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Exploring Vulnerability–Resilience–Livelihood Nexus in the Face of Climate Change: A Multi-Criteria Analysis for Mongla, Bangladesh

Nur Mohammad Ha-Mim [1], Md. Zakir Hossain [1], Khan Rubayet Rahaman [2] and Bishawjit Mallick [3,4,*]

1 Urban and Rural Planning Discipline, Khulna University, Khulna 9208, Bangladesh; nurhamimurp15@gmail.com (N.M.H.-M.); zakir@ku.ac.bd (M.Z.H.)
2 Department of Geography and Environmental Studies, St. Mary's University, Halifax, NS B3H 3C3, Canada; khan.rahaman@smu.ca
3 Chair of Environmental Development and Risk Management, Faculty of Environmental Sciences, Technische Universität Dresden (TUD), 01062 Dresden, Germany
4 Marie Curie Global Fellow at Institute of Behavioral Science, University of Colorado Boulder, Boulder, CO 80309, USA
* Correspondence: bishawjit.mallick@tu-dresden.de; Tel.: +49-351-463-42590; Fax: +49-351-463-42516

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Abstract: This article illustrates the critical findings of an empirical investigation of resilience, vulnerability, and livelihood nexus in one of the worst cyclone-affected sub-districts "Mongla" in Bangladesh. Results obtained from the survey conducted in 2018 and 2019 explore the co-existence of climate change vulnerability and resilience at the rural household level. Additionally, the study identifies the role of assets (e.g., land, cash, and livestock) in order to enhance the resilience of poor inhabitants. Quantitative data have been collected using structured and semi-structured interviews. The outcome of the study demonstrates that the relationships between vulnerability and resilience are very complex and exist in the study area. An exciting outcome has revealed that in some places, more vulnerable people exhibit higher resilience capacity and vice versa. Furthermore, this research emphasizes that local livelihood systems may be improved if appropriate policies are considered by local government organizations in collaboration with multiple stakeholders. Consequently, the local citizens have to play their critical role to assist government policies in order to enhance resilience at the community level. Moreover, local residents can have a better understanding of their livelihood issues in the face of climate change.

Keywords: index; multi-criteria analysis; vulnerability; resilience; nexus; Mongla; Bangladesh

1. Introduction

Coastal zones are being considered as one of the critically vulnerable areas for existing ecosystems and human settlements under the contemporary climate change scenarios. A sophisticated and dynamic relationship exists between vulnerability and resilience that are explained in the scholarly literature [1–3]. Scholars elucidate that vulnerability can overlap with resilience and may integrate these concepts in building a useful framework to design adaptation pathways for remote and disadvantaged communities [2–4]. Therefore, this research particularly intends to analyze the issues of households' livelihood, vulnerability and resilience mechanisms to respond to climate-induced shocks. Essentially, the households and communities become vulnerable to climate-induced shocks such as cyclones, storm surges, heavy rainfall, flooding etc. Indeed, the vulnerabilities are aggravated depending on geographical location, housing conditions (i.e., building materials in particular); economic factors such as limited income opportunities, lack of savings; and political factors like tenure insecurity at the community level. Despite the high resilience status of some communities across coastal cities in diverse locations of the world, some communities are having issues such as lack of social network, collaboration among government and private sectors, and updated contingency plans to deal with climate-induced shocks in recent times. This paper considers resilience and vulnerability as two isolated concepts in generating a model that demonstrates relationships among several criteria in a typical coastal geographic setting.

Understanding the co-existence of vulnerability and resilience narratives in an integrated framework helps to explore adaptation pathways among the remote and disadvantaged people in the face of climate change and climate extremes [4]. Vulnerability is often seen as inversely proportionate to resilience as enhancing resilience will automatically reduce vulnerability [5–7], but the complexity appears when the situation differs in the context of location and geography [3,4]. For example, in the light of the literature, flood mitigation measures upon building the coastal defense walls may reduce the chance of flooding [8]; however, the measures can exacerbate the risk of economic security of the people living in the area [9]. Additionally, a school of thought reveals that people of remote areas have a wealth of experiential knowledge from living with uncertainties considering dynamic climatic variables and with scarce resources [3,10,11]. Interestingly, people living in the disadvantaged areas have more reliable social networks, efficient but straightforward settlement patterns, as well as flexible and mobile livelihood arrangements, which make them more capable of adapting to climate change than built environment [4,12]. Usamah et al. [2] have explained the relationship between vulnerability and resilience in the context of informal settlements in two provinces of the Philippines and the outcome has been a paradoxical relationship between vulnerability and resilience. The communities or households may have factors that contribute to their vulnerability relating to geography, economy, housing and land tenure along with the factors that contribute to their resilience such as trust, social cohesion and sense of community, social solidarity, social control, social networks, community involvement, regular communication and respect for culture and values. It can also have factors of vulnerability that contributes to enabling their resilience, such as daily economic hardship, which contributes to their psychological resilience and tenure insecurity that strengthens their social cohesion. This is how vulnerability and resilience can co-exist in the lives of coastal communities or households. Therefore, it broadens the scope of adaptation planning for the remote and disadvantaged communities by highlighting their vulnerability and resilience differential.

Concepts of resilience and vulnerability have been well-established in different ways by scholars, ranging from opposite sides of the spectrum to overlapped relationships [1–5,13,14]. Few scientists have argued that vulnerability and resilience are two reflective concepts and may not be separated [15–17]. Consequently, Adger [18] argues that vulnerability and resilience may exist at the same time and can overlap depending on situations. However, this paper attempts to measure household, livelihood, and vulnerability index by employing contemporary climate change vulnerability framework [19] in a typical rural setting in Bangladesh. This index describes climate change vulnerability as a function of exposure, sensitivity, and adaptive capacity. Here, the susceptibility of the households and communities towards the climate-induced shocks and stresses are considered to be an outcome of their access to social, economic, political, physical, and environmental assets. Note that the asset profile of the households and communities influence the likelihood of being exposed to hazardous events (external dimension of vulnerability).

Furthermore, their capacity to cope with additional negative impacts of climate variability (internal dimension of vulnerability) are being answered. In the case of calculating the household's livelihood resilience to climate-induced shocks and stresses, each household's responses or anticipatory behaviors to mitigate current and future climate shocks and stresses are considered. It is worth noting that in the recovery approach framework, resilience is defined as "the ability in crises to maintain function based on ingenuity or extra effort" [3]. This implies the fact that the adaptive actions of a system facilitate the development of a system's resilience. Agard et al. [20] describes adaptability as crucial to maintaining and increasing resilience in a changing climate. Therefore, households' responses such as green roofing for extreme temperature measures and adjusting the building construction mechanisms have direct impacts on vulnerability reduction. Additionally, the enhanced resilience capacity is visible while considering future stresses into a healthy lifestyle as a measure of adaptation.

