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Identifying Climate Scenarios and an Index-Based Assessment of Household Vulnerability to Climate Change in the South-West Coastal Region of Bangladesh

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Abstract

Climate change harms the households of coastal areas in Bangladesh because of the geographical position and changes in the climatic elements that are primarily at play. This study looks at the pattern of two prominent climatic elements: temperature and precipitation over thirty years, from 1992 to 2021, focusing on how those factors have changed. The findings revealed an upward increase in all elements, i.e., the maximum temperature, the lowest temperature, and the amount of precipitation. Using the Livelihood Vulnerability Index, this research looked at how vulnerable households are to the effects of climate change in the southwestern coastal area, namely in Amadi Union and Koyra Upazila in the Khulna district of Bangladesh. The original data came from a survey of 276 households and secondary data on rainfall and temperature for the period beginning in 1992 and continuing through 2021. The research conducted a comparative analysis to determine the household's vulnerability to climate change. The empirical research found that families in the Amadi union were moderately exposed to the effects of climate change and the weather variability regarding their strategies for making a living, their social networks, the food they have, and their level of health. By considering the socio-demographic elements, social networks, livelihoods, natural disasters, and climate variability, households of the Amadi union were equally vulnerable regarding their adaptation potential and exposure. These findings have implications for the governments, donor agencies, and other relevant agencies in Amadi Union, Koyra Upazila, and Khulna, initiating and implementing initiatives to adapt to climate change and increase household resilience.

Keywords: *Climate change, Climatic trend, Vulnerability, Livelihood Vulnerability Index.*

1. Introduction

Bangladesh is one of the countries that is among the most vulnerable to the effects of climate change. This vulnerable situation is due to the country's undesirable location, flat, low-lying topography, high density of population, extreme poverty, dependence on climate-sensitive industry segments, particularly agriculture and fisheries, and ineffective institutional characteristics (Climate Change Cell, 2006; DoE, 2012; Ahmed et al., 2013). Severe weather events have occurred in Bangladesh, a nation with a total area of 147,570 square kilometers and roughly 160 million people (BBS, 2001; Dewan, Yamaguchi, and Rahman, 2012). On average, there are 1015 people per square kilometer, and the yearly growth rate is 1.37 percent (BBS, 2011). The 35 million people who reside in the Bay of Bengal's low-lying coastal districts are particularly at risk from natural disasters such as storm surges caused by cyclones, coastal floods, river bank erosion, sea level rise, and saline water intrusion (BBS, 2013); (Dasgupta et al., 2014). The beaches of Bangladesh are dynamic, have multiple functions, and are challenging to represent spatially (FAO, 1998). The coastline of Bangladesh contains 147 sub-districts and 19 districts, with a combined size of 47,201 km^2 in total (BBS, 2013).

The country's coastline, which accounts for 32% of its total land, exacerbates the consequences of climate change. The problem at hand is the climate alteration in every region of the earth. Climate change results in weather that is both more severe and unpredictable (IPCC, 2007). Climate change includes both the increase in frequency and the increase in intensity. Disasters, such as floods, cyclones, tornadoes, tidal surges, storm surges, river banks, shoreline erosion, and droughts, are frequent occurrences in the tropical region of Bangladesh (Hahn, Riederer, and Foster, 2009).

The "cyclone season" runs from April to May and September to November, negatively impacting the lives of people experiencing poverty in twelve districts (Abu et al., 2017). These districts include Khulna, Bagerhat, and Satkhira. People of Khulna, Bagerhat, and Satkhira in the Southwest coastal zone lost their lives and their means of subsistence when river dams, dykes, and polders ruptured as a result of Cyclone Aila's tidal surges that reached a height of 13 feet on May 25, 2009. Before Aila, on November 15, 2007, a storm named Sidr battered the coastal districts of Bangladesh with a surge that was as high as 16 feet. In October 2022, storm Sitrang attacked the coastline of Bangladesh (The Daily Samakal, 2022). Recently, hundreds of residents were affected by flooding in Mafraq City's central and western areas. It is vital to manage such floods in

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order to keep them under control and reduce the effects they have on the local population (Amoush et al., 2017).

According to the Intergovernmental Panel on Climate Change (IPCC), climate change, induced by humans, is causing a dangerous and widespread disruption in nature, affecting billions of people worldwide (IPCC, 2022; Ahmed, 2019). Those populations and ecosystems that are the least equipped to adapt to changing conditions are the ones that will suffer the most (IPCC, 2022). The rising intensity and frequency of weather extremes, droughts, and flooding are already exceeding the limits of tolerance that plants and animals have evolved to resist, leading to the loss of entire ecosystems, such as forests and coral reefs (IPCC, 2022). They have put millions of people in danger of starvation and dehydration, particularly in Africa, Asia, Central and South America, tiny islands, and the Arctic (DoE, 2012). To reduce the number of lives lost, the biodiversity, and the infrastructure destroyed due to climate change, urgent, ambitious, and speedy adaptation to climate change is required, in addition to rapid and significant reductions in greenhouse gas emissions (IPCC, 2022).

