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Exploring the Dynamics of Climate Change Vulnerability and Adaptation of Southwestern Coastal Communities in Bangladesh

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Abstract:- The geographical location of Bangladesh places it as one of the most disaster-prone countries in the world, with this condition prevailing more in the coastal areas of which the Satkhira district is a part. This paper presents an assessment of climate vulnerability of communities through an evaluation of a vulnerability index that combines a wide variety of inland and coastal climate hazards. Results have shown that 29.73% are vulnerable, while 65.60% are highly vulnerable to the impacts brought forth by climate change. This research presents critical insights in aiding local decision-makers through the examination of vulnerabilities in developing appropriate adaptation strategies. These are all very important for developing a better adaptive capacity by the coastal population in resisting climate-related extreme events. The identified adaptation strategies are compatible with the present climatic condition and have the intention of mitigating the long-term risks from the change in climate along with the immediate threats. It is envisaged that the research will contribute to improving livelihoods and enhancing resilience among affected communities to current and future climatic hazards. The study recommended focused interventions in livelihood protection and reduction of vulnerability in most disaster-prone areas, such as Satkhira District. Adaptation is urgently needed for the very survival of these communities. This will help them in framing appropriate strategies that can reduce and control the risks from present and future climatic events. Hence, this study underlines the most important need for proactive measures to safeguard the most vulnerable populations inhabiting the Bangladesh coast.

Keywords:- *Vulnerability, Hazards, Climate Change, Indexing, Coastal.*

I. INTRODUCTION

Due to globalization, we are facing numerous problems like, climatic hazards, global warming, poverty and hunger, etc. and all these events lead people to vulnerability in many aspects of life. Vulnerability is the state of being exposed to the possibility of being attacked or harmed, either physically or emotionally. It is a measure to identify how easily hazards can create effects on human livelihood and physical property.

The 1970s and 1980s research on disaster risks and vulnerability had a considerable impact on the vulnerability literature (Prowse, 2003). The behavioural paradigm and the structuralist paradigm are two schools of thought that can be used to characterize catastrophe vulnerability studies (Adger, 2006). According to the behavioral paradigm, risks are brought on by strong natural factors, and failure to adjust is due to "poor perception of risks and hazards" (Burton et al., 1993 as cited in Adger, 2006). Due to its limited ability for adaptation, dense population, flat landscape, and susceptibility to several natural calamities such as cyclones, storm surges, sea level rise, tidal floods, bank erosion, etc., Bangladesh's western coastal region is extremely vulnerable (Islam, Uddin and Bala 2018). It is becoming more and more obvious that different towns along the western coast are affected by disasters in different ways—and not always uniformly. The location of the family, the gender of the head of household, and the assessment of disaster vulnerability in terms of exposure, sensitivity, and capacity for adaptability across various well-being groups were all considered in this study. There are many factors that contribute to vulnerability, including physical ones (such as poorly designed housing), social ones (such as poverty, inequality, and social exclusion), economic ones (such as reliance on a few industries in rural areas), and environmental ones (such as poor environmental management and climate change) (UNDRR Terminology, 2017). Five important adaptation approaches have been discussed based on criteria such as geographic location, adaptation providers, sustainability and gender attitudes, vulnerability, and system resilience (Hossain and saha, 2015). These methods include, among others, the construction of cyclone shelters, the installation of pond sand filters (PSF), the development of salinity-resistant rice varieties, the planting of floating gardens and dike crops, the binding of rivers, and the construction of robust dwellings. These techniques have been proven to be sustainable due to their efficacy, benefits to the stakeholders, wide acceptance, and accessibility. They also encounter challenges include inadequate site selection, poor operation and maintenance, a lack of money, resources, and local implementation experience. Despite challenges, these methods have improved the livelihood vulnerability of the villagers by increasing productivity, income, and food security. Thus, it is believed that these changes will help Bangladesh's western coastal region avoid further alterations. Climate change is a vital consideration to make people more vulnerable. Climate not only affecting environment but also

affecting human (Thornton et al., 2014). Due to climate change, natural hazards are regular phenomenon in recent times. Natural hazards from coastal storms, flooding, cyclone and sea level rising are increasing every year and threatening human life and property (Weis et al., 2016). According to the Pressure and Release model, vulnerability can define by three dimensions such as root causes, dynamic pressure and unsafe conditions. The negative consequences of natural hazards are the result of vulnerability of the society at risk exposed (Fuchs et al., 2012). Besides climate change, poverty also a major factor of vulnerability and both are widely linked in the context of vulnerability (Coirolo & Rahman, 2014). The people of coastal regions are facing more challenges due to their geographical location and human settlement patterns under the contemporary climate change context (Ha-Mim et al., 2020). Deprivation in different aspects like, safe drinking water, access to resources, education, safety nets, government intervention, employment, etc. lead coastal people to vulnerable situation. Adaptation strategies help to cope up the effects of hazards and reduce vulnerability. The term adaptation can be explained from different point of views in different disciplines. In broader sense, adaptation in the context of human dimensions of global change usually refers to a process, action or outcome in a system (households, community, race, groups, regions, country) for the system to better cope with, mange to some changing condition, stress, hazard, risk or opportunity (Smit & Wandel, 2006). To reduce the effects of continues damages of natural hazards, people of coastal regions introduced themselves with some adaptive capacity or strategies which helping them to better cope up with the challenges of environmental hazards (Engle, 2011).

A crucial initial step in effective disaster risk reduction is vulnerability assessment. Disaster management in many at-risk nations is primarily focused on operations related to emergency response, disaster relief, and rehabilitation (Roy & Blaschke, 2015). This paper is going to assess the vulnerability scenario and assess the adaptation capacity or strategies of coastal people.

II. MATERIALS AND METHODS

A. Study Area

The research was conducted in three unions of Shayamnagar Upazila in the Satkhira district: Gabura, Munshigonj, and Burigoalini. Gabura Union, located in the southeastern part of Satkhira district, lies adjacent to the world-famous Sundarbans and is separated from the mainland by the Kholpetua River. Covering an area of 41.26 square kilometers, Gabura is bordered by Padmapukur Union to the north, the Kapotakhha River and Khulna district to the east, and the Sundarbans and Kholpetua River to the south. It is approximately 27 kilometers from the upazila headquarters and 82 kilometers from the Satkhira district headquarters. The union is renowned for crab fattening, which engages about 40% of the population, making it a preferred livelihood over shrimp farming. Additionally, 19% of the residents depend on shrimp farming, 23% on agriculture, and others engage in fishing, day labor, and small trades. Despite its economic activities, over 75% of the population lives below the poverty line. The literacy rate is 35.9%, with male literacy at 38.8% and female literacy at 33.2% (Census 2011).