Most of the climate change and disaster risk reduction literature revolve either around vulnerability or resilience [1–3,6,21–25]. The interrelationship between vulnerability and resilience is widely recognized as antonymous, i.e., one is being the opposite of the other [2]. Both research streams often take an opposing position in terms of disaster risk reduction that might be called either "vulnerability preference" or "resilience preference" [26]. However, the discrete view of vulnerability and resilience can mislead decision-makers in managing a crisis event when prompted [2–4]. An integrated approach to vulnerability and resilience at the local context can provide a deeper understanding of coping and adaptive capacity, which helps stakeholders to realize climate hazards more holistically [2–4,21]. Few researchers have explained how the vulnerability of the household co-exist with resilience by using the households' responses or coping strategies in the post-disaster situation [2,4,27]. However, almost none of this scientific evidence has independently analyzed the co-existence between livelihood vulnerability and resilience by measuring households' pre-disaster situation where physical, socioeconomic and political factors construct livelihood vulnerability indexing. As most of the researchers have considered a discrete view of vulnerability and resilience and concern is growing among the scientific community to relate these two concepts, this research article demonstrates that a holistic approach is possible to consider in generating a useful framework in the face of climate change. For this, the article explores the households' vulnerability–resilience nexus that expands the range of policy options and develops an appropriate support system for the vulnerable population while addressing climate-induced shocks. Moreover, the study triggers questions to researchers and practitioners for a need of a holistic model that can serve better for people living in the vulnerable areas in Bangladesh.

2. Materials and Methods

2.1. Study Area

We have considered Mongla Upazila (sub-district level of the administrative boundary of the country) of Bagerhat district in Bangladesh as our study area. Mongla occupies approximately 1461.20 sq. km. of area in which 1260.87 sq. km. is the land and the rest are coast and water [28]. The area lies between 21°05′ and 22°40′ north latitudes and between 89°30′ and 89°47′ east longitudes (See Figure 1 for details). On the south of the study area, the Bay of Bengal is situated that includes the coastal mangrove ecosystems. This Upazila is one of the most affected coastal zones of the country in the face of climate change. Chila and Burirdanga Unions (i.e., the smallest strata of local government) of Mongla Upazila are considered as the case study settlements among seven Unions of this sub-district because these areas have suffered from cyclones in last two decades. Moreover, these two unions are ruminated as the most populated coastal areas in the southern districts of the country. The rural inhabitants are primarily depending on fisheries activities and related resource extractions from the nearby Sundarbans for their livelihood. Climate-induced hazards such as extreme cyclone and tidal surges (i.e., category two and over), severe floods (e.g., at least three events in a calendar year), river erosion, excessive rainfall, and saline water intrusion are few of the regular natural events happen in this area. The areas in these unions are regularly accepting more people and expanding the rural settlements at a significant rate as the population changes take place from 2001 to 2011 at a rate of 0.86% per year [28]. As a result, the areas are exposed to more risks of natural events in the changing climate. It is projected that the south-western part of Bangladesh (that includes Mongla Upazila) will encounter a minimum of 1.2, a median of 2.0 and maximum of a 2.6-°C temperature rise by 2060 upon considering the base years 1970–2000 [29]. The trend of the average annual rainfall of Mongla Upazila shows a significant increase (about 7.79 mm/year) with a confidence level of approximately 95% during the period 1958–2007 [30]. In case of 1 m sea-level rise, it will affect 15 million people in southwestern Bangladesh and 17,000 sq.km lands will be submerged with Mongla Upazila utterly underwater [31].

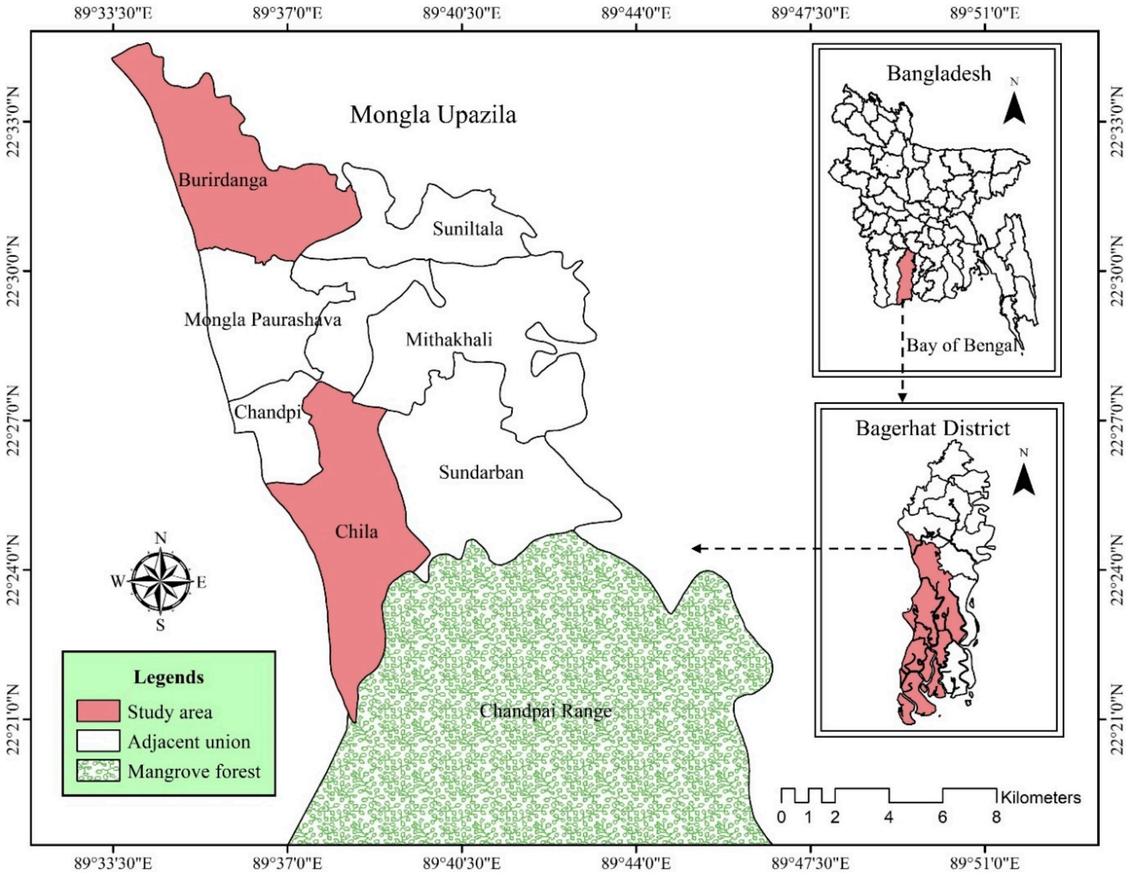


Figure 1. Map of the study area. Source: generated by the authors using the data provided by the GIS unit of the Local Government and Engineering Department (LGED) of the Government of Bangladesh (2020).

