determined by the number of sub-component indicators in each major component:

$$CF_d = \frac{\sum_{i=1}^n w_{M_i} M_{di}}{\sum_{i=1}^n w_{M_i}}$$

The contributing factor (exposure, sensitivity, or adaptive capacity) in the formula above is denoted by CF_d . The major components for each union are represented by M_{di} . The weight of each major component is indicated by w_{M_i} . The number of major components in each contributing factor is indicated by n . The following equation is used to integrate exposure, sensitivity, and adaptive capacity after they have been determined for the study area:

$$LVI-IPCC = (exposure - adaptive\ capacity) * sensitivity$$

where, LVI-IPCC is the LVI according to the IPCC vulnerability paradigm as a function of vulnerability. On a scale of -1 (least vulnerable) to 1 (most vulnerable), the LVI-IPCC is measured.

Results and Discussion:

In the following table 02, the sub component socio demographic information has been calculated using ratio scale only while other components have been calculated using percentage scale for more accurate results. The vulnerability index value is calculated by using observed values. The value of minimum and maximum number is confined from 0 to 100 except for average family member in a household. Because, the average family member in a house can never be a number near to 100. Thus, the observed index of this

sub component is 7.5, the maximum value is 8 and the minimum value is 2. So, this table reflects basically the weighted average value of the total eight components showing the observed index values, maximum and minimum numbers for each component which have been used in calculating the final LVI-IPCC calculation in table 03. For instance, to calculate the index value of food, we have to subtract the subcomponents value from minimum value and then divide the subtract value with the range (maximum- minimum). Thus, after getting all the sub components index value, we have to calculate the mean value. The calculation of sub-component value for food is given below:

STEP 1

$$index_{FOOD} = \frac{72-0}{100-0} = 0.72$$

STEP 2

$$Food = \frac{\sum_{i=1}^n index_{sdf}}{n} = \frac{F_1+F_2+F_3+F_4}{4} = \frac{0.72+1+0.62+0.607}{4} = 0.737$$

Table 02: Actual sub-component values and minimum and maximum sub-component values with weighted Average Value

Sub-components	Vulnerability Index	Observed value	Max value	Min value	Units	Weighted Average value	Major component	Dimensions
Dependency ratio	0.066	0.066	10	0	Ratio	0.336	Socio demographic Profile	Adaptive Capacity
Percent of female headed Households	0.025	2.5	100	0	Ratio			
Average family member in a Households	0.917	7.5	8	2	Count			
Do you have any family member who is working in other communities outside?	0.26	26.0	100	0	Percent	0.47	Livelihood Strategies	
Do your household incomes solely depend on only agriculture/ forestry/ fishery?	0.68	68.0	100	0	Percent			
Have you received any aid after any disaster or natural hazard?	0.78	78.0	100	0	Percent	0.5026	Social Network	
Have you provided any aid after any disaster or natural hazard?	0.22	22.0	100	0	Percent			
Have you ever borrowed money from a neighbor or relative to solve financial crisis immediately after disaster or natural hazards?	0.467	46.7	100	0	Percent			
Have you ever lent money to a neighbor or relative to solve financial crisis immediately after disaster or natural hazards?	0.413	41.3	100	0	Percent			
Have you ever gone to any local government to ask for financial assistance?	0.633	63.3	100	0	Percent			
Have you built your house with disaster resistant materials?	0.813	81.3	100	0	Percent	0.442	Natural Capital Skills and Knowledge	
Do you have legal land ownership?	0.253	25.3	100	0	Percent			
Have you ever exchanged your knowledge about climate change with your family members, neighbors, or relatives?	0.393	39.3	100	0	Percent			
Do you think that you are aware of climate change and its impact?	0.307	30.7	100	0	Percent			
Do you have any family members with chronic illnesses (e.g., Arthritis, Asthma, Cancer etc.)?	0.34	34.0	100	0	Percent	0.50325	Health	Sensitivity
Have you ever received any medical examination and treatment services from the local government or any other private institution like an NGO?	1	100.0	100	0	Percent			
Do your family members miss school or work due to illness?	0.28	28.0	100	0	Percent			
Do you have access to safe sanitation facilities?	0.393	39.3	100	0	Percent	0.562	Water	
Do you face difficulties with the accessibility of drinking water during natural hazards and disasters?	1	100.0	100	0	Percent			
How much distance do you need to cross to get the accessibility of drinking water?	0.08	8.0	100	0	Percent			
Do you have any stable water supply sources that can be used in the time of disaster occurrences?	0.607	60.7	100	0	Percent	0.737	Food	
Do you think that you have self- sufficient food sources?	0.72	72.0	100	0	Percent			
Do you face difficulties in finding food resources during disaster?	1	100	100	0	Percent			
Do you have saved crops for next year or the time of disaster?	0.62	62.0	100	0	Percent			
Do you have saved seeds and breeds for next year or the time of disaster?	0.607	60.7	100	0	Percent			
Did you receive any warning about upcoming natural hazards or disasters?	0.093	9.3	100	0	Percent	0.123	Natural Hazard Disasters and Climate Variability	Exposure
Had any of your family members died in or disaster or any of the family members is injured by natural hazards?	0.153	15.3	100	0	Percent			