Bangladesh is in South Asia (Ahmed et al., 2013). These tidal currents are indeed the source of a broad range of weather events, such as tropical cyclones, severe storms, coastline erosion, seasonal wind, vaporization for monsoon rains, floods, and saline intrusion (Islam et al. 2015). According to Ahmed et al. (2013), the coastal areas of Bangladesh are more prone to being negatively affected by the consequences of global warming (Ahsan and Warner, 2014). This study aims to analyze the climate scenarios and evaluate the sensitivity of a portion of Bangladesh's coastal areas to the effects that climate change will have on the way people live in that location. The Livelihood Vulnerability Index (LVI), produced by Hahn et al., is applied here in this research (Hahn, Riederer, and Foster, 2009). This index takes its primary data from housing units and uses some variables. As a result, it can measure not only the degree to which households are vulnerable to the effects of natural disasters and climatic variability but also their capacity for adaptation and their level of sensitivity to the effects of climate change. In addition, the computation of this index is more straightforward than other indices because it utilizes primary data from residences (Adger et al., 2009).

2. Materials and Methods

2.1 Study area profile

The research has been carried out in Amadi Union, Koyra Upazila, and Khulna, Bangladesh's southwest coastal districts. One of the most well-known sub-districts in Bangladesh's southern coastal belt is the Koyra sub-district of the Khulna District (Ahsan and Warner, 2014). The union's 41.47 square kilometer area is bordered to the north by the Chadkhali Union, to the east by the Maheshwarpur Union, to the south by the Koyra River, and to the west by the Kopotakkho River. In the Amadi Union, there are 27 villages and 17 mauzas (BBS, 2011). The meeting of three rivers, the Kopotakkho, the Sakbaria, and the Koyra River, is where the Koyra Subdistrict is situated. Men (19868), women (20336), and 8445 households make up the total population of 40200. The Amadi Union has a 77 percent literacy rate, which includes 14 high schools and three colleges (BBS, 2011; Koyra Upazila., 2011; Amadi Union Parishad, 2022). Due to its coastal location, the research area experiences cyclones, tidal waves, inundation, heavy rainfall, river erosion, saline soils, and waterlogging (Ahsan and Warner, 2014). Sidr in 2007 and Aila in 2009, two catastrophic storms, devastated the region in close succession (BBS, 2011). The Harinkhola Dam in Koyra Upazila of Khulna collapsed by 200 meters recently due to Cyclone Sitrang, and the seaports of Mongla and Payra received Distress Signal Number 7. As a result of Cyclone Sitrang, ten to twelve local villages, notably Upazila Parishad, were inundated, and the high tides in the nearby rivers surged by five to seven feet above regular waves (The Daily Samakal, 2022).

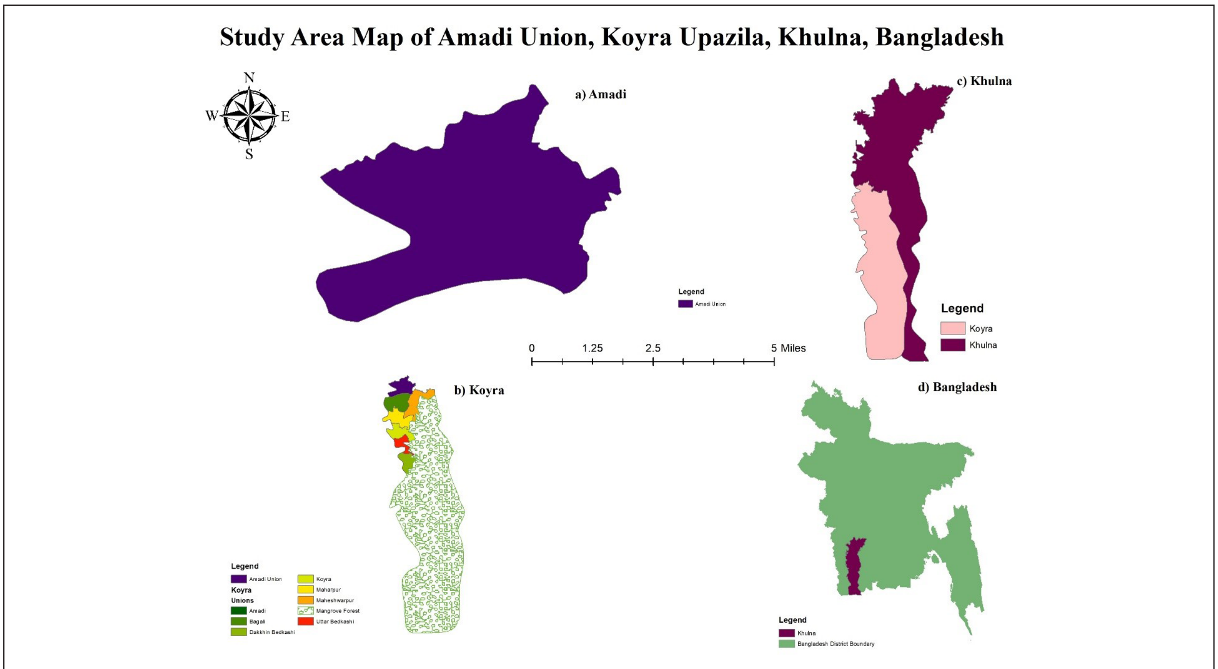


Figure 1. Amadi Union, Koyra Upazila, Khulna, Bangladesh

2.2. Data Collection

Primary and secondary data have been used to examine the climatic scenarios and livelihood vulnerability of Amadi Union, Koyra upazila, and Khulna, Bangladesh.