Munshigonj Union, located 15 kilometers from the Shayamnagar upazila headquarters and 70 kilometers from the Satkhira district headquarters, spans 39 square kilometers. It is surrounded by Burigoalini Union to the north and east, Isshawripur Union to the west, and the Malonchi River and Sundarbans to the south. The Malonchi River forms a natural boundary separating it from the Sundarbans. The union's primary livelihood is fishing, a significant occupation that often involves children, negatively impacting their education. Approximately 70% of the population lives below the poverty line. The literacy rate is 50.1%, with male literacy at 57.1% and female literacy at 43.7% (Census 2011).

Burigoalini Union, established in 1950, is located beside the Sundarbans in the southeastern part of Satkhira district. It covers an area of 43.10 square kilometers and is bordered by the Kholpetua River to the east, Isshoripur Union to the west, and Atulia Union to the north. The union consists of 20 villages spread across nine wards. Crab fattening is the dominant livelihood, involving 42% of the population, while 19% depend on forest resources, 16% on shrimp farming, and 23% on agriculture and other occupations. Despite its economic diversity, about 64% of the population lives below the poverty line (Profile of Burigoalini Union, 2014).

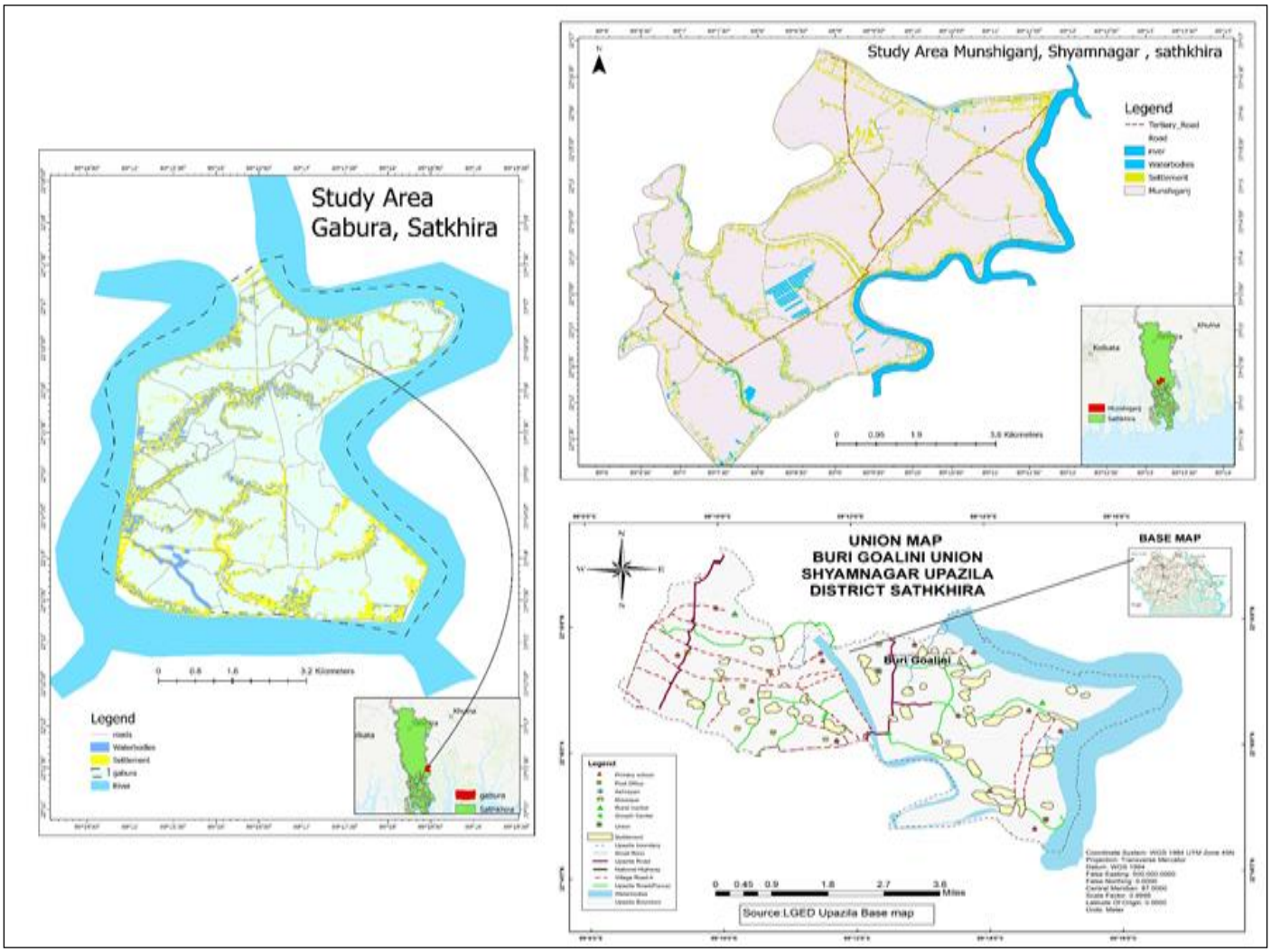

Fig 1. Study Area: Gabura, Munshiganj and Buri Goalini

B. Sample Determination

In the survey stage of the research, use Raosoft data sampling calculation method. The Raosoft sampling is mainly a primarily calculation method which gives you the sample size of a survey based on total household, margin of error, confidence level or uncertainty and the response distribution level. The formula for Raosoft calculation method is given below,

$$x = z\left(c/100\right)^2 r(100-r)$$

$$E = sqrt\left[(N-n)x \Big/ n(N-1)\right]$$

$$n = Nx \Big/ \left((N-1)E^2 + x\right)$$

Where, N is the household size, E is the margin of error r is the fraction of responses that you are interested in, Z(c/100) is the critical value for the confidence level c and n is the sample size.

Table 1: Sample Determination of the Research

Total Household of Study Area	**19728**
Confidence Level	95%
Marginal Error	5%
Sample Size	407

C. Major Components

The study created a variety of analysis techniques to achieve our goals. We started "Household Vulnerability Indexing" to evaluate the vulnerability of the south-western coastal region. Our analysis' second section evaluates the study area's adaption strategies. The study developed "Principal Component Analysis" to evaluate the adaption strategies. It was important to decide major components and indicators for indexing.