Table 03: Major Components and Final Calculation of LVI

Dimensions	Major components	Sub-components values	Number of Sub-Components per Major components	Vulnerability Index value of Major Components	LVI-IPCC Calculation	Final Result
Adaptive Capacity	Socio-demographic Profile	0.336	3	0.4449	LVI= (Exposure- Adaptive Capacity)* Sensitivity = (0.123- 0.4449) *0.604 = -0.194	-0.194
	Livelihood strategies	0.47	2			
	Social network	0.5026	5			
	Natural capital, Skill, and knowledge	0.442	4			
Sensitivity	Health	0.50235	4	0.604		
	Water	0.562	3			
	Food	0.737	4			
Exposure	Natural Hazard, Disasters and Climate Variability	0.123	2	0.123		

The vulnerability index for adaptive capacity is 0.4449 which suggests a moderate level of adaptive capacity. Besides, the sensitivity vulnerability index is the highest value of all which is 0.604 which means the community people is moderately sensitive to vulnerabilities. Moreover, the vulnerability index value of exposure is 0.123 which is the lowest of all the scores 0.123 which clearly reflects that the area is more exposed to vulnerabilities due to their geographical position other than other climatic variabilities. So, it can be seen that the final calculation of LVI- IPCC and the result is -0.194 which indicates that the people of the study area are moderately vulnerable for the context of livelihood vulnerabilities.

Socio-demographic Profile (SDP)

The first sub-component of this major component is dependency ratio. The dependency ratio index measures the ratio of dependents (people who are typically not in the workforce, such as children and the elderly) to the working-age population. The number of people under 15 or over 64 divided by the total number of people between the ages of 15 and 64, stated as a percentage, is the dependence ratio (BBS, 2011). In the context of the Livelihood Vulnerability Index, lower dependency ratios often indicate a lower level of vulnerability. This is because a smaller proportion of dependents typically mean fewer people relying on a limited workforce and resources, which could indicate a certain level of resilience in the community. The result of dependency ratio of this study is 0.066 which means that the majority of the community people of the study area are working class people. Suva Rani (29), a local women said,

“The elderly people face different types of challenges during disasters. They cannot even move and save themselves. But we also feel guilty because during

that time most of us remain busy to save ourselves and as our sons and daughters mostly reside outside of this area near the towns for education purpose, we hardly find anyone who can help those elderly people. Sometimes, my husband also lives in the distant places for earning livelihood, so I am bound to live like that.”