In this study, we have considered two unions to understand differences of livelihood patterns and available resources while preparing the evaluation indices (See Figure 2). Note that, we have chosen one union with close proximity to the coast and the other union with the maximum distance from the coast (See Figure 1 for details). According to the population census of 2011 (i.e., the latest so far), the population of two Unions mentioned above, such as Burirdanga and Chila are 15,311 and 20,973, respectively, and the household size in Chila is 4373, which is slightly higher than that of Burirdanga (3827) [28]. The major socio-economic and demographic characteristics of the sample households show that most of the respondents in Burirdanga and Chila are male (63.3% and 59.2%), whereas the female respondents in these two Unions were 36.7% and 40.8%, respectively (see Table A1 for details). The average age of the household heads in both regions was around 44 years. For most of the respondents, their religion is Hindu. The average household size is 4.8 persons which is similar to national average (4.48 persons) for rural Bangladesh [28]. The average income in Burirdanga and Chila union is 15816.33 Taka (USD 197.70) (±7284.9 Taka, USD 91), and 11234.69 (USD 140) (±5626.48, USD 70.33) Taka and average number of safety nets by household is 0.82 (±0.73) and 0.80 (±0.65), respectively. The subsequent standard deviation provides a scenario of inequality of income and land ownership pattern in these unions. Despite the locational advantages to the coast, both Unions do have issues with water scarcity. We have noted that 40% of respondents in both regions do not have access to safe drinking water. The scarcity of water is also evident as in Burirdanga Union only 12.2% households have adequate water supply with a monthly spending of 167.35 (USD 2.09) (±208.30 Taka, USD 2.60) Taka for buying water whereas in Chila Union it is 16.3% and 233.67 (USD 2.92) (±120.93, USD 1.51) Taka. Moreover, similar documents have revealed that saline water intrusion in the local communities is a significant by-product of the climate change situation. Despite these similarities between the Burirdanga and Chila Unions of Mongla, differences in some key issues also can be found. For example, the Burirdanga possessed more dependent members, girl children, social safety nets, households with inherited property, access to electricity, access to information sources, access to khas land, affordability of transportation means and assistance form extended family members, compared to those of the Chila Union. Conversely, in the Chila Union, the households have greater access to sanitary latrine, access to safe water, savings in bank/NGOs, disaster management training, vocational training, and NGO membership than its counterpart region's households. The contrasts between these two geographical locations on different socio-economic and socio-demographic issues evidence the differences and draw attention to the fact that the Chila Union is in a more disadvantaged position than the Burirdanga Union.

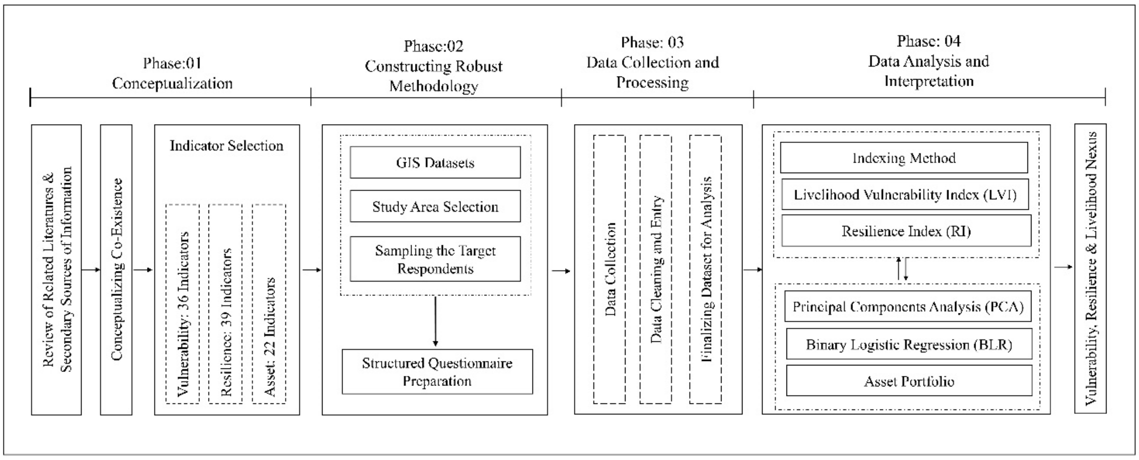


Figure 2. Schematic diagram demonstrating the steps followed in this research.

2.2. Data Collection and Analysis

A set of methods were adopted in order to collect and analyze data in completing this study (See Figure 2). Despite some constraints of collecting the required data in such remote rural setting, we opted to assemble information scientifically upon following several steps such as:

2.2.1. Structured Questionnaire

We developed structured questionnaires to survey households at the studied unions. The questionnaire consisted of several parts for the respondents, including but not limited to socioeconomic information, current professions, social capital and networks, access to essential services and foods, available resources for adaptation (e.g., cash, livestock, land, etc.), access to hospitals and health clinics, and future adjustment plans regarding the extreme weather events.

2.2.2. Secondary Sources of Information

We collected secondary information from diverse, reliable sources aligned with our study objectives. Note that, some of the documents were available only in the local language (i.e., Bengali) and it was required to translate these into the English language. For example, local government documents demonstrating plans of adaptation and necessary measures were available in the form of leaflets, pamphlet, and short essays. These documents were only available in local language for the readers who could understand it. Moreover, we collected relevant reports, published and unpublished academic theses, peer-reviewed international journal articles, and photographs from newspapers.

2.2.3. Geographic Information Systems (GIS) Data Sets

Before identifying the study areas and for sample selection, we collected reliable sources of GIS data sets from Local Government Engineering Department (LGED) and the GIS lab at Urban and Rural Planning Discipline of Khulna University. We transformed the maps according to our need and projected into the real world using WGS84 system so that the map could represent a specific location of our interests without any distortions. Note that, we crosschecked the validity of GIS data sets from different sources as it was critical for selecting the studied local government units in Mongla.

2.2.4. Sampling the Target Respondents

We considered household as the targeted unit of the sample. For this, we divided Mongla district into five diverse zones depending on the coastal proximity. Then we opted to introduce several grids (i.e., cells) on the map of two targeted unions. Afterwards, we picked six grids that were randomly selected by performing the automatic cell selection process through computer platforms (See Figure 3 for details).