Table 2: Major Components of Vulnerability Assessment

	Major Component	Indicator/Sub-component	Explanation	Functional Relationship	Unit
Adaptive Capacity	Socio-Demographic Profile (SDP)	Sex of HH	Household Head is female headed then that household will be more vulnerable	Positive	Male /Female
		Education of Household	Members of household with no education	Positive	Count
		Number of Family Member	Household have 6 or higher number of members	Positive	Count
		Safety nets	Households which are not able to access safety nets are more vulnerable	Negative	Yes/ No
		Disability	Household have disable member	Positive	Count
	Food (F)	Portions of Food	Eat smaller portions of food in 3 or more days of week	Positive	Count
		Times	Counts of eat less than three times in a day	Positive	Count
		Borrow Money	Borrowed money to buy food	Negative	Count
Sensitivity	Institutional Services (IS)	Membership in community-based organization	Member attached with community-based organizations	Negative	Yes/ No
		Received Assist From NGO	Household received no assist from NGOs	Positive	Yes/No
		Got Relief	Household got relief in the time of natural hazards	Negative	Yes/No
	Infrastructure Facilities (IF)	Lives in kutcha House	Household lives in kutcha house are more vulnerable	Positive	Yes/No
		Sanitary Toilet	Household have no access to sanitary toilet	Positive	Yes/No
		Drinking Water	Access to safe drinking water	Negative	Yes/No
		Distance of Cyclone Center	Distance of cyclone center from house	Positive	Value
	Economic Function (EF)	Savings	Household have savings	Negative	Yes/No
		Having Dept	Household having depth in amount	Positive	Monitory Value
		Productive Assets	Having livestock	Negative	Count
		Amount of land	Household have no productive land	Positive	Yes/No
Exposure	Exposure to Natural Hazards Warning (ENH)	Flood In last 5 years	Number of floods occurred in last 5 years.	Positive	Count
		Cyclone In last 5 years	Number of Cyclone occurred in last 5 years.	positive	Count
		River Erosion In last 5 years	River erosion occurred in last 5 years	positive	Count
		Warning	Households that did not receive warning about natural hazards	positive	Count

D. Exploring the Nature of the Data

➢ *Distribution of Respondents*

From this pie chart, we can see we got most of our respondents from Buri Goalini Union. We took 2nd highest number of respondents (29.80%) from Munshigonj Union. Due to accessibility issues and weather complexities, we took our least number of respondents (9.60%) from Gabura Union.

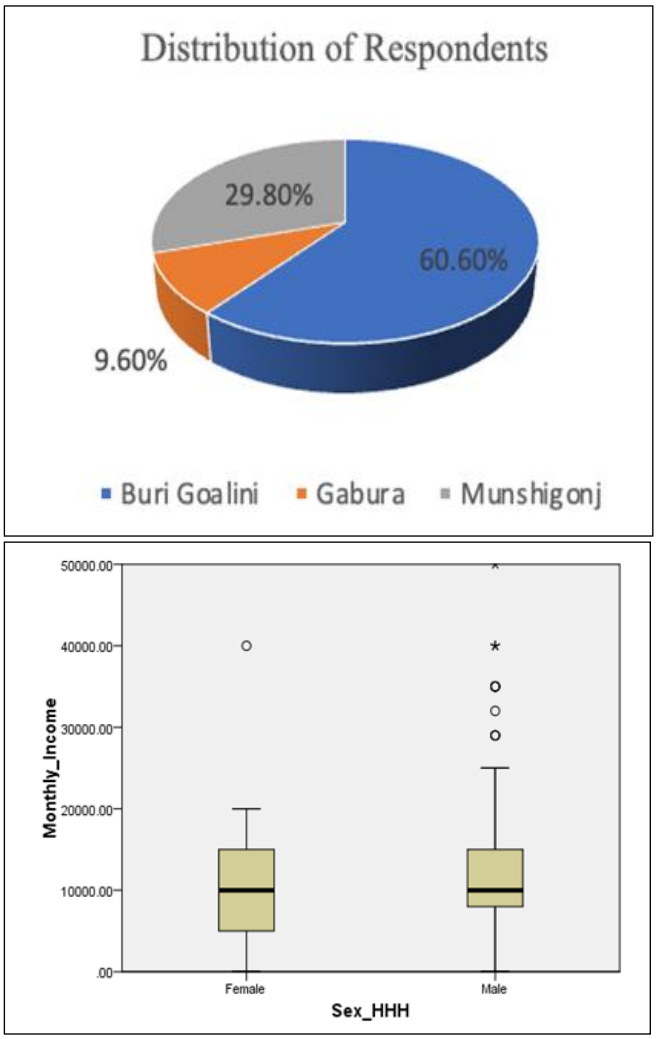

Fig 2: Distribution of Respondents among Unions

➢ *Income of Households*

The chart shows that monthly income of the households is normally distributed. But the monthly income curve is not perfectly symmetrical. It has positive or right skewness (as the tail in right side is longer than left side) which means the mean of income will be greater than the median of income.

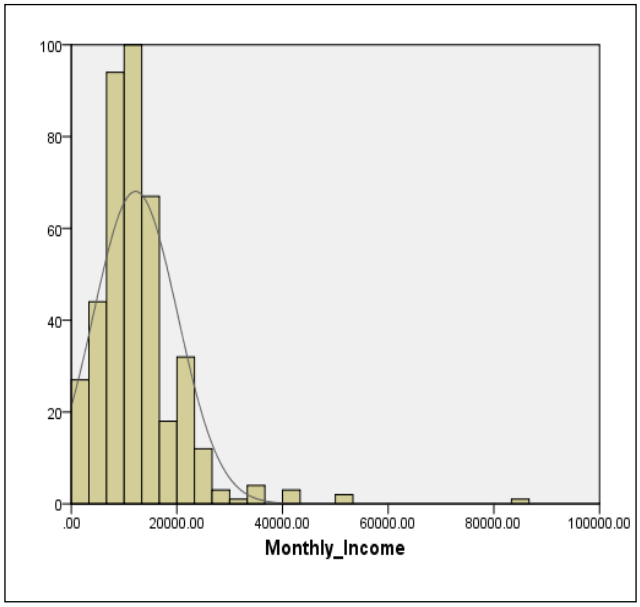

Fig 3: Monthly Income of Households and the Relation of Income with the Gender of Household Head

The two box plots of monthly income of households with male and female households show differences in the median income, income in the first quartile, income in second and third quartiles and the fourth or upper quartile. Firstly, the median income of female headed households is slightly higher than male headed households. Secondly, in the first quartile overall male headed households are generating more income than female headed households which means the lower income households with male household head are generating more income than households with female head. Thirdly, in the third and fourth quartile or the middle 50% households, the female headed households also starting with a lower income than male headed households but reaching more income in the upper side. Lastly, in the upper quartile male headed households are generating more income than female headed households and there are some higher income outliers in the male category which is not seen in female headed households.