Again, according to the result, the index value of female headed household is 0.025. A female headed household index value of 0.025 in calculating the Livelihood Vulnerability Index typically means a lower proportion of households led by females relative to the total number of households in the area being assessed. There are some driving factors behind the poor value. According to the report of UNDP, the conventions that diminish women's rights and capacities are at the core of gender bias in Bangladesh. These have intricately and entwined historical, cultural, social, and economic foundations. Traditionally, men have been the dominant decision-makers and breadwinners in society, while women have been relegated to supporting positions. The continued practice of child marriage restricts girls' access to economic and educational opportunities while upholding conventional gender norms (The Daily Star, 2023).

Livelihood Strategies (LS)

When the Livelihood Vulnerability Index is applied, an index value of 0.26 for those people who work outside the community indicates that a significant proportion of community members are employed outside of their immediate vicinity which can also be called migration in the short term or long term. Rahim Mia (48), a local Imam of the community confronted,

“Most of the time, the men of the households live far away in the monsoon season. Because, the crops are destroyed by the flood. So, since the male members do not find any sources to earn, they go to Dhaka and pull rickshaw or do other day laboring to feed the children. God is sometimes very cruel during the monsoon.”

However, during the fieldwork of this study, it is found that the community people are somehow not happy with the migration. Besides, not only the male members but also some female members also have to migrate to earn livelihood which put the female-headed household at uncertainty.

The value of vulnerability index of depending on agriculture/ forestry/ fishery is 0.68 means the community people are vulnerable because they have high dependency on the previously-mentioned sectors as their only source of livelihood. Besides, they have high level of income instability, less livelihood diversification, and more resource dependency.

Social Network (SN)

The vulnerability index value of receiving aid after any hazard or disaster is 0.78 and asking for financial aid from the local government is 0.063 which means that the community people of this study area is highly dependent on external reliefs and aids because they do not have proper management of their resources (Harvey and Lind, 2005).

On the other hand, the index values of providing aid, borrowing, and lending money after any natural hazard or disaster are 0.22, 0.467 and 0.413 respectively which means that the people of that area have less tendency to provide assistance during or immediately after the natural disturbances. Abdur Rahim (53), a local shop owner said,

“I save money all year around because I know I cannot afford to make a strong building to live. So, I save some money from my business and when the flood comes and my house is broken, I use that savings to repair my house. As a result, I cannot lend money to others though they need them. Because, that time I have no option left with myself.”

However, there can be many reasons behind this problem of not having strong social networks, but the main reason is that the people are already financially vulnerable by themselves and, as a result, they cannot help themselves let alone the neighbors. However, the overall index of vulnerability for social networks is 0.5026 which indicates that the social network is not well structured in this study area and needs further improvement.

Natural Capital, Skill, and Knowledge (NC)

It is a matter of unfortunate that the index value of vulnerability for the sub-components of building the house as disaster resistant is very high, which is 0.813. This result indicates that due to some reasons, the community people of the study area do not or cannot make their houses safe against climatic hazards and the reasons include-

- 83% of Bangladesh's population lives in unsanitary, non-engineered homes and poverty is the primary cause of inadequate housing. Regularly, many properties sustain damage from disasters, and during disasters, residences incur the greatest financial losses (GOB, 2008).
- Sometimes, after disaster the external bodies immediately rush to the affected area and try to help the victims by providing them financial support to make their settlements and some of the houses are well-built and some are temporary, but still, they follow the previous designs or whatever design they provide to the affected people do not align with the culture or tradition with the respective areas which make the victims again vulnerable (Islam et.al., 2013).

However, most of them have legal ownership of their house with the vulnerability index value of 0.253 with the index value of 0.393 and 0.307 for exchanging the knowledge of climate change and being aware of the impacts of climate change which indicates that the community people of this area are quite aware of the impacts of climate change and the impacts of it on the livelihoods. So, the overall vulnerability index value of natural capital, skills, and knowledge is 0.042 which means that there are some efforts to attain the skills and gathering knowledge by sharing them among the community people. While interviewing, one of the local residents named Fatema (17) said,

“My husband is a day labor and we have two babies. He hardly can earn money to live on; how can we imagine to live in a distant place for safety. If our death is destined in that way, we will die. Because we have no other option than living here unsafely.”