2.2.1. Primary data

The “Household Questionnaire Survey” was used to collect the primary data, and the sample size was initially determined using the “Yamane formula” (1967) with a 95% confidence level, 10% precision, and 50% prevalence:

$n = N/(1 + Ne^2)$ (1) (Yamane, 1967)

where, n = Sample size

N = Household size

E = Margin of error

Here, household size = 8445

The margin of errors = 0.005, and the sample size is 382 households.

$n = 8845/(1 + 8445 * (0.005)^2)$ =381.95

Using statistics from the 2011 national census, which determined the union’s total population, 276 residences, rather than (n= 382), were surveyed in the Amadi union due to weather conditions, a lack of time, and a shortage of employees. When the field team arrived at the block, community leaders were called to inform them of the study’s purpose and request permission to meet homes. The Expanded Program on Immunization of the World Health Organization (WHO)’s “random walk” technique served as the basis for the home sampling strategy (WHO, 2005). The survey was conducted in August 2022 from the 20th to the 26th.

2.2.2. Secondary data

Secondary data is information that another party has previously gathered. Data sources include government reports, websites, books, journal articles, and internal documents. Second-hand data sources include the Bangladesh Bureau of Statistics, World Bank Group, Climate Change Knowledge Portal, NASA Prediction of Worldwide Energy Resources (POWER) access data viewe, World Climate Data, Diva GIS portal, and Amadi Union Office. Secondary data on climatic elements were collected from the following source, as shown in the Table, and then processed in DIVA-GIS and MS Excel.

2.3. Examination of Climate Scenarios

2.3.1. Trend analysis of climatic elements (temperature and rainfall)

The trend analysis uses the monthly maximum temperature and monthly lowest temperature data. Y = a + bx connection was used to calculate the central tendency value (represented by value a) and rate of incremental value (represented by value b). Then, a straightforward statistical analysis was performed using the mean, range, standard deviation, and coefficient of variation (RECOFTC, 2016). The following relationships were used to derive linear trend line equations based on the 30 years of temperature time series records (1992–2021). This study has calculated the climatic elements trend analysis only for the Koyra Upazila, not the Amadi union because union-level data is too small to find the climatic variations. Climatic elements data, i.e., temperature and rainfall, are similar for both the Union and Upazila levels. That is why this study has used the Upazila level data to analyze the climatic trend of Koyra Upazila.

$Y = a + bx$ (2) (RECOFTC, 2016).

Thus, for a given time t, the estimated value Y_e of Y (temperature axis) can be written as

$Y_e = a+bx$ (3) (RECOFTC, 2016).

The value of a and b was computed by using equations 3 and 4 respectively

$\sum Y = na + b\sum x$ (4) (RECOFTC, 2016).

Hence, $a = \sum Y/n$ as b becomes zero.

$\sum xy = a\sum x + b\sum x^2$ (5) (RECOFTC, 2016).

Hence, $b = \sum XY/\sum x^2$

where n is 30 (climatic data series of 30 years), and t is the corresponding time. The existing and future maps are prepared using DIVA-GIS 7.5 world climate data (RECOFTC, 2016).

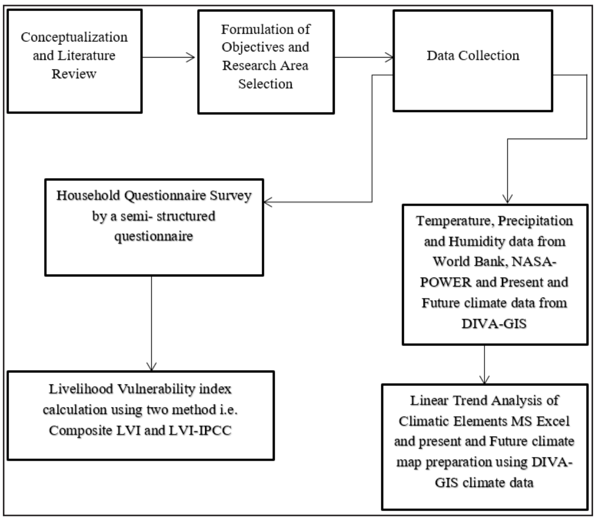


Figure 2. Methodological framework of the research

2.3.2. Assessment of Livelihood Vulnerability

2.3.2.1. Calculation of Livelihood Vulnerability Index (LVI)

This study utilized a metric known as the Livelihood Vulnerability Index (LVI), conceived by Hahn and his colleagues (2009). The extent to which a household is susceptible to the impact of climate change and natural disasters, as well as the household’s capacity for adaptability and responsiveness to the effects of climate variability, can be determined by some variables. These variables include the family’s location, the family’s socioeconomic status, the family’s level of education, and the family’s story of income, etc. (Hahn et al. 2009). Except for the data about temperature and precipitation, the computation of this index is made much simpler, thanks to the utilization of data gathered from individual residences.

The research relied on a total of eight essential components, including the socio-demographic profile (SDP), livelihood strategies (LS), social networks (SN), natural capacity, health (H), food (F), water (W), and natural disasters (ND). While calculating the vulnerability index, Hahn et al. (2009) used a symmetrical weighted average method. This method ensures that each indicator contributes the same amount to the overall index, despite different components, including varying numbers of indications. As a result of the fact that each hand would be tracked on a unique scale, it was first necessary to normalize each indicator so that it could be represented by an index employing equation 6:

$$\text{Index } X_{ij} = (X_{ij} - \text{Min } X_i) / (\text{Max } X_i - \text{Min } X_i)$$

(6) (Hahn et al. 2009).