Table 3: Scenario of Monthly Income in Study Areas

ean	Median	Mode	Standard Deviation	Mini-mum	Maxi-mum
12162.50	10000.00	15000.00	7968.89164	00	85000.00

➢ *Financial Capabilities of Households*

The pie chart shows that most of the households that we surveyed do not have any savings which demonstrates their vulnerability of falling in poverty trap in kind of sudden shock. Only 35.46 % have said that they have some savings. The household savings chart of three unions paints the same picture that we have seen earlier. In Buri Goalini and Gabura the number of households without savings is double compared to the number of households with savings. Although the difference is a little bit smaller in Munshigonj, the number of households without savings is still greater than the number of households with savings.

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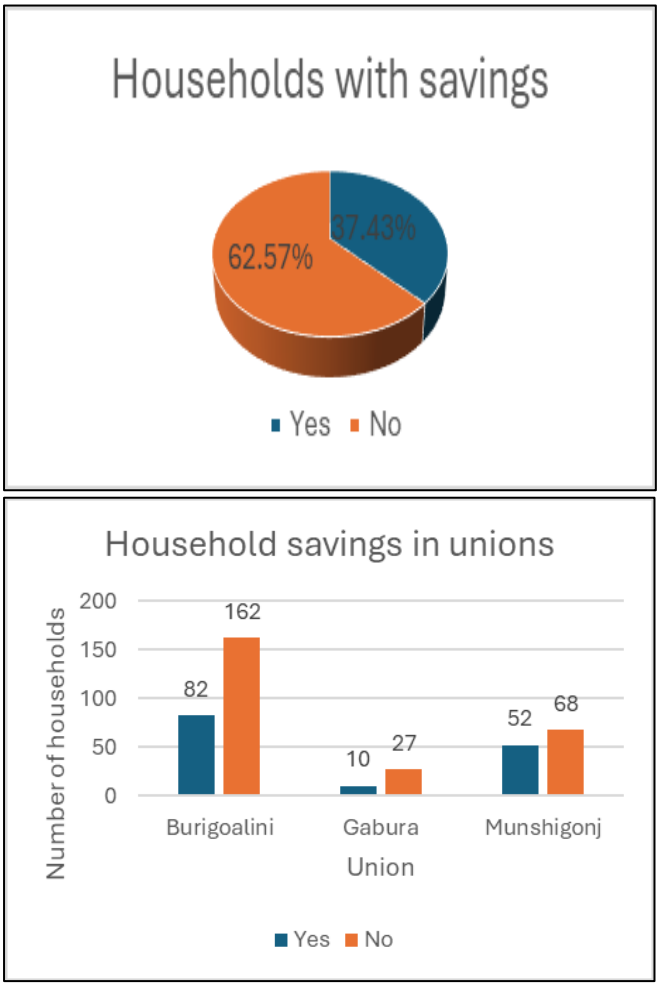

Fig 4: Financial Capabilities of Households

➢ *Going to Cyclone Shelter During Disaster*

This chart shows the percentage of households who went to cyclone shelters during times of emergency in all three unions. We can see same trend in all the unions that almost double number of households took shelter compared to the number of households who did not take shelter, The percentage of households taking shelter is highest in Gabura (71.06%) among these three unions.

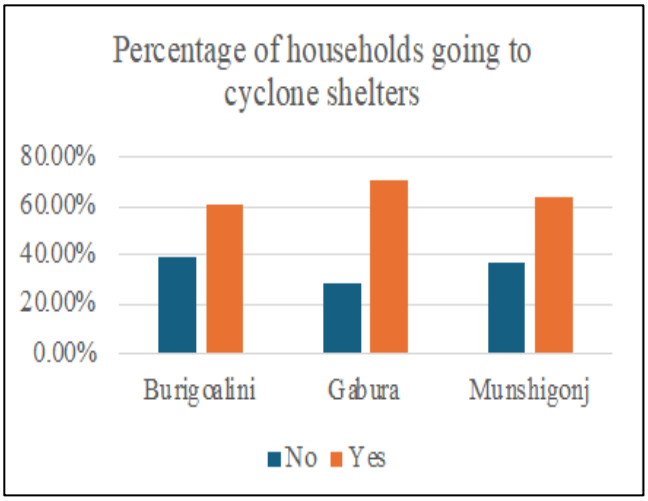

Fig 5: Household Go to Cyclone Shelter During Disaster

This chart shows the reasons behind people staying at home rather than going to cyclone shelters at time of disasters. The major reason in all the three unions for not going to cyclone shelters is the 'fear of losing assets. The second major reason is the lack of space in cyclone shelters. The third major reason almost got similar number of responses which is 'lack of transportation'. 'No warning message'(the one in deep blue) got the least amount of responses as the reason for not going to cyclone shelters, but the reason is significantly more visible in Munshigonj compared to other 2 unions. Another differential fact is that 'long distance from house' is only visible in the Buri Goalini union which is not an issue in the other 2 unions.

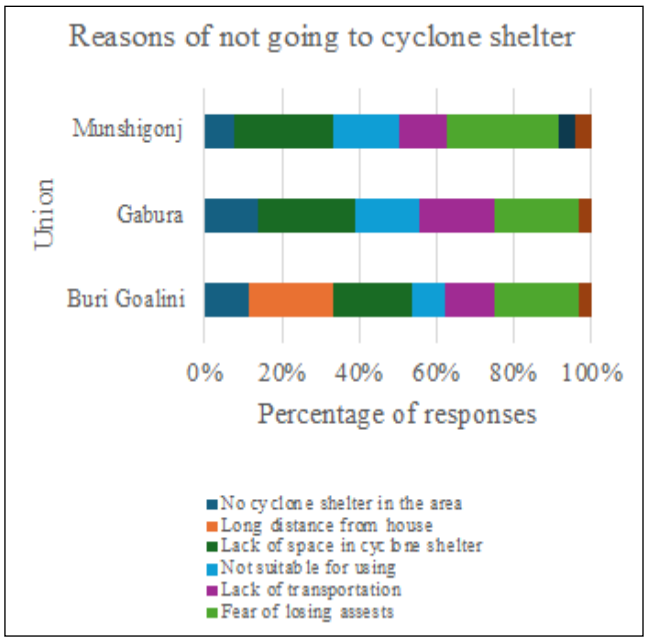

Fig 6: Reasons of not Going to Cyclone Shelter

E. Livelihood Vulnerability Index

The study developed six major components of the Livelihood Vulnerability Index which are, socio-demographic profile, food, institutional services, infrastructure facilities, economic function and natural disaster-warning. These six major components hold in total of twenty-three sub-components or indicators. We developed this index by providing equal weight among all sub-components by followed the equal weighting index method. Each of them receives 1/23 weight.