Health (H)

A vulnerability index value of 0.34 for family members with chronic health diseases within the livelihood vulnerability index indicates a moderate level of vulnerability for this specific group within the community. There are many reasons behind this issue such as-

- Although government hospitals provide affordable healthcare, they are sometimes unreachable, overcrowded, understaffed, and without necessary medications (Amin, 2008).
- Hospitals in upazila are understaffed, and patients are not receiving high-quality care (Tajmim, 2022).
- In Bangladesh, the current healthcare system is not focused on the needs of the poor, particularly in rural areas (Khandakar, 2014).
- Many impoverished individuals, especially those living in urban slums, as well as hundreds of thousands of women and children in rural areas lack access to services that could lessen the intensity of their sickness, and they lack the "goods" necessary to sustain health (Mannan, 2013).
- A significant percent of the population is mostly unaware of the services provided by community health clinics (Yaya et al., 2017).

However, little portion of the community people also misses their schools and colleges due to the illness which is identified by the index value of 0.28 and moderate level of people have safe access to the sanitation facilities with the index value of 0.393 because some local NGOs are working on the sanitation project in this study area. An interesting fact is identified from the study which is the parents of this community are very much interested to make their children educated other unlike other rural areas of Bangladesh.

Water (W)

A vulnerability index value of 0.08 for households needing to travel a distance to access safe drinking water within the Livelihood Vulnerability Index indicates a relatively low level of vulnerability for this particular aspect within this community people of the study area where a vulnerability index value of 0.607 for households having any stable water supply source during times of disaster within the Livelihood Vulnerability Index indicates a moderate to high level of vulnerability for this specific aspect within the community. The Member of Union Parishad, Md Joynal (58) stated,

“Most of the people of this community are living under the poverty line. So, they cannot afford to have a water reservoir at their house individually. So, I am trying for these poor people to get at least combined water reservoirs in the

least distance to make sure the supplies of water during the heavy monsoon or flood.”

However, there are some reasons behind having the issue of finding safe water accessibility during disaster such as-

- One major hazard to people's access to clean drinking water is salinity intrusion (Hasan, 2023), which can occur in both surface and groundwater (Abedin et al., 2014).
- In Bangladesh's coastal villages, rising salinity levels have not only made it difficult to find clean drinking water, but also nearly impossible to practice rice farming, the traditional industry in the area. Meanwhile, shrimp farms, which thrive in the salt water and have proliferated there, do not require a lot of day laborers (Bagri, 2017).

However, with the vulnerability index 0.562, the community people have moderate level of vulnerability in case of health.

Food (F)

The vulnerability index of having self-sufficient food is 0.72 which indicates that the community people do not have sufficient food to get the necessary nourishment for themselves. They not only face difficulties in finding foods during or after any natural hazards or disaster but also, they have vulnerability index value of saving crops for the next year is 0.62 and saving seeds for the next year is 0.607 which means that they have less tendency to become self-sufficient in case of food or there are some other reasons behind this vulnerability such as-food insecurity is a result of impoverished households' lack of access to food, which includes a lack of funds, other resources, or enough food for them to produce adequate food on their own (Hossain and Shahabuddin, 2005). Besides, natural hazards also slow the accessibility of food more vulnerable (Rahman & Ferdousee, 2023). As a result, the poor people do not feel the motivation to save food for the upcoming natural hazards, thus, they find difficulties in fetching food during any natural events.

Natural Hazards, Disasters and Climate Variability (NDCV)

The sub-components of climate variability for this study area are high and the value of vulnerability index of receiving any early warning is 0.093 which means that people get early warnings and the index value of anyone dying due to natural hazard is 0.153 which means that near about no one is died due to any kind of natural phenomena in the study area. So, the overall value of NDCV is moderate and the people have less exposure. However, from the graph (Figure 03), we can see that food has the highest value of vulnerability and NDCV has got the lowest value of vulnerability. However, water has

the second highest value of vulnerability and SDP has got the second lowest value. Besides, health, social network, livelihood strategy and natural capital have got the rank of third, fourth, fifth and sixth rankings with their vulnerability index value.