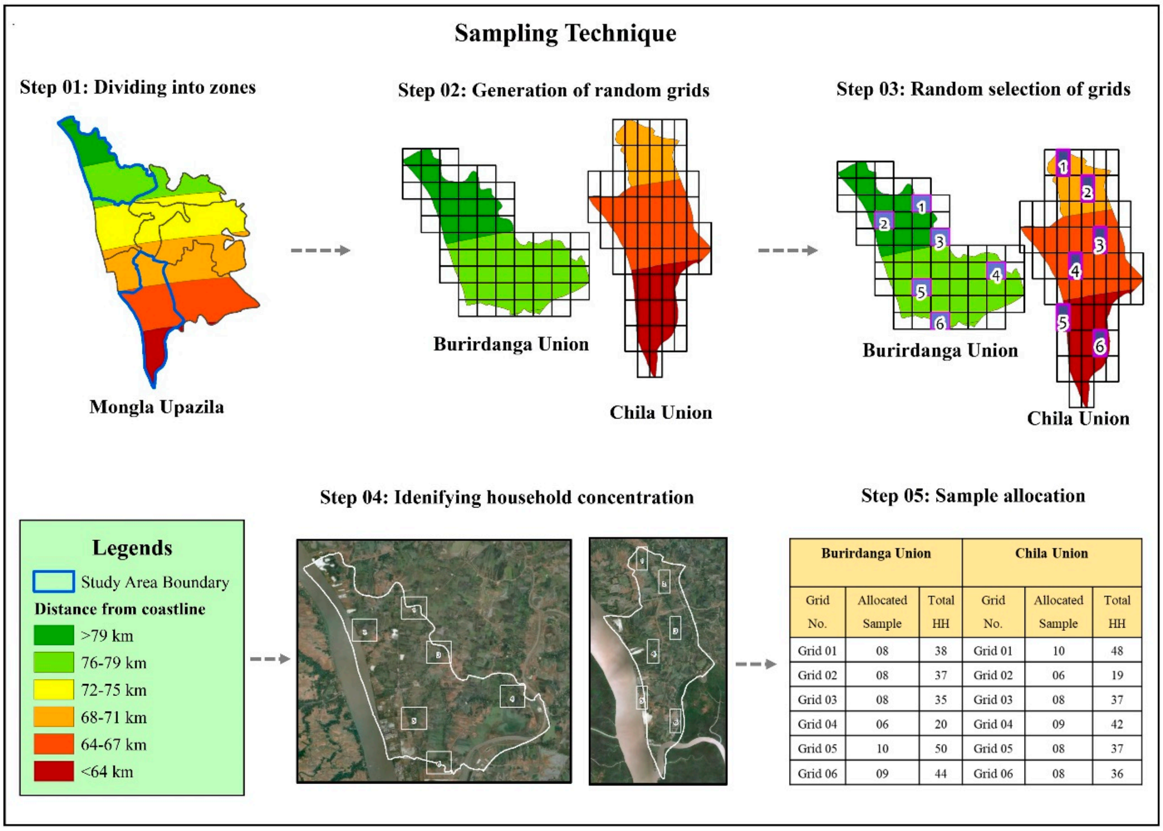


Figure 3. Exhibits the step-by-step sampling technique adopted in this study. Source: generated by the authors (2020).

The sample size in each grid was determined according to the formula proposed by Yamane [32], which had been widely used in similar types of studies. Note that, we had a total identified sample of 443 in two unions. However, depending on the precision level and margin of error (i.e., less than 10%), we reached an agreement of conducting a sample of 82. Consequently, we agreed to conduct the survey of 98 households to attain better precision level considering the total population of the area; 22% of the population could be considered.

2.2.5. Generating the Indices

We reviewed widespread literature to generate the indices to answer our research question. These scholarly research outcomes assisted us to develop our original framework and indices so that we could evaluate the relationships between vulnerability and resilience in the study area. Few of the methods we reviewed demonstrated the following:

- Mapping changing nature of vulnerability and resilience framework and methods [22,33,34];
- Attempting to measure relationships of vulnerability and livelihood concepts based on socioeconomic data [19,23,35–38];
- Generated models of household livelihood vulnerability and resilience indices [24,36,39–42];
- Community-based vulnerability and resilience mapping in the time of climate change [25,34,42–45]

We include seven significant components (that comprise a total of 36 indicators) to measure Household Livelihood Vulnerability Index (HLVI) (see Table A2). Table A2 includes an explanation of how each sub-component or indicator was quantified and the source of the indicator. The methodology we used here is developed for the calculation of the "Household Livelihood Vulnerability Index" [24,39], "Climate Vulnerability Index (CVI)" [40], "Livelihood Vulnerability Index" [36] and "Human Development Index (HDI)" [41]. We identify three major components or dimensions to construct Household Resilience Index (HRI), and a total of 39 sub-components or indicators has been selected (see Table A3 for details). It relies on the statistical behavior of physical, socioeconomic, and political variables where the weighting and aggregation mechanism of the composite resilience indicator is similar to Household Livelihood Vulnerability Index (HLVI).

2.2.6. Summarizing Outcomes

We developed both a vulnerability and resilience index by providing an equal weight, where each of the sub-components or indicators contributes equally to the overall index. In the LVI all the thirty-six indicators are equally weighted, so that each of them receives a 1/36 weight. The weight of each major component is calculated by multiplying 1/36 with the number of sub-components or indicators inherited by them (e.g., weight for major component socio-demographic profile is $5 \times 1/36$). If the number of sub-components or indicators in each major component is changed, the weights have been adjusted according to same principle as mentioned above. In the resilience index (RI), weights for dimensions and indications have been defined according to a similar methodology as above. As each of the sub-components have been measured on a different scale, it is essential to standardize each as an index. The equations (see Equations (1) and (2)) used for this standardization were first used in the Human Development Index (HDI) [41] to calculate the life expectancy index, later it was widely used in calculating LVI [24,36,39] and RI [45]. The Equation (1) has been used for the sub-components or indicators which have direct or positive functional relationship with vulnerability or resilience. Whereas indicators expected to have inversely related to vulnerability (such as mobility and access to remittance, access to relief) were standardized using Equation (2). Equation (2) has been used for normalization of indicators regarding LVI as no indicators which have inverse relation with resilience have been considered here. Both equations were employed subsequently to normalize information for ensuring the fact that the higher index value meant high vulnerability, high resilience and vice versa.

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

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

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. After normalization, indicators were averaged plugging the data 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 represents the value of one of the major components for household S (Socio-demographic profile (SDP), Livelihood strategies (LS), Social and political network (SP), Income and food access (IF), House, water, and sanitation services (HWS), Health, and Natural disasters and climate extremes (NDCE)), $Index\ X_{s^i}$ is the normalized value of the i^{th} indicator for household S, and n is the number of indicators under each major component or dimension.

Once major components value for each of the household is calculated, Equations (4) and (5) are used to calculate Household Livelihood Vulnerability Index (HLVI) and Household Resilience Index (HRI), respectively.

$$\begin{aligned} \boldsymbol{HLVI} = {} & (SDP \times W_i) + (LS \times W_{ii}) + (SPN \times W_{iii}) + (IFA \times W_{iv}) \\ & + (HWSS \times W_v) + (HE \times W_{vi}) + (NDCE \times W_{vii}) \end{aligned} \quad (4)$$

$$\boldsymbol{HRI} = (EA \times W_i) + (PA \times W_{ii}) + (SA \times W_{iii}) \quad (5)$$

where, for Equation (4), $HLVI$ = household livelihood vulnerability index, SDP = value of major component socio-demographic profile, LS = value of major component livelihood strategies,

SPN = value of major component social and political network, IFA = value of major component income and food access, $HWSS$ = value of major component house, water and sanitation services, HE = value of major component health and $NDCE$ = value of major component natural disaster and climate change. Based on the consideration of equal weight for each indicator, the W terms refers to the weight that was applied to each major component: $W_i = 0.14$, $W_{ii} = 0.11$, $W_{iii} = 0.25$, $W_{iv} = 0.17$, $W_v = 0.11$, $W_{vi} = 0.05$ *and* $W_{vii} = 0.17$.