➢ *Normalization*

For normalization of process followed by two equations.

$$\text{Index } X_s = \frac{X_s - X_{min}}{X_{max} - X_{min}} \quad (1)$$

$$\text{Index } X_s = \frac{X_{max} - X_s}{X_{max} - X_{min}} \quad (2)$$

Where index X_s is the normalized index value and X_S is the original value of the indicator for household S, X_{max} and X_{min} are the maximum and minimum values of the indicator at the household level.

The (1) has been used for the sub-components or indicators which have direct or positive functional relationship with vulnerability whereas sub-components which have negative relationship with vulnerability were normalized by using (2).

➢ *Major Component Value*

The second step of vulnerability indexing is finding the value of major components. In here, equation (1) and (2) were used for normalized. After normalization, indicators were plugged into equation (3) to calculate the value of major components for each household.

$$M_S = \frac{\sum_{i=1}^{n} Index\ X_s i}{n} \quad (3)$$

Where, M_S is the value of one of the major components for household S. $Index\ X_s i$ is the normalized value of i^{th} indicator for household S, and n is the number of indicators under each major component.

➢ *Household Livelihood Vulnerability Index*

Once the major component value for each household was determined, the livelihood vulnerability index for each household was determined using the indexing approach. Livelihood Vulnerability Index,

$$LVI = (SDP \times W_i) + (F \times W_{ii}) + (IS \times W_{iii}) + (IF \times W_{iv}) + (EF \times W_v) + (ENH \times W_{vi}) \quad \ldots\ldots(4)$$

Where, LVI is the livelihood vulnerability index. SDP = Value of socio-demographic major component, F = Value of food major component, IS = Value of institutional services major component, IF = Value of infrastructure facilities major component, EF = Value of economic function major component, ENH = Value of exposure to natural hazard major component and $W_i, W_{ii}, W_{iii}, W_{iv}, W_v, W_{vi}$ are the weight of five major components respectively.

According to the equal weight method, we used equal weight for each indicator. W refers to the weight that was applied to each major component. So, the weight of six major components: W_i = 0.22, W_{ii} = 0.13, W_{iii} = 0.13, W_{iv} = 0.17, W_v = 0.17, W_{vi} = 0.17

The method of calculating weight for each major component was, W = n (number of indicators X equal weight of each indicator or sub-component).

F. Principal Component Analysis

Principal Component Analysis is basically a dimension reduction method. It mainly reduces the dimension of large data set and make smaller one. In this study we conducted Principal Component Analysis (PCA) for understanding the inner relation of adaptive strategies in our study areas. PCA can be broken down into five steps. We will go through each of step and providing logical explanations of what PCA is doing and simplifying mathematical concepts such as standardization, covariance, eigenvectors and eigenvalues.

➢ *Standardization*

In this step, we standardized the range of the continuous initial variables so that each one of them contributes equally to the analysis. For that, at first, we decided our variables. The variables list shown in below.

Table 4: Variables for PCA

Serial	Variables
1	Did any of your family members attended climate change/DRR training?
2	Growing a number of different crops
3	Using different varieties
4	Focusing on homestead farming
5	Making house on raised plinths
6	Elevated courtyard
7	Fix additional pillars to the house to prevent it from collapsing
8	Elevated latrines to avoid spread of diseases
9	Cooking on elevated platforms
10	Shifting into saline tolerant fishes (crab, shrimp)
11	Women started hand crafting
12	Preserving drinking water in earthen pot/tank
13	Build rainwater reservoir for drinking

➢ *The Equation of Standardization is,*

$$z = \frac{Value - Mean}{Standard\ Deviation}$$

Mathematically, this can be done by subtracting the mean and dividing by the standard deviation for each value of each variable

➢ *Covariance Matrix Computation*

Covariance matrix represents the relation between the variables, and it helps to understand how the variables of input data set are varying from the mean with respect to each other. Covariance matrix is a symmetric matrix. Here is the formula of calculating covariance matrix.

$$\mathrm{Cov}(x, y) = \frac{\sum(xi - x) * (yi - y)}{N - 1}$$

➢ *Compute the Eigenvectors and Eigenvalues*

An eigenvector is a nonzero vector that changes at most by a scalar factor when that linear transformation is applied to it. The corresponding eigenvalue is the factor by which the eigenvector is scaled.

Let A be a square matrix (in our case the covariance matrix), ν a vector and λ a scalar that satisfies $A\nu = \lambda\nu$, then λ is called eigenvalue associated with eigenvector ν of A.

Rearranging the above equation,

$A\nu-\lambda\nu =0$; $(A-\lambda I)\ \nu = 0$

Since we have already known ν is a non- zero vector, only way this equation can be equal to zero, if

$\det(A-\lambda I) = 0$

➢ *Feature Vector*

After finishing computing eigenvectors and eigen values the next step is feature vector. Feature vector is for extracting principal components in order to significance.

➢ *Recast Data Along Principal Component Axes*

The aim is to use the feature vector formed using the eigenvectors of the covariance matrix, to reorient the data from the original axes to the ones represented by the principal components (hence the name Principal Components Analysis). This can be done by multiplying the transpose of the original data set by the transpose of the feature vector.

III. RESULTS

A. *Livelihood Vulnerability Index (LVI)*

➢ *LVI Summary*

Table 5: Livelihood Vulnerability Index Summary

Scale of Vulnerability	Number of Households	Number of People	Percentage
Not Vulnerable	1	5	0.25%
Vulnerable	121	631	29.73%
Highly Vulnerable	267	1261	65.60%
Very Highly Vulnerable	19	95	4.67%
Total	407	1992	

Scale measures of vulnerability, 0 to 0.2 = Not Vulnerable, 0.21 to 0.39 = Vulnerable, 0.40 to 0.59 = Highly Vulnerable, 0.60 to 1 = Very Highly Vulnerable (Suryanto & Rahman, 2019)

In all, 407 households throughout our three study sites were polled. 1992 people total live in these 407 households. Only 1 out of 407 households falls into the category of not being vulnerable. There are a lot of households that are in danger. 267 households, or about 65.60 percent of all households, fall into the "Highly Vulnerable" category. On the other side, 121 households, or 29.73% of all households, fall into the "Vulnerable" category. 19 households are extremely vulnerable. These 19 households fall under the category of "Very Highly Vulnerable."