Index Xij signifies the index score (0–1) of the sub-component or indicators for union j, Xij signifies the value of the ith hand for each union, and Max Xi and Min Xi illustrate the maximum and minimum values of the ith indicator throughout all blocks. After indexing all of the arrows, the average of the importance of the hands was used to get the value of each significant component. Finally, the following equation 7 was used to determine each of the eight primary members:

Livelihood Vulnerability Index,

$$LVI_j = \frac{(W_{SDP}SDP_j + W_{LS}LS_j + W_{SN}SN_j + W_{NRE}NRE_j + W_H H_j + W_F F_j + W_{ND}ND_j)}{W_{SDP} + W_{LS} + W_{SN} + W_{NRE} + W_H + W_F + W_{ND}}$$

(7) (Hahn et al. 2009).

The total weights of each single component are added together to get the vulnerability index, which is the same thing. The number of subcomponents used to manufacture an element might impact the Wmi, also known as the component's overall weight. For instance, if the SDP consists of four indicators, the WSDP will similarly contain four. In this scenario, the livelihood vulnerability index for district j, abbreviated as LVIj and "the livelihood vulnerability index for district j," corresponds to the weighted mean of seven primary components. To ensure that each sub-component contributes an equal amount to the total LVI, the weight values of each significant element, which Wmi denotes, are calculated according to the absolute number of sub-components contained within that considerable component (Sullivan, 2002). This research utilized a scale of LVI grades ranging from 0 to 0.2, being considered not to be vulnerable, 0.21 to 0.4 being moderately vulnerable, and 0.441 to 0.5 being very vulnerable (Suryanto and Rahman, 2019).

2.3.2.2 LVI-IPCC

The IPCC-LVI is yet another tool to create indices that indicate vulnerable places. According to the Intergovernmental Panel on Climate Change, vulnerability results from three contributing elements: adaptive capacity, susceptibility, and exposure. Adaptive capability refers to an individual's ability to adjust to changing conditions (IPCC, 2001; IPCC, 2011).

Vulnerability = *f* (Exposure, Sensitivity, and Adaptive capacity) (8) (IPCC, 2001).

The following equation brings together, among other factors contributing to openness, the components of the vulnerability index known as exposure, ability to adapt, and sensitivity (Hahn et al., 2009).

$$CF_j = \frac{\sum_{i=1}^{n} W_{mi} M_j}{\sum_{i=1}^{n} W_{mi}}$$

(9) (IPCC, 2001).

Where Wmi is the number of factors that comprise each component, CFj is the factor contributing (exposure, sensitivity, or adaptive capacity) to the union j, and Mij is the significant component for the j union indexed by i. Following the IPCC's definition of vulnerability, IPCC-LVI was computed after accounting for exposure, sensitivity, and adaptive capacity.

IPCC-LVI = (EI – AI) × SI (10) (IPCC, 2001).

The sensitivity index is SI, the adaptive capacity index is AI, and the exposure index is EI. This study employed the LVI-IPCC scale, ranging from (-1) to (-0.4), which is not vulnerable, through (-0.41) and (0.3) which is moderately weak, and (0.31) and (1) which is highly vulnerable (Suryanto and Rahman, 2019).

3. Results and Discussion

3.1. Examination of climatic scenario

3.1.1. temperature

The following figures show a positive linear maximum temperature trend in Koyra Upazila, Khulna. In 1992, the annual maximum temperature was 42.35 degrees Celsius; in 2021, it was 43.48 degrees Celsius. The current maximum yearly temperature of Koyra Upazila ranges from 30 degrees Celsius to 31 º degrees Celsius, which will increase to 33 degrees Celsius by the year 2100, showed in the maps. However, Hossain et al. (2014) showed that the lowest average temperature is in January, and it will gradually increase until June, fluctuating from July to October, and then decreased until December in Dhaka.

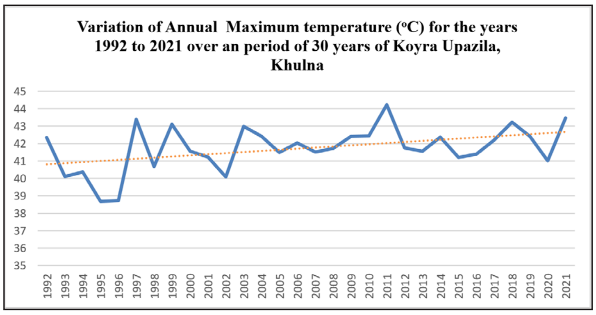
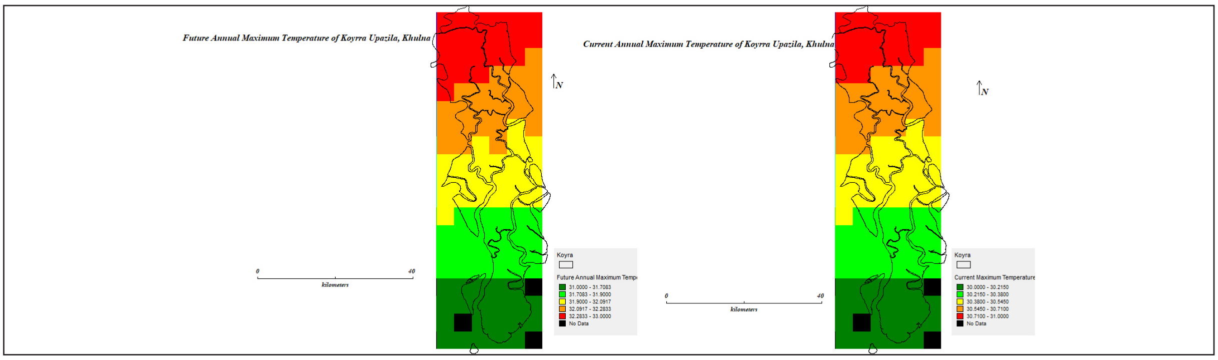