Additionally, for Equation (5), HRI = household resilience index, EA = value of major component economic adaptation, PA = value of major component physical adaptation, SA = value of major component social adaptation. Like HLVI, based on equal weight approach, W terms refer to the weight of major component, where: $W_i = 0.28$, $W_{ii} = 0.54$ *and* $W_{iii} = 0.18$.

3. Results

We have summarized our results in two main parts as (i) co-existence of vulnerability and resilience is presented through juxtaposing vulnerability and resilience index score of the households; and (ii) the underlying factors of households' adaptive responses or resiliency that support this co-existence continuum as an outcome of Principal Components Analysis (PCA) and Binary Logistic Regression (BLR).

3.1. Juxtaposing Vulnerability and Resilience

The household-level livelihood vulnerability index (LVI) and resilience index (RI) is measured and graphically plotted in Figure 4 where the "y" axis represents a household's vulnerability scores and "x" axis illustrates a household's resilience scores. This juxtaposition aims to categorize households depending on their vulnerability and resilience considerations. The figure identifies four possible types of co-existence that endure in the lives of coastal residents. Note that the boundaries of each quadrant are exemplifying average scores of these indices. Different thresholds may have produced different classifications, although the general tendencies revealed in Table 1 remains true if other thresholds are used.

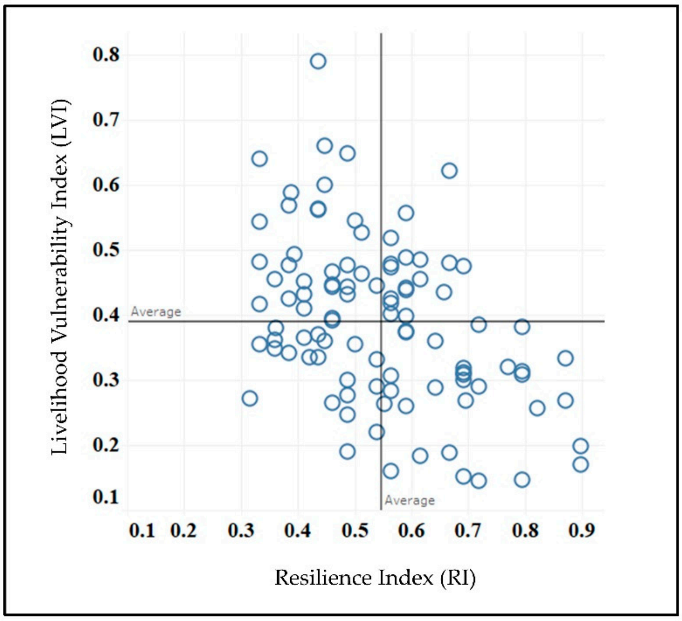


Figure 4. Juxtaposing households' livelihood vulnerability and resilience index.

The four possible types of co-existence pattern of coastal households can be presented as, (i) households with high vulnerability and low resilience, (ii) households with high vulnerability and high resilience, (iii) households with low vulnerability and low resilience and (iv) households with low vulnerability with high resilience (See Figure 5 and Table 1 for details).

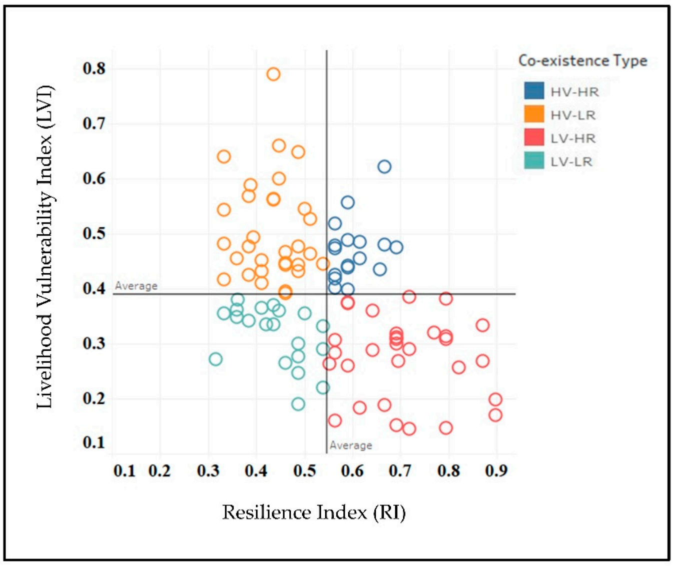


Figure 5. Differentials vulnerability and resilience nexus among coastal households.

Table 1. Nature of co-existence of vulnerability and resilience.

Category of Households			Characteristics
LVI Score	**RI Score**	**Figure Legend**	
High	High	HV-HR	Households with high vulnerability and high resilience
High	Low	HV-LR	Households with high vulnerability and low resilience
Low	High	LV-HR	Households with low vulnerability and high resilience
Low	Low	LV-LR	Households with low vulnerability and low resilience

3.2. Factors Affecting Households' Adaptive Responses to Climate Change

A total of 22 variables of a household's assets have been selected for a PCA model with orthogonal rotation (i.e., varimax). It is intended to employ the PCA method of factor analysis for identifying contributory factors or components that may shape the households' adaptive response against adverse impacts of climate change (see Table 2 for detail).

Table 2. Loadings of adaptive responses blocks on the first seven principal components.