➢ *Livelihood Vulnerability in Communities*

Table 6: LVI of Buri Goalini Union

Level of Vulnerability	Number of Household	Percentage
Vulnerable	65	26.53%
Highly Vulnerable	165	67.35%
Very Highly Vulnerable	14	5.71%
Not Vulnerable	1	0.41%

Out of 245 households, 165 are classified as "Highly Vulnerable." The data shows that 165 of the 267 highly vulnerable households are in the Buri Goalini union. Many households are in precarious situations. There are 65 vulnerable households in the union.

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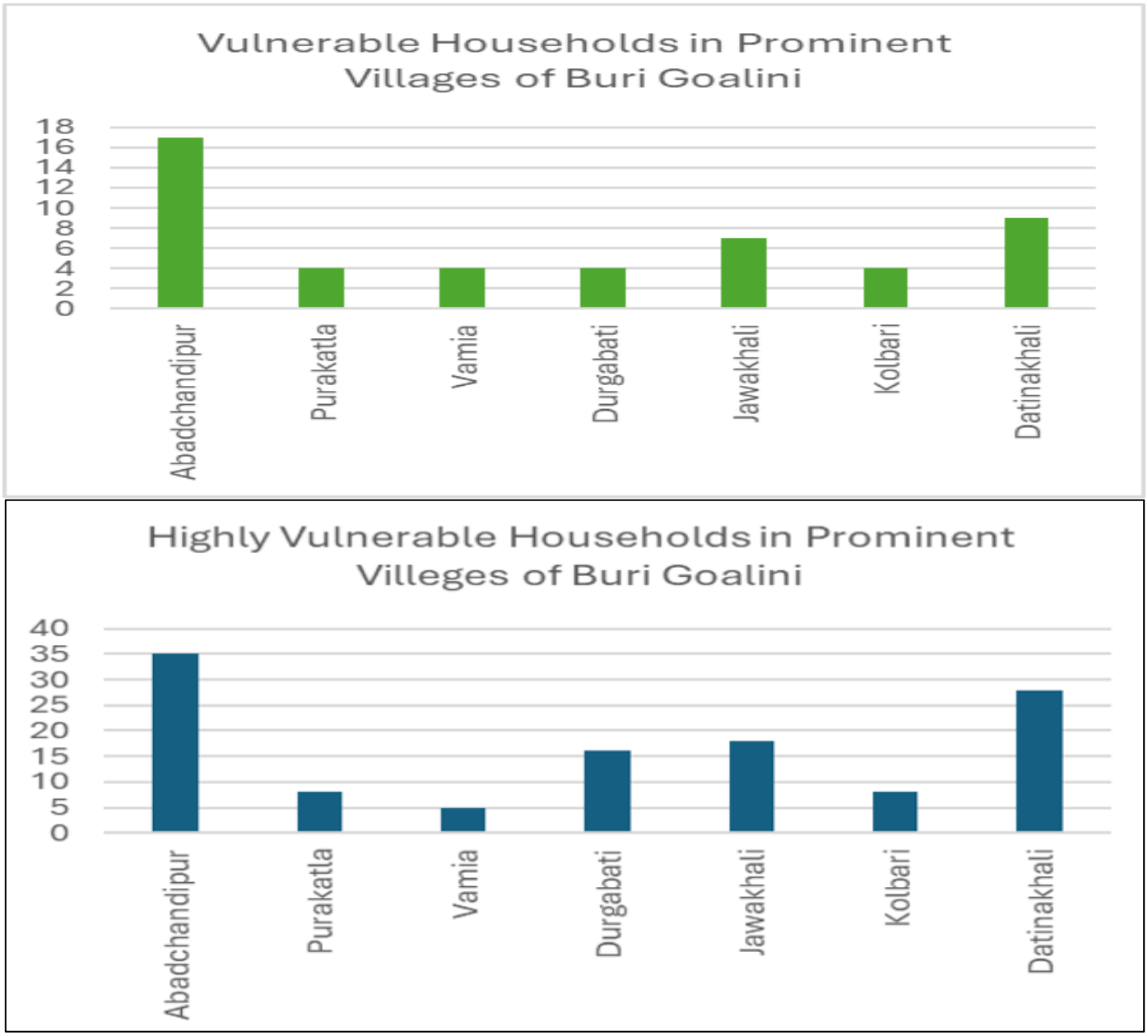

Fig 7: Vulnerable and Highly Vulnerable Households in the Villages of Buri Goalini

These are the union's well-known villages. The survey indicates that Abadchandipur has the most vulnerable households, with a total of 17. There are 4 vulnerable households in each of the following: Purakatla, Vamia, Durgabati, and Kolbari. The village of Durgabati is also vulnerable in several ways. In this village, there are 9 vulnerable households. Two villages, namely Abadchandipur and Datinakhali, are home to most of the highly vulnerable households. 35 homes in Abadchandipur are highly vulnerable. On the other hand, there are a lot of extremely vulnerable households in Datinakhali. Vamia has the fewest households that are highly susceptible out of all these villages. There are only 5 highly vulnerable households in Vamia.

Table 7: LVI of Munshigonj Union

Level of Vulnerability	Number of Households	Percentage
Vulnerable	39	31.2%
Highly Vulnerable	83	66.4%
Very Highly Vulnerable	3	2.4%

In the Munshigonj union, 125 surveys were done. We discovered that 39 households are vulnerable, and 83 households are highly vulnerable among these 125 surveys. In Munshigonj, 66.4% of the households surveyed maintain their way of life in a highly vulnerable manner. The rate of extreme vulnerability in Munshigonj is little bit lower than other two unions of the upazilla. Only 3 households are very highly vulnerable among 125 households.