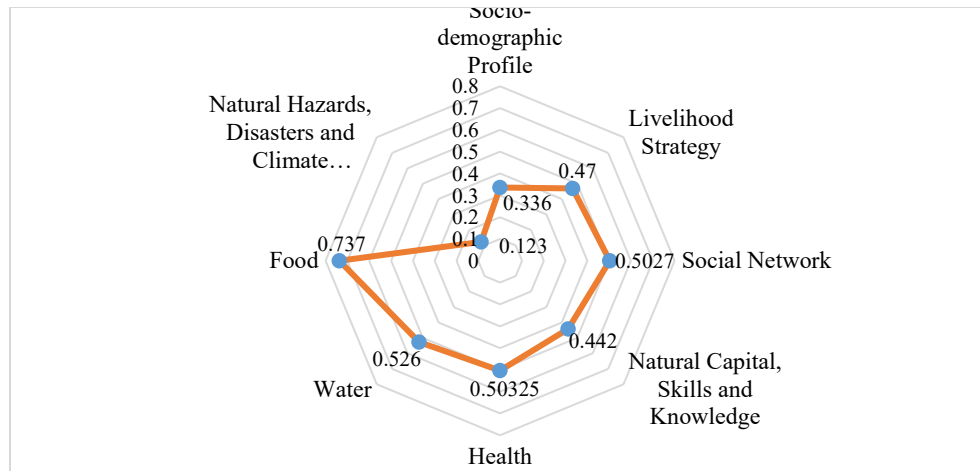


Figure 03: Vulnerability Spider Diagram of the major components of the LVI for Koyra

This graph shows the above-mentioned sub-components through the three dimensions which are- adaptive capacity, sensitivity and, exposure. Here, we can see that the study area has less exposure, moderate adaptive capacity but high level of sensitivity which means that this dimension needs to be focused more to reduce the existing vulnerability of the study area.

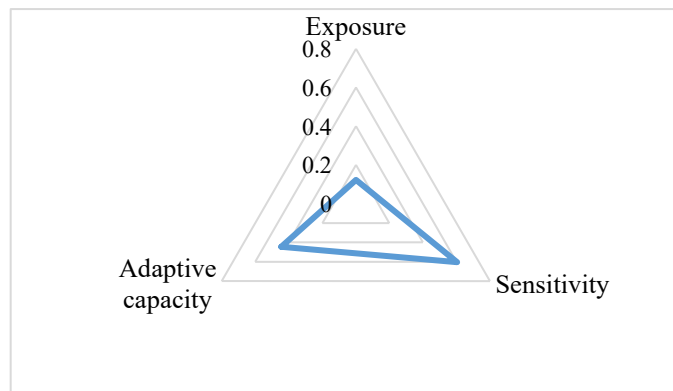


Figure 04: Vulnerability triangle Diagram of the contributing factors of the LVI for Koyra

Social and Resource Map by Using PRA Tool

The social map of the Sundarban has been created as a mapping exercise and is used to display (Figure 05) data about the infrastructure, population distribution, social stratification, village layout, and healthcare services. In addition to health, water and sanitation, education, leadership, vulnerability, and indigenous skill maps, this map has a wide range of applications. It also fosters a positive environment where outsiders and villagers can interact and better understand one another's cultures, educational standards, socio-economic backgrounds, and other issues. The vulnerable and portrayed segment of the community is integrated into the development process if these social maps are included in the planning process. In addition to being useful for solving a variety of local

issues and being incorporated into the planning process, this map is effectively used in the Sundarban and is found to be helpful in identifying the most vulnerable section of the village community in Uttar Bedkashi and Dakshin Bedkashi union in Koyra. The resource map is typically used to display data about land, water resources, cropping patterns and land use, productivity, management of land, soil, and water resources, degraded areas, etc. This map aids in determining the status of forest resources in the Sundarban and the degree of resource exploitation, hence assisting in the identification of strategies and tactics for preserving and enhancing the current forest and other resources of the study villages. This theme resource-oriented map, which is similar to maps of agriculture, water resources, and forests, shows how the Koyra's resources are used for forestry, cropping patterns, land use, and resource usage.