Principal Components	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Household Capital							
Access to *khas* land	**−0.759**	0.272	−0.106	0.150	−0.123	−0.089	0.187
Access to open water fishing	**−0.736**	0.083	−0.054	−0.017	0.101	−0.017	0.066
Having inherited property	**0.647**	−0.075	−0.144	0.004	0.400	−0.038	0.229
Acreage of Land ownership	**0.589**	0.173	−0.208	0.303	0.210	0.144	0.096
Having *pucca* (brick/concrete) housing	**0.484**	0.145	−0.251	0.458	0.096	0.031	−0.304
Having contracts with local elites	**0.475**	0.205	−0.063	0.299	−0.372	0.074	−0.072
No. of earning member	**0.467**	0.089	−0.039	−0.285	0.175	−0.095	0.086
Have savings in Bank/NGOs	**0.430**	0.383	−0.344	0.144	0.010	−0.047	−0.126
Training and Saving							
Disaster management training	−0.110	**0.821**	−0.030	0.183	−0.033	0.056	0.097
Vocational training	−0.096	**0.796**	0.214	−0.174	−0.025	−0.101	0.048
Having cash saving	0.333	**0.488**	−0.196	0.115	0.148	0.333	0.021
Institution and Knowledge							
Membership in locally organized committee or samiti	−0.043	0.015	**0.776**	−0.086	0.153	−0.028	−0.156
Access to credit facilities	−0.052	0.068	**0.723**	−0.009	−0.227	0.173	0.180
Having membership in the NGO's microfinance project	0.143	0.353	**0.637**	0.265	−0.093	−0.286	0.029
Knowledge about modern, intensive farming techniques	0.164	0.317	**−0.530**	0.075	0.187	−0.040	−0.162
Health and Hygiene							
Drinking water quality	−0.065	−0.106	0.012	**0.786**	0.090	0.050	0.236
Water reservoir ownership	−0.048	0.244	−0.049	**0.636**	−0.132	0.182	−0.303
Hygienic sanitary latrine	0.302	0.132	0.074	**0.531**	0.347	−0.462	−0.078
Emergency Response							
Availability of transportation means	0.148	0.186	0.086	−0.161	**0.634**	0.420	−0.229
Having assistance from family members	0.119	−0.056	−0.203	0.155	**0.619**	−0.086	0.005
Mitigation Capacity							
Access to cyclone shelter	0.080	0.002	0.059	0.170	0.011	**0.853**	0.026
Social Safety							
Number of social safety nets	−0.026	0.134	0.079	−0.004	−0.054	0.029	**0.877**
Eigenvalue	**4.045**	**2.448**	**1.960**	**1.589**	**1.425**	**1.218**	**1.150**
Variance (%)	**18.384**	**11.127**	**8.910**	**7.222**	**6.478**	**5.538**	**5.228**
Cumulative variance (%)	**18.384**	**29.512**	**38.421**	**45.643**	**52.121**	**57.659**	**62.887**

Extraction method: PCA; rotation method: varimax with Kaiser normalization (rotation converged in 12 iterations). Bold values indicate high factor-loading of variables and variance of each factor. Determinant of correlation matrix was: 0.001.

In the PCA, the Kaiser–Meyer–Olkin measure has verified the sampling adequacy for the analysis with a value of 0.616. This is well above the acceptable limit of 0.5. Moreover, the Bartlett's test of sphericity demonstrates significance at $p < 0.0001$, indicating that correlations between items are sufficiently significant for PCA and the average communality is >0.500. Thus, factor analysis is considered statistically valid [46,47]. Seven components/factors have been retained following the Kaiser criterion, (i.e., only factors/components having Eigenvalue > 1) and "point of inflexion" of Tabachnick and Fedell [48]. The scree plot is slightly ambiguous and indicates inflexions that will justify retaining components up to seven. In the seventh component, the "point of inflexion", i.e., stable plateau, is observed in the scree plot (Figure 6). Collectively, these seven principal components accounted for 62.89% of the variance in the original 22 variables included in the analysis.

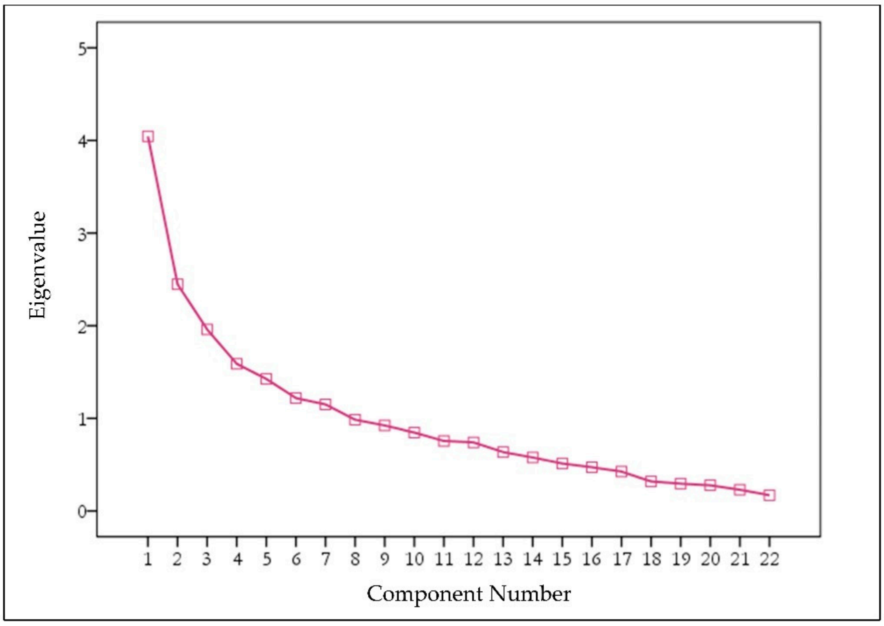


Figure 6. Use of scree plot to retain major seven factors.

The dominance of all the main component indicators is summarized in Table 2. The first principal component (PC1), termed as "household capital", constitutes eight variables and explains 18.38% of the variance. The second set (PC2), summarized as "training and saving", constitutes three variables and explains 11.13% of the variance. The third PC (PC3) is related to "institution and knowledge" includes four variables and explains 8.91% of the variance. The fourth PC (PC4) implies "Health and hygiene" and includes three variables, explains 7.22% of the variance. The fifth PC (PC5) can be summarized as "emergency response" explaining 6.478% of the variance. The sixth PC (PC6) set demonstrates "mitigation capacity" and includes one variable, explains 5.538% of the variance. Finally, the seventh principal component (PC7), named as "social safety", explains 5.23% of the variance, including one variable. All these seven factors or components have links with household's exposure and sensitivity to climate change and thus influence household's adaptive responses. The PCA is used to identify the significant factors, but it does not provide information about the influence of all significant variables of a factor. To compute the exact influence of each relevant variable with the statistical significance, it is critical to computing regression analysis. As the aim is to identify the exact extent of influence of the variable that contributes for being highly resilient/adaptive over being lowly resilient/adaptive to climate change and vice versa; the Binary Logistic Regression is performed in order to generate the relevant model.

3.3. Extent of Influence on the Household's Adaptive Response

In the Binary Logistic Regression, to pass the data sufficiency test, collinearity and multi-collinearity among independent variables should be avoided. Following Hair [49], after a bivariate correlation, the variable "access to open water fishing" was removed from the BLR model because of its strong collinearity (r > 0.60) with "access to *khas* land". At this point, the total Binary Logistic Regression variable turned down to 21 from 22. Furthermore, the cross-tabulation with the dependent variable "having hygienic-sanitary latrine" identified cell frequencies less than five. Following Field [46], this variable was excluded from meeting the condition of data sufficiency test. Finally, 20 variables were entered into the BLR model. The result of the BLR model with factors that significantly influenced household's adaptive response/resiliency were included in Table 3.

Table 3. Factors likely to influence the adaptive responses of the households.