Figure 3. Variation of Annual Maximum temperature (ºC) for the years 1992 to 2021



Figures 4. (left) and **5.** (right). Map of Annual Maximum Temperature (Current and Future) of Koyra Upazila, Khulna Source: World Climate Data 2022

Yet for each month in 2021, compared to 1992, the monthly minimum temperature has also increased linearly. The temperature variation lends credence to the observed size and frequency of extreme weather events, resulting from global warming. Figure 6 shows that there is a positive linear trend of minimum temperature in Koyra Upazila, Khulna. In 2013, the annual minimum temperature was recorded lowest at 17.73 degrees Celsius. In 2017, it was the highest at 19.34 degrees Celsius. In 2021, the annual minimum temperature was 18.87 degrees Celsius, and in 1992 it was extremely low at 18.27 degrees Celsius.

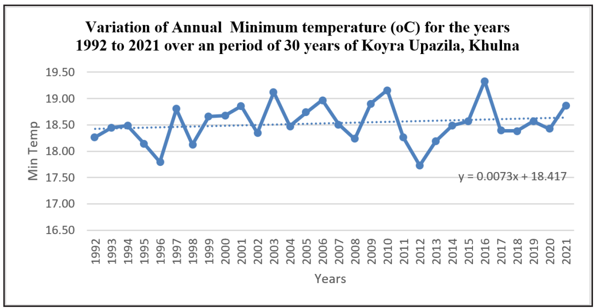


Figure 6. Variation of annual minimum temperature (°C) for the years 1992 to 2021

3.1.2. Rainfall

The second climatic element to examine climate scenarios is the amount of rainfall. The annual precipitation of Koyra Upazila has a positive linear trend that denotes an increment in yearly rain. The annual rainfall (SD value) in 1992 was 2.64, which increased to 6.72 in 2021, achieving a more significant increase in annual precipitation and cyclones, i.e., Mahasen and Nargis attacks. In 2007, the annual rainfall (SD value) was 5.76, and this year cyclone Sidr attacked the coastal belt of Bangladesh. In 2020, several cyclones shot the coastal belt of Bangladesh, i.e., Foni, Bulbul, and Amfan, and the precipitation level (SD value) of that time was 7.48. The Figure below represents the Khulna district's annual precipitation from 1992 to 2021. The following maps show current and future annual precipitation. The yearly rainfall ranged from 1170 mm to 2072 mm and 1794 mm to 2022 mm.

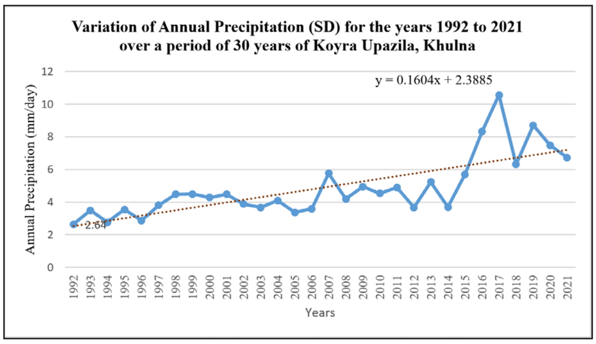
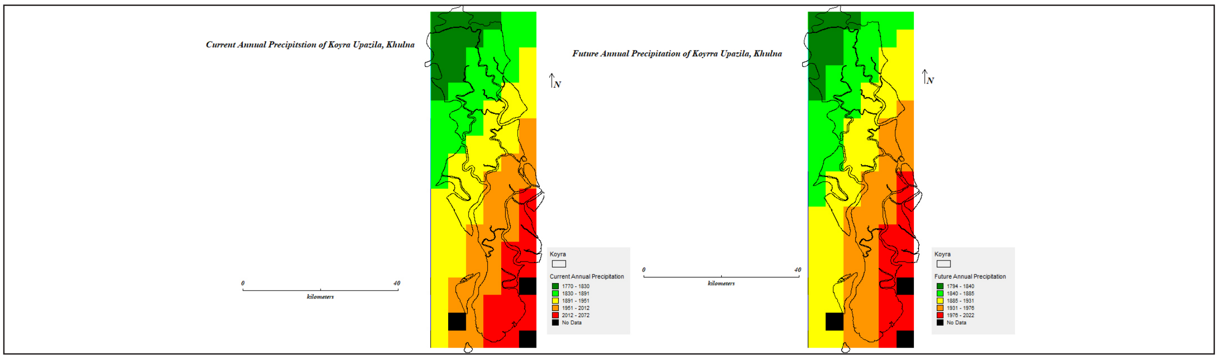