These maps aid in analyzing the issues surrounding forest changes, determining their root causes, which will help in developing strategies for sustainable management. By involving the local population in the identification and assessment of these resources, this kind of map determines the benefits and issues related to forest resources and serves as an effective tool for participatory planning.

Figure 05: Social and Resource Map of Uttar Bedkashi and Dakshin Bedkashi



Mangrove Dynamics and Ecological Backlash in Koyra Upazila

The significant numbers of mangroves have changed in the last 20 years between the year 2000 and 2020 which is illustrated in figure 06. Landsat 5 (30m resolution, month-February) data have been used to identify the LULC of 2000 and Landsat 8 (30m resolution, month- February) data have been used to observe the change which is increased by a great number in the year 2020.

From this we can assume that this number will further increase in the recent future which indicates that the area of mangrove which is also a natural shield from cyclones or other hazards in the southern part of Bangladesh is decreasing and creating the residents of this area more vulnerable and exposed to climate change and other climatic hazards. This decreasing trend of mangroves is not only affecting the livelihoods of the people surrounding the area but also imposing threats to the wildlife and marine resources of the mangrove area.

Figure 06: LULC Map of Koyra in 2000 and 2020

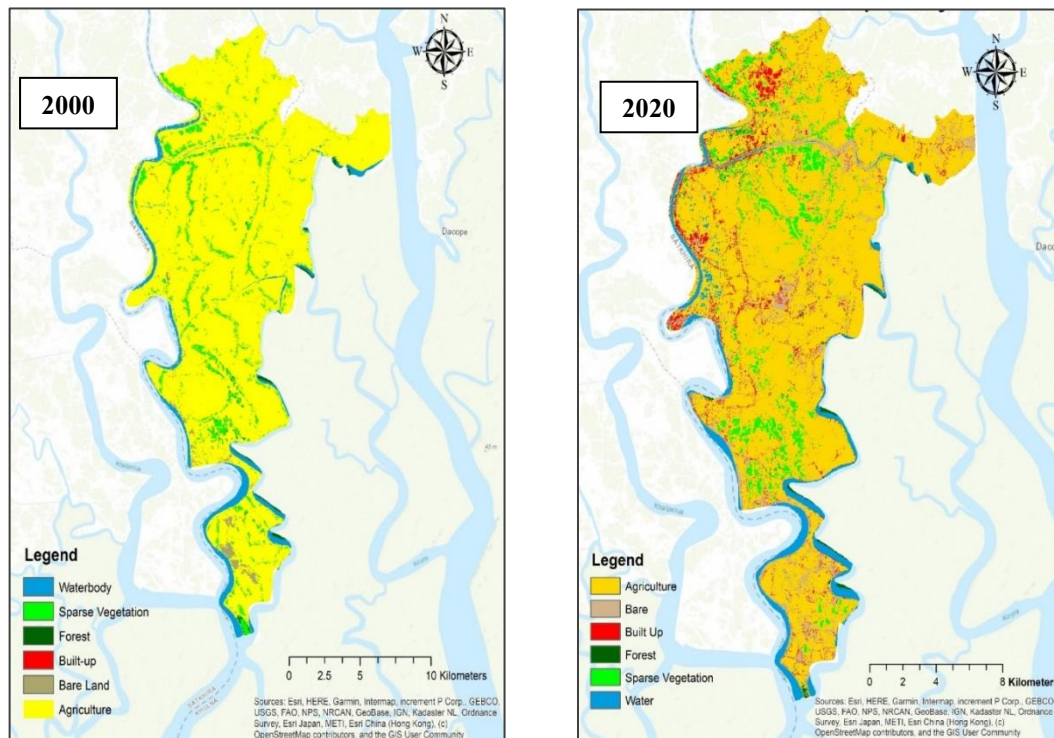
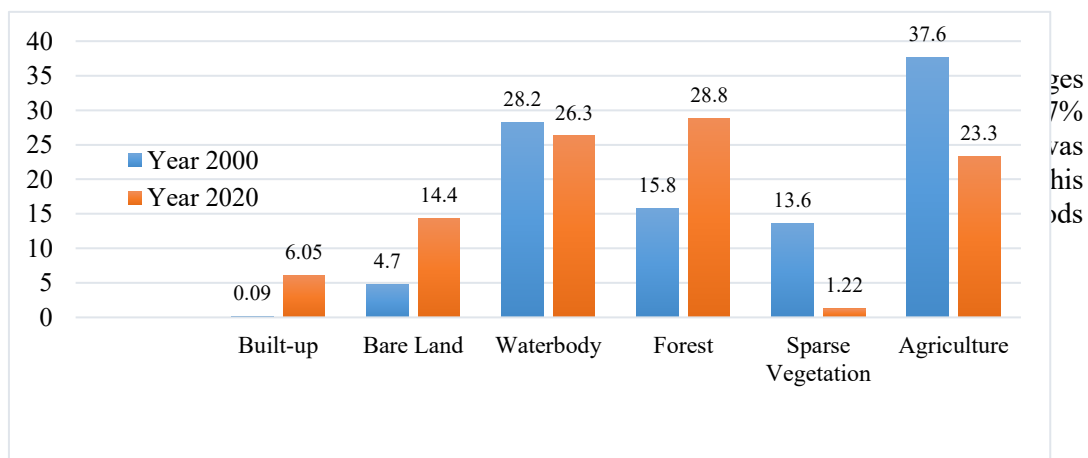