Variable (n = 98)	B (Beta Coefficient)	Exp (B): Odds Ratio	Wald Chi-Square	Standard Error	Sig.
Constant	−14.871	0.000	13.481	4.050	0.000
Access to khas land	1.144	3.140	1.295	1.005	0.255
Having inherited property	1.498	4.473	1.994	1.061	0.158
Acreage of Land ownership	0.021	1.021	0.788	0.023	0.375
Having *pucca* (brick/concrete) housing	**2.042**	**7.708**	**3.820**	**1.045**	**0.051** *
Having contacts with local elites	0.405	1.499	0.199	0.907	0.656
No. of earning member	1.162	3.196	1.888	0.846	0.169
Have savings in Bank/NGOs	0.544	1.723	0.237	1.118	0.626
Disaster management training	0.547	1.728	0.244	1.107	0.621
Vocational training	1.615	5.028	1.987	1.146	0.159
Having cash saving	0.124	1.132	0.019	0.910	0.892
Membership in locally organized committee or samiti	0.708	2.030	0.460	1.044	0.498
Access to credit facilities	1.183	3.265	0.990	1.189	0.320
Having membership in the NGO's microfinance programs	**2.151**	**8.594**	**4.594**	**1.004**	**0.032** **
Knowledge about modern, intensive farming techniques	**1.990**	**7.313**	**3.532**	**1.059**	**0.060** **
Drinking water quality	1.169	3.218	1.867	0.855	0.172
Water reservoir ownership	0.976	2.654	1.161	0.906	0.281
Availability of transportation means	0.581	1.788	0.411	0.906	0.522
Having assistance from family members	0.960	2.611	1.104	0.913	0.293
Access to cyclone shelter	**2.428**	**11.34**	**5.300**	**1.055**	**0.021** **
Number of social safety nets	**1.585**	**4.879**	**4.627**	**0.737**	**0.031** **

Note: Bold values are used to highlight the significant factors/variables and their statistics. Dependent Variable: "Lowly Resilient" (used as reference category) and "Highly Resilient". Cut point: lowly resilient = less than average resilience index value and highly resilient = greater than average resilience index value. Significance level: * significant at $p \leq 0.10$, ** significant at $p \leq 0.05$.

The predictive power of the model is significant ($x^2(20) = 69.645$, *Pseudo-*R^2 (*Nagelkerke*) = 0.703, $p \leq 0.001$). It explains that the model is statistically (70.3%) successful while predicting the household's adaptive response/resiliency using the exploratory variables. It indicates that "having *pucca* (brick/concrete) housing", "having membership in the NGO's microfinance programs", "knowledge about modern, intensive farming techniques", "access to cyclone shelter" and "number of social safety nets" are the exploratory variables, which have a significant influence on households' adaptive response/resiliency rather than the other variables.

The odds of being in the highly resilient category are 7.708 times higher among households who have *pucca* housing than households who do not. Similarly, for households who have membership in the NGO's microfinance project, know modern, intensive farming techniques and have access to cyclone shelter, the odds of being in the highly resilient category are, respectively, 8.594, 7.313 and 11.34 times higher than the households who do not have these accessibilities. For social safety nets, a one-unit increase in social safety net number, the odds of being in the highly resilient category increase by 4.879 times.

Intrinsically, it is important to note that households with access to several opportunities such as: *khas* land, inherited property, contacts with local elites, savings in bank/NGOs, disaster management training, vocational training, cash saving, membership in samite (i.e., local community institutions), access to credit facilities, safe water accessibility, water reservoir ownership, availability of transportation, and assistance from family members, are likely to be more resilient than households not having these opportunities. For "acreage of land ownership" and "no of earning member" a one-unit increase in acreage of land and earning member number, the odds of being in the highly resilient category increases precipitously. Here all the exploratory variables show odds ratio > 1 and positive *beta coefficient* (B) which refers that for all the variable positive increase or positive response will increase the chance (odds) of being in the highly resilient category.

4. Discussion

Upon summarizing the information, four possible scenarios can be obtained to explain household's vulnerability and resilience characteristics in our study area (see Figure 7 for details). These four scenarios are representing the best case, worst case, self-made and prodigal son categories to understand the types of co-existence, which are adopted from Briguglio's [50] study on vulnerability and resilience framework for small states. The best-case category applies to the households that are less vulnerable in terms of their physical, social, and political dimensions. Additionally, this information explains a significant number of economic, social, and physical adaptation strategies to deal with climatic change as the LVI score is less than 0.5, and simultaneously RI index score remains more than 0.5. Diversified asset ownership helps these households to build adaptation strategies in dimensions above that include having inherited property, productive land ownership, contact with local elites, assistance from sanitary latrines, hygienic latrines, access to cyclone shelter, and availability of transport means (i.e., roads and waterways in particular). Besides, almost 70% households in this category have access to assets such as having "*pucca*" (brick and concrete made) houses, disaster management training, vocational training, membership in the NGO's microfinance projects, knowledge about modern and intensive farming techniques, water reservoir ownership, and a number of social safety nets to build social, physical and political adaptation strategies.

The *worst-case category* applies for the households that are highly vulnerable to climate change and do not have a significant number of adaptation strategies to deal with. These households mostly live in *khas* land and depend on the open water fishing for their livelihood. While comparing to the *best-case scenario*, the households in the *worst-case category* have less access to assets such as inherited property, institutional savings (i.e., bank balance), access to micro-finance projects, land ownership, having disaster management and vocational training, and assistance from family members, which make them less resilient to climate change. A similar notion can be depicted in a study conducted in Indonesia, which explained the evidence of having a high level of vulnerability at a given low level of resilience [3]. The study reveals that households are highly vulnerable in terms of their income, education, and housing condition and lowly resilient due to lack of capacity to implement learning and adaptation, including lack of social capital networks [3].

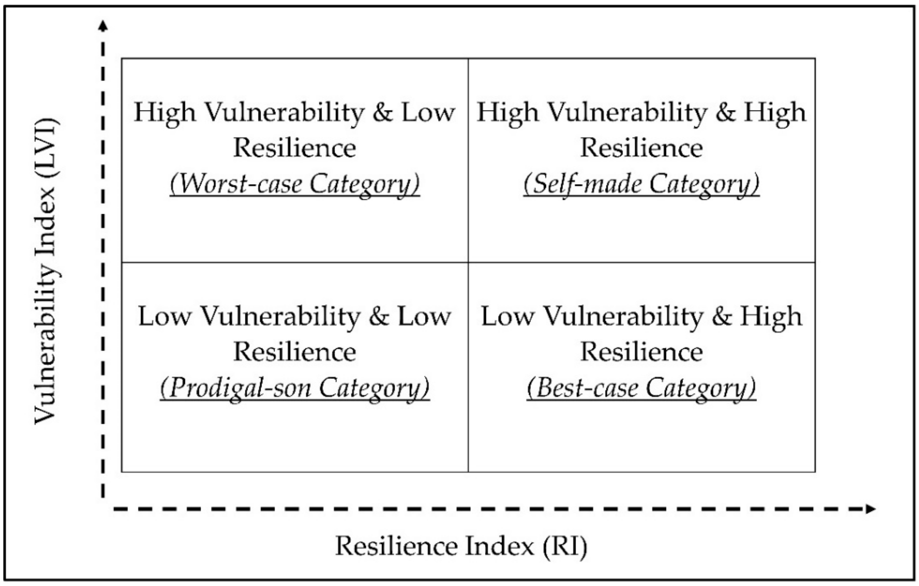
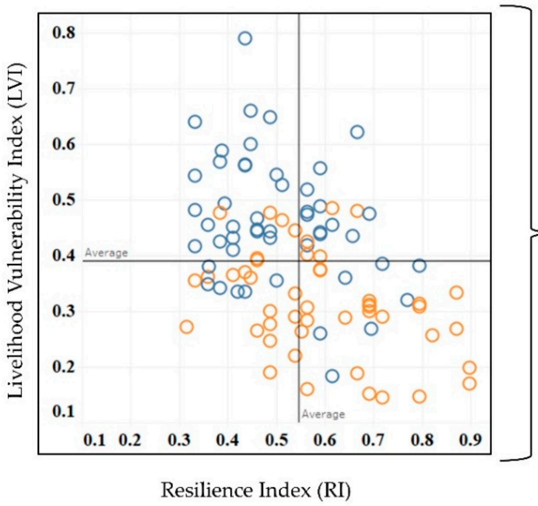