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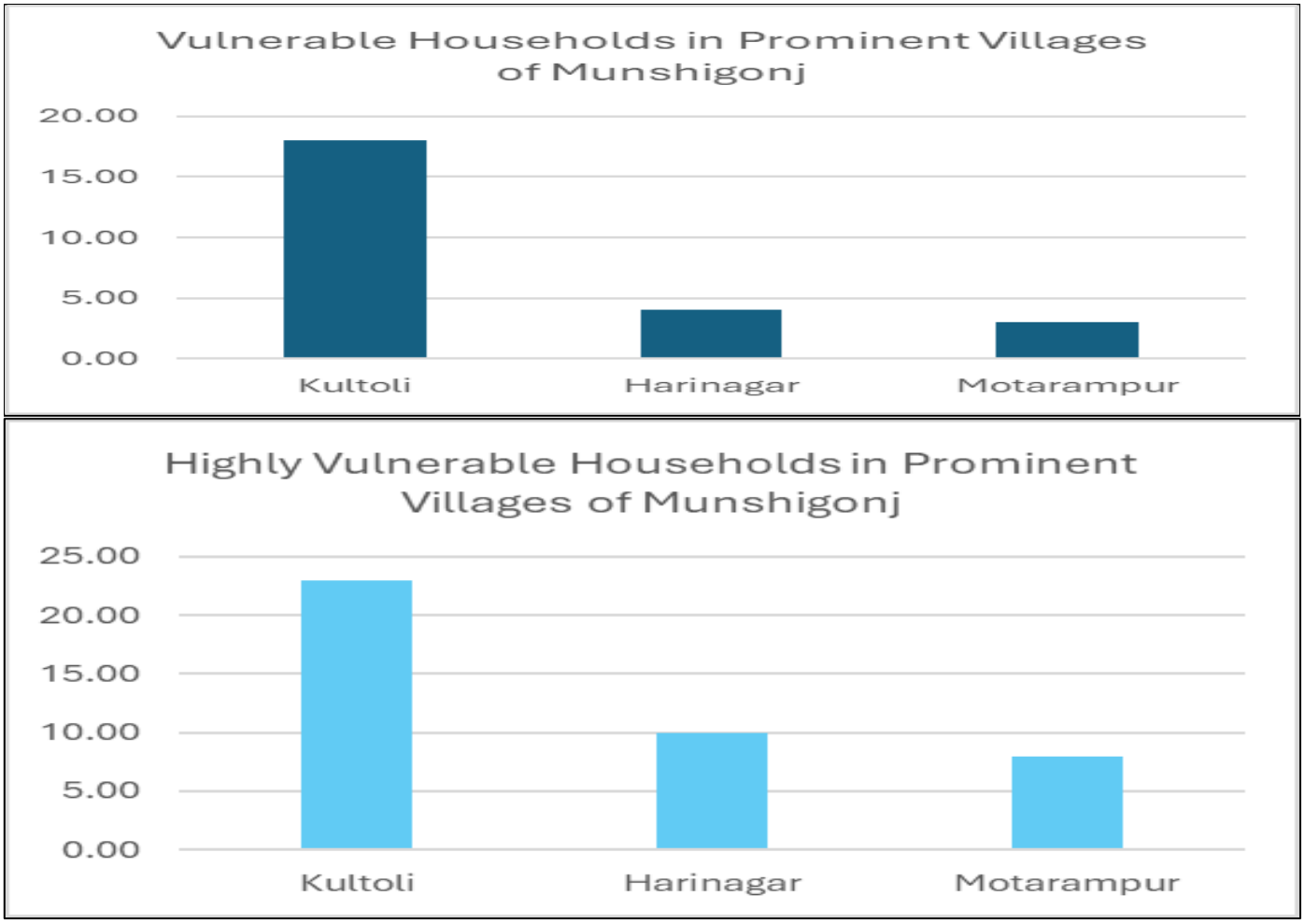

Fig 8: Vulnerable and Highly Vulnerable Households in Munshigonj Union

Kurtoli, Harinagar, and Motarampur are prominent villages in Munshigonj village. Kultoli has highest number of vulnerable households among others. It has 18 households which are vulnerable in their livelihood condition. Kultoli village is home to a sizable population of highly vulnerable people. In that area, 23 households are very vulnerable. In the Munshigonj survey results, 19% of the households were classified as highly vulnerable and were in Kultoli village. In the village of Harinagar, 10 households are highly vulnerable, compared to 8 in Matarampur.

Table 8: LVI of Gabura Union

Level of Vulnerability	Number of Households	Percentage
Vulnerable	10	27.02%
Highly Vulnerable	26	70.27%
Very Highly Vulnerable	1	2.70%

Gabura is one of the most remote areas of Shyamnagar upazila. In total 37 households' data has been collected from the union. 26 households and almost 71% households are in highly vulnerable category of the union. 10 households vulnerable.

Chakbara village has 30.76% highly vulnerable households out of the 26 highly vulnerable households in Gabura. There are a total of 8 highly vulnerable households in Chakbara village. In addition to Chakbara, there are 5 very vulnerable households in Morol Bari and 7 highly vulnerable households in Lokkhikhali village.

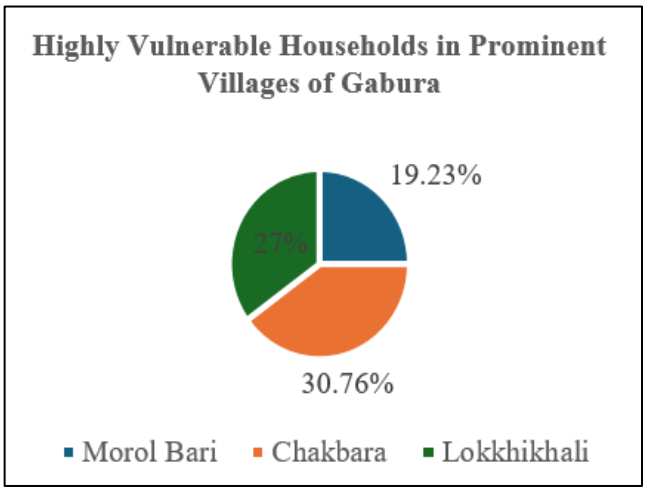

Fig 9: Highly Vulnerable Households in Villages of Gabura Union

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➢ *Average Livelihood Vulnerability Index*

Table 9: Average LVI of Buri Goalini, Munshigonj and Gabura

Name of the Union	Average LVI
Buri Goalini	0.44
Munshigonj	0.44
Gabura	0.45

The average LVI table shows that all three unions have roughly the same average livelihood vulnerability index. Buri Goalini, Munshigonj, and Gabura have average LVIs of 0.44, 0.44, and 0.45, respectively. The three unions' average vulnerability indices fall into the category of "Highly Vulnerable" with values ranging from 0.40 to 0.59.