Figure 07: Differences of LULC between 2000 and 2020 in Koyra



Conclusion and Recommendations

In order to evaluate the relative vulnerability of livelihoods to climate change and to identify the sectors and contributing factors that influence these potential risks, we have presented two alternative methods: the LVI–IPCC utilized a formula based on the theoretical IPCC vulnerability framework, which frequently serves as the basis for vulnerability assessments, and the LVI was calculated using the composite index approach. A thorough representation of the key elements influencing the security of household livelihood is offered by the composite index technique. When the vulnerability spider diagram is used to compare two or more research areas, this analysis offers more details. The IPCC framework approach combines the main elements with a straightforward formula that can direct population-level intervention activities. To reach a broad audience of users in the field, methods were outlined, and math and statistics utilized for the analysis were meant to be simple. The approach's limitations encompass the subjective selection of sub-components and the directionality of the relationship between the sub-components and vulnerability; the masking of extreme values through the use of means in the indices' calculation; and the potential for selection bias resulting from the exclusion of empty households from the sample.

Notwithstanding these drawbacks, the LVI gives public health experts and development organizations a place to start when evaluating the livelihood vulnerability of the communities they serve to the effects of climate change. This allows them to create advocacy agendas, design programs, and make sure that the community's most vulnerable sectors are strengthened. Compared to if we had only conducted a vulnerability assessment on one sector, we have been able to present a more complete picture of the study unions by breaking down the key factors that affect a population's susceptibility to climate change and examining the relationships between the factors.

In addition, the primary components of sectoral vulnerability, or relative indicators, offer data for programming and resource allocation to the people and sectors most at risk from climate change. To measure the condition of community social relationships more precisely, more work is required to build the sub-components of Social Networks. To assess vulnerability among communities in a union, the LVI approach could be tested at the community level. To ensure representative samples are at the community level, a sampling frame has to be constructed and some of the sub-components would need to be altered for application. A longer-term replication of this study in the same place would provide light on how unions' exposure, ability for adaptation, and sensitivity vary when fundamental sectors such as food, water, and health are improved, and adaptation techniques are implemented voluntarily or out of necessity. Lastly, it was really very difficult to find Upazila-based data for climate variability though it fluctuates a little in the Upazila level. But still, if the data could be found, more authentic result could be produced.

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