Figure 7. Annual Precipitation (mm) of Koyra Upazila, Khulna District, over the period 1992 to 2021



Figures 8. (left) and **9.** (right). Map of Annual Maximum Rainfall (Current and Future) of Koyra Upazila, Khulna
Source: World Climate Data, 2022

3.2. Assessment of Livelihood Vulnerability

3.2.1. Livelihood Vulnerability Index (LVI) of Amadi Union, Koyra, Khulna

Data from 276 households in the Amadi Union, Koyra were used to calculate the LVI and the LVI-IPCC. The LVI scores suggest that families in Amadi have a moderate vulnerability (LVI=0.40), and the LVI-IPCC scores indicate the same thing (-0.0013). Therefore, these scores reflect the same conclusion.

According to the findings, the vulnerability indices of the primary component fell somewhere in the range of 0.24 to 0.55. The index varied from 0 to 0.2, representing non-vulnerability, 0.21 to 0.4, representing moderate vulnerability, and 0.41 to 0.5, representing very vulnerable. The composite value of the LVI was 0.40, which indicates moderate exposure according to the index.

The Socio-Demographic Profile (SDP), consisting of six subcomponents, was the first significant component of the study. The analysis, as a whole, was conducted using these six subcomponents. According to the socio-demographic profile index, which gave the degree of vulnerability a score of 0.24, the level of exposure was assessed to be moderate on the indexed scale. The dependency ratio index for the Amadi Union was 0.278, which indicated that the proportions of the people, under 15 and over 65 years old, who were dependent were moderate, showing moderate vulnerability. Additionally, the proportions of dependents, under 15 and over 65 years old, were reasonable and indicated moderate exposure. It is estimated that approximately 18% of the heads of households in the union did not have a primary education, which means that they did not ever attend school at any time in their lives. On average, 5.17 persons called each house their home, and the vulnerability score for the typical family member was 0.314, which is in the moderate range. In addition, the average age of heads of households was 38.67 years old, with an index of the average age of

0.408, suggesting a greater degree of vulnerability. Just 12.3 percent of household members possessed any expertise, either formal or informal, while women headed 16.3 percent of households. Based on this statistic, it may be deduced that households headed by women will be more vulnerable than those led by men.

Table 1. Indexed major component and overall LVI value (calculated using equation 12)

LVI-IPCC	Major Component	Sub Component	Amadi, Koyra
Adaptive Capacity 0.377	Socio-demographic profile (SDP)	Percentage of Female-headed household	0.24
		Average Age of Household Head	
		Dependency ratio	
		Percentage of Households where the Head of the household Head had not attended school	
		Percentage of Households where members had any formal or informal skill	
		An average family member in a household	
	Livelihood Strategies (LS)	Percentage of Households dependent solely on agriculture as an income source	0.55
		Percentage of Households dependent on other occupations	
		Percentage of Households who have the burden of a loan	
	Social Networks (SN)	Average Time to reach nearest vehicle station (Minutes)	0.48
		A percentage of HHs have communicative devices (TV, radio, mobile, etc.) at home	
		Percentage of HHs where a family member is affiliated with any organization	
Sensitivity 0.44	Food (F)	Percentage of Households dependent solely on the family farm for food	0.46
		Percentage of Households struggle to find food to support the whole year	
		Percentage of Households with a primary irrigation source	
		Percentage of Households that do not save crops	
	Natural Capacity (NC)	Average Household income per month	0.34
		Percentage of Households using natural resources for livelihood	
		Percentage of Households with fertile land	
	Health (H)	Average Time to health facility (minutes)	0.51
		Percentage of Households with a family member with chronic illness	
		Percentage of Households receiving treatment from government or private hospitals	
	Water (W)	Percentage of Households that utilize a natural water source	0.48
		Average Time to reach water source (minutes)	
		Percentage of Households reported to have a water availability problem	
Exposure 0.374	Natural disasters and climate variability (ND)	The average number of flood, cyclone, storm surge, and river bank erosion events in the past six years (Years: 2016-2021)	0.374
		Households that did not receive a warning about the pending natural disasters	
		Mean standard deviation of the monthly average of average maximum daily temperature (years: 1992 to 2021)	
		Mean standard deviation of monthly average minimum daily temperature (years: 1992 to 2021))	
		Mean standard deviation of monthly average precipitation (years: 1992 to 2021)	
LVI-IPCC -0.0013	Overall LVI (using equation 03)	0.40	

The plan consisted of three sub-components subdivided into the Livelihood Strategies (LS), the second most essential aspect of the project. When each of the individual components is aggregated, Amadi displayed a level of susceptibility that is noticeably elevated to a much higher level. There are 39 percent of households in the neighborhood whose sole source of income comes from agricultural endeavors. Amadi is also home to families heavily dependent on various types of employment, including but not limited to business people, drivers, day laborers, fishermen, and a variety of others. In addition, the weight of loan payments is carried by 56% of households, which implies a higher level of vulnerability. This value demonstrates that a family's dependence on the agricultural sector makes them more vulnerable to the effects of climate change than families whose primary source of income is not agriculture. They are more resilient to the impacts of climate change. Because around 70 percent of people live outside of cities and work in other economic sectors, they are far less vulnerable to the effects of climate change.