B. Factors Affecting Households' Adaptation Strategies

In this study we have been selected 13 variables for Principal Component Analysis model with varimax rotation. We conduct PCA model of factor analysis for identifying the influences of factors that may shape the households' adaptation strategies against environmental disaster.

➢ *KMO and Bartlett's Test*

KMO and Bartlett's test (Snedecor and Cochran, 1983) is used to test if k samples have equal variances. Equal variances across samples are called homogeneity of variances. Some statistical tests, for example the analysis of variance, assume that variances are equal across groups or samples.

Table 10: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.561
Bartlett's Test of Sphericity	Approx. Chi-Square	852.693
	df	91
	Sig.	0.000

13 variables were chosen for PCA. KMO and Bartlett's Test was started to see if PCA could be created. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy in this experiment is 0.561, which is greater than 0.5. The significance threshold, however, is 0.000. The factor analysis can proceed to the next stage if the value of is greater than 0.5. (Factor Analysis, 2020),(Ha-Mim et al., 2020). Our variables were suitable for PCA, as evidenced by the result.

➢ *Explaining Total Variance*

Table 11: Variance Matrix

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% Of Variance	Cumulative %	Total	% Of Variance	Cumu-lative %
1	2.114	15.102	15.102	1.898	13.558	13.558
2	1.852	13.231	28.333	1.636	11.686	25.244
3	1.452	10.374	38.706	1.465	10.464	35.708
4	1.198	8.557	47.263	1.460	10.429	46.137
5	1.104	7.883	55.146	1.193	8.523	54.660
6	1.042	7.440	62.586	1.110	7.926	62.586

First, we need to look at the eigen value to identify how many components are being extracted. must be greater than 1 to retrieve component eigenvalues. Only 6 components in our study have eigenvalues greater than 1. These 6 factors together account for 62.586 percent of the total variance. One of these, component 1, can explain the most variance. Component 1 may account for 13.558% of the overall variance in adaption strategies, and Component 2 can account for 11.68% of the overall variance in the dataset. These 6 components can describe the factors affecting households' adaptation strategies against environmental disaster in southwestern coastal region.

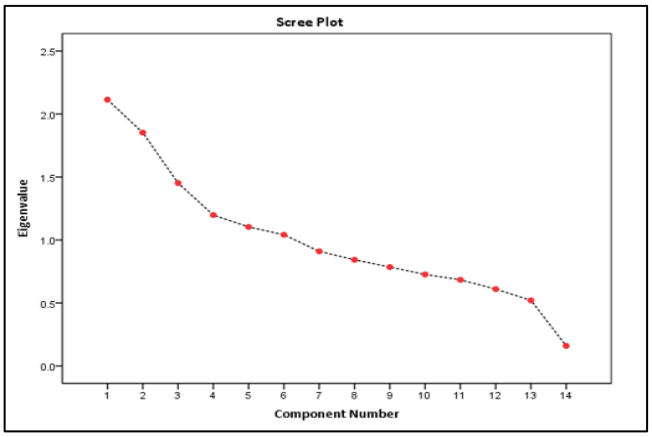

Fig 10: Scree Plot of PCA

The eigenvalue distribution according to component numbers is represented by a scree plot. We can notice that the curve line in this graph gradually decreases from component 1 to 14. The component eigenvalues from 1 to 6 are greater than 1. So, from 14 components, these 6 components were extracted.

➢ *Component Transformation Matrix*

Table 12: Component Transform Matrix

Principal Components	PC1	PC2	PC3	PC4	PC5	PC6
Training						
Did any of your family members attended climate change/DRR training?	-0.543	0.626	0.541	0.130	-0.008	0.062
Sanitation and Nonagricultural Production						
Elevated latrines to avoid spread of diseases	0.805	0.424	0.328	-0.128	-0.168	0.145
Shifting into saline tolerant fishes (crab, shrimp)						
Build rainwater reservoir for drinking						
Infrastructure						
Making house on raised plinths	0.189	0.074	-0.126	0.964	0.114	-0.003
Elevated courtyard						
Cooking on elevated platforms						
Agricultural Innovation						
Growing a number of different crops	0.081	0.353	-0.267	-0.182	0.874	-0.029
Using different varieties						
Health and Safety						
Fix additional pillars to the house to prevent it from collapsing	-0.026	-0.335	0.257	0.038	0.253	0.869
Focusing on homestead farming						
Preserving drinking water in earthen pot/tank						
Women Empowerment						
Women started hand crafting	0.123	-0.431	0.668	0.052	0.362	-0.468
Variance (%)	13.558	11.686	10.464	10.429	8.523	7.926
Cumulative (%)	13.558	25.244	35.708	46.137	54.660	62.586

This table shows the dominance of 6 components in adaptation strategies of those areas. The first principal component (PC1) termed as "Training" and it can explain 13.558% variance, PC2 termed as "Sanitation and Nonagricultural Production" and it can explain 11.686 % variance, PC3 termed as "Infrastructure", explains 10.464% variance, PC4 termed as "Agricultural Innovation", explains 8.523%, PC5 termed as "Health and Safety", explains 10.429% and finally PC6 termed as "Women Empowerment", explains 7.926% variance. All these six factors or components have influence household's adaptive responses. The PCA is used to identify the significant factors.

IV. CONCLUDING REMARKS

This research has explored the level of vulnerability and adaptation techniques in coastal region's households. The study also provides well-defined understanding about how geographical location affects people's livelihood activities. In addition to, this research helps to get clear idea about factors that affecting households' adaptation strategies against environmental hazards.

The findings of this research incorporate the underlying factors behind vulnerability. People of Buri Goalini, Munshigonj and Gabura are facing vulnerability related issues depending geographical location, land ownership, infrastructure development, lack of government innovation, lack of stakeholder participation, unemployment, etc. In this study we measure the level of vulnerability according to vulnerability indexing. We categorized households in three different levels like "Vulnerable", Highly Vulnerable" and "Very Highly Vulnerable". Most of the households of these areas are facing numerus problems in their daily life. Because of deprivation in several aspects of life they are facing vulnerable situation in their livelihood activities. In addition to, all these three areas are disaster prone area, however disaster are daily phenomena in these areas. They have to fight with such events regularly. That why their adaptation strategies are based on the concept of tackling down the effects of natural hazards like, elevated courtyard, elevated latrine, etc.

The results of this study will provide a distinctive knowledge. It also aids those who try to enhance the capacity of marginalized and coastal populations to comprehend their condition, thoughts, and needs.

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