The Social Network (SN) was the third component, and it was subdivided into three different parts to understand it better. Amadi revealed a higher degree of susceptibility when each constituting element was considered (0.488). The average time necessary to reach the next vehicle station was 19.48 minutes, and an index score of 0.262 indicates moderate vulnerability. Around 94.9 percent of residents had communication equipment, such as televisions, radios, and mobile phones (59.1 percent). This equipment included radios, televisions, and mobile phones. Only 25.4% of people living in households were members of any government or non-government bodies, that would make people more vulnerable to the effects of climate change.

The fourth component was food (F), broken down into four distinct subcomponents before being assembled. The total score for this component was 0.46, suggesting a greater degree of susceptibility to the consequences of climate change. This score was determined by adding together all of the values of the sub-components. The fact that 51.4% of households had trouble locating sufficient food to last throughout the year indicates greater vulnerability. When a family knows they will always have food available, they can better deal with the pressures from the outside world, such as those brought on by extreme weather (World Bank, 2010).

As a result of the fact that people, communities, and nations have access to more significant amounts of high-quality food, actual prices decline. Because of this decline, the basic incomes of these organizations can grow, as they develp strategies for adjusting to the effects of climate change (World Bank, 2010). In the Amadi Union, approximately 32% of the households obtained all their food from family farms, while 82% did not store their crops. This hugepercent presents a challenge since farm households that derive most of their nourishment from their crops are more exposed to the adverse effects of climate change. According to the food subcomponent index, the families whose primary food source comes from their crops are most sensitive to climate change's impacts. These households do not store food for use in times of need when the weather is unexpected. And just 19% of households have access to some irrigation supply, which leaves them vulnerable to the effects of climate change and makes them more likely to be affected by natural disasters.

The seventh primary component of the formula was denoted by the letter "W," and it was water, composed of three sub-components. The element of the vulnerability index known as water has Amadi's highest recorded score of any other location (0.48). Most Amadi households, 58.7%, have claimed that natural water sources are their primary potable water supply. The existence of natural water sources increased the likelihood that a family would fall victim to waterborne diseases. Moreover, natural water sources made it more challenging to obtain water during the dry season. Because of the proximity of the water sources to one another in each of these villages, the majority of the responsibility for gathering water fell on the shoulders of the women and children. The number of hours working mothers spent watching for their children and sending them to school did not significantly change. They are compelled to look for alternative water sources to satisfy their family's requirements for water in an area where seventy percent of households reported having water availability problems. It takes an average of seven minutes to get to the closest source of water, which gives it an index value of 0.16, indicating a reduced level of vulnerability. In recent years, the Tigris River has faced a number of challenges, including a lack of resources, dam construction by neighbouring countries, and the inflow of industrial and agricultural waste water as well as local trash (Hadithi et al., 2019).

The eighth and final main component was natural disasters and climatic variability (ND), which had five sub-components to make up the components as a whole. When everything was considered, the data for the Amadi Municipality suggested a higher level of danger (0.374). A notice about an imminent natural hazard with indices of 0.275 was provided to around 27.5 percent of households in the Amadi Union that did not receive a warning about the most catastrophic flood, drought, and cyclone event that has occurred in the preceding six years in the region. During the past six years, the Amadi Union has documented an annual average of three instances of flooding, cyclones, storm surges, and bank erosion (Years: 2016-2021).

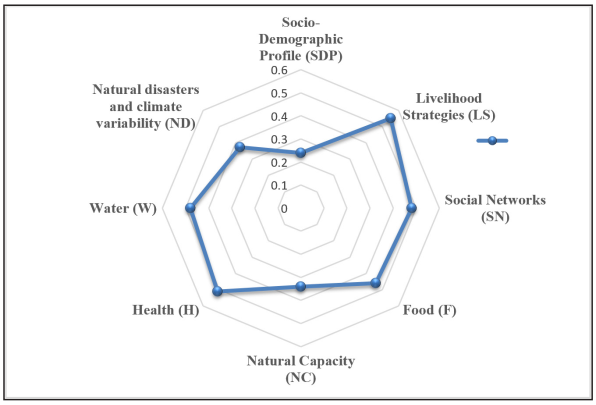


Figure 10. Vulnerability score of the major components of the Livelihood Vulnerability Index (LVI) for Amadi Union, Koyra Upazila

2016 and 2017 witnessed the fewest natural disasters (2), compared to 2020, which had the most natural disasters (5). Given that the index for this union is 0.3, it can be deduced that its susceptibility to the effects of climate change is moderate. During the 30 years, the Amadi Union reported an index of 0.464 for the mean and standard deviation of monthly average minimum daily temperatures and an index of 0.53 for the mean standard deviation of monthly average maximum daily temperatures. Both of these values were based on monthly averages. The weights, observed for Amadi's indices on the mean standard deviation of monthly average precipitation, were 0.263 throughout the research, which spanned from 1992 to 2021. According to the mean standard deviation of the monthly average rainfall, these values would indicate that the Amadi Union had a degree of susceptibility in the middle of the spectrum.

3.2.2. LVI-IPCC for Amadi Union, Koyra, Khulna

The following figures show a positive linear maximum temperature trend in Koyra Upazila, Khulna. In 1992, the annual maximum temperature was 42.35 degrees Celsius; in 2021, it was 43.48 degrees Celsius. The current maximum yearly temperature of Koyra Upazila ranges from 30 degrees Celsius to 31 º degrees Celsius, which will increase to 33 degrees Celsius by the year 2100, showed in the maps. However, Hossain et al. (2014) showed that the lowest average temperature is in January, and it will gradually increase until June, fluctuating from July to October, and then decreased until December in Dhaka.

According to the data, the overall score for the LVI-IPCC was -0.0013. This places it in the category of vulnerable or moderate, depending on how the index, is interpreted. According to the final IPCC weighted LVI scores, a score between (-1) and (-0.4) indicates that a region is not vulnerable to climate change and variability; a score between (-0.41) and (0.3) suggests that an area is weak or moderate; and a score between (0.31) and (1) indicates that a part is the most vulnerable to climate change and variability. Scores ranging from (-0.31) to (1) show a vulnerable to moderate level of exposure. The eight key components were first separated into their respective categories—exposure, sensitivity, and adaptive capacity to arrive at the LVI-IPCC.

Table 2. IPCC-LVI contributing factors and their indexed value

Contributing Factors	Major components for Amadi Union	Number of sub-components per major component	Contributing factor values	LVI–IPCC value for Amadi
Adaptive Capacity	Socio-demographic profile (SDP)	6	0.377	-0.0013
	Livelihood Strategies (LS)	3		
	Social Networks (SN)	3		
Sensitivity	Food (F)	4	0.447	
	Natural Capacity (NC)	3		
	Health (H)	3		
	Water (W)	3		
Exposure	Natural disasters and climate variability (ND)	5	0.374	

The Intergovernmental Panel on Climate Change (IPCC) has come up with a definition of vulnerability that considers exposure, sensitivity, and adaptation. This idea is depicted in the form of the vulnerability triangle, which at any given time can have any value between 0 (which indicates a low contributing component) and 0.44 (which indicates a vital contributing part) (high contributing factor). Based on the vulnerability triangle findings, it is possible to deduce that the families comprising the Amadi Union were moderately vulnerable to climate change and variability. When one considers the circumstances of the families in the association regarding their access to water, their state of health, and their inherent abilities, one arrives at the current state of affairs. We observed that the Amadi Union homes had a capability for household adaptation that made them less sensitive to the effects of climate change.

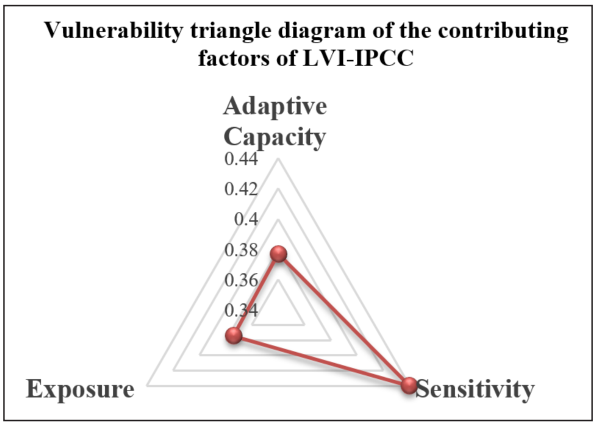


Figure 11. Vulnerability triangle of LVI-IPCC for Amadi Union, Koyra Upazila

The fact that adaptable capacity received a score of 0.377 and exposure received a score of 0.374 indicates that adaptive capacity is almost equal to exposure, although sensitivity received a score of 0.44. Amadi Union is more vulnerable to the effects of natural catastrophes and climatic fluctuations than its ability to adapt.

4. Conclusion

In particular, the LVI and LVI-IPCC methodologies were presented in this study so that the relative susceptibility of populations to the effects of climate change could be determined. Each strategy offers a comprehensive investigation of the elements contributing to the precariousness of households' means of subsistence in a given region. The LVI and LVI-IPCC calculation algorithms were developed to be easily comprehended by many people across various contexts. When comparing two or more research regions using vulnerability spider and triangle diagrams, more information is attained. Our methodology has a few flaws, the most notable of which are the subjectivity involved in selecting the sub-components, the directionality of the relationship between the sub-components and vulnerability, the masking of extreme values by using methods to calculate the indices, and the potential for selection bias due to the exclusion of empty homes from the sample. All of these issues are discussed in more detail below. It is possible to repeat this study in the same region over time to learn more about how districts' exposure, aptitude for adaptability, and sensitivity change as adaptation methods are implemented. In subsequent studies, improving the Social Networks and Natural Capacity subcomponents may be necessary to obtain a more precise measurement of social links. The LVI approach can also be used to analyze the vulnerability of a neighborhood within a district by evaluating the neighborhood level. The Livelihood Vulnerability Index (LVI) is a valuable tool for urban planners. It allows them to assess people's livelihoods' susceptibility to climate change's effects in their areas and devise ways to bolster the most vulnerable industries. In addition, this research provides a valuable tool for understanding the demographic, socioeconomic, and health factors that influence climate sensitivity at the district or community level. Professionals in public health, lawmakers, and development organizations will all be able to benefit from this tool. The research also demonstrates the trend, existing status, and predicted future conditions of the climatic elements. These findings encourage local citizens and the government to create plans and take appropriate action in response to the state of the climatic factors.

Conflict of Interests

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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