Figure 7. Nexus between livelihood vulnerability and household resilience.

The *self-made category* applies for the households with a high degree of physical, social, and political vulnerability and at the same time, they build up their resilience by adopting a significant number of strategies to deal with climatic changes. Furthermore, assets such as having membership in the NGO's microfinance project, membership in locally organized committee or Samiti and linkages with local elites help the households in this category to build several socioeconomic and political responses. These make the households more resilient than the households who are in the *worst-case category,* although households in both categories are highly vulnerable. Additionally, other two types of ownerships such as households' access to the inherited property and land ownership are slightly higher than the households in the *worst-case category,* which also contribute to the resilience of the households in the *self-made category*. Finally, the *prodigal-son category* applies for the households who are less vulnerable in terms of their physical, social and political dimensions. In addition, they do not have indicative economic, social and physical adaptation strategies to deal with climatic change as they have less access to the criteria as mentioned above cited in the *best-case category*. The geographical context of these four categories reveals that a higher number of households in the Chila Union are resilient although they are more vulnerable than the households of Burirdanga Union. In Burirdanga Union, 10.20% households are found in the self-made category where in Chila union it is 26.35% and on average 18.37% peoples are found in the self-made category. This elicits that 26.53% households of Chila union have high degree of vulnerability and at the same time built up their resilience through adopting a significant number of adaptation strategies to deal with climatic change where in the Burirdanga union these types of households are 18.37%. Besides that, 40.82% households of Burirdanga union are registered in worst-case category where in Chila union it is 30.61% and in average 35.71% households are registered in worst-case category. The same types of explanation can also be given for best-case category and prodigal-son category.

The preceding analysis reveals that a household with low asset profile can have a low vulnerability and high resilience power whereas, in some cases, households with higher asset profile can be more vulnerable and less resilient in the time of climate change. Additionally, the above four categories can further be characterized into eight groups based on these households' assets. It then allows identification of the appropriate vulnerable group according to the classifications. Under any of these eight categories, as shown in Figure 8, each of the categories needs differential treatment and policy measures for building adaptability. It is also vital for the selection of appropriate beneficiaries or participants. For example, category three households need to have the highest priority in terms of any crisis event as their asset is low with having a high level of vulnerability and low level of resilience and the same types of consideration need to made for other categories as well.



Category	Asset Profile	Vulnerability	Resilience
C-01	*Low*	*Low*	*Low*
C-02	*Low*	*Low*	*High*
C-03	*Low*	*High*	*Low*
C-04	*Low*	*High*	*High*
C- 05	*High*	*Low*	*Low*
C-06	*High*	*Low*	*High*
C-07	*High*	*High*	*Low*
C-08	*High*	*High*	*High*

Legends: Asset Profile
○ High Asset Profile
○ Low Asset Profile

Figure 8. Vulnerability and resilience differential in different asset profile.

5. Concluding Remarks

This research has explored the relationship between vulnerability and resilience and provides a well-defined knowledge about the same that is seemingly paradoxical in a typical rural setting in Bangladesh. The outcomes demonstrate a systematic understanding of the extent of rural households' livelihood and vulnerability within the co-existence framework. Moreover, resilience articulates as an integrated mechanism of adaptation planning for diverse social groups.

The findings have revealed that households having similar exposure to the climate extreme can have differential levels of vulnerability and resilience over time. People may have low vulnerability with low resilience, low vulnerability with high resilience, high vulnerability with low resilience and high vulnerability with high resilience, which have been categorized as four possible types of co-existence. This notion also illustrates that households with different asset profiles are embracing similar exposure to a climate extreme. However, the same group of people may have different vulnerability and resilience schema over time. Additionally, people are facing vulnerability-related issues depending on geographical location, tenure insecurity, social exclusion, inadequate infrastructure, and political bias in resource distribution. Consequently, they have recognized themselves as being resilient to climate change by having strong social cohesion, economical and physical adaptation practices. Intrinsically, the physical, social, natural, financial, and human capital play differentiated role in enhancing the resilience.

The findings of this research contribute unique knowledge of sustainability and adaptation planning by highlighting differential climate change vulnerability and resilience nexus scenarios in a coastal area of Bangladesh. We strongly believe that incorporating vulnerability and resilience concepts into an integrative framework may advance adaptation planning at local level in order to enhance resilience. The discrete view of asset, vulnerability, and resilience can mislead decision makers when managing eminent crisis events. Thus, it is essential to integrate vulnerability, resilience, and assets in one framework for evaluating climate related hazards more holistically. Therefore, this research indicates the efficacy of understanding vulnerability, resilience, and asset nexus in a scientific model to generate mainstream adaptation policy for diverse social groups.

It is worth noting that in the scope of this study, we have used quantitative research strategy for analyzing a primary dataset obtained directly from the field. The methods adopted can be used in similar socio-economic and geographic contexts. Furthermore, the research on co-existence of vulnerability and resilience in this study opens windows for using mixed method and qualitative judgements for further investigations. Additionally, researchers may concentrate on understanding the concept of vulnerability and resilience in terms of poverty, which may reveal interesting findings in the future. Finally, we recommend that a similar scientific approach may be useful elsewhere to understand the complex relationships among vulnerability, resilience, and assets possessed by communities in the face of climate change.

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Appendix A

Table A1. Major socioeconomic and demographic characteristics in Mongla, Bangladesh.

Characteristics		Burirdanga Union (n = 49)	Chila Union (n = 49)	Test Statistics (*p*-Value)
Household size (number)		5.12 (±1.25)	4.47 (±1.06)	t (96) = 2.78, **(0.006 ***)**
Age of household head (years)		46.16 (±13)	42.31 (±7.4)	t (96) = 1.77, **(0.080 *)**
Respondents	Male	63.3%	59.2%	$\chi^2(1)$ = 0.172, (0.678)
	Female	36.7%	40.8%	
Religion	Muslim	38.8%	53.1%	$\chi^2(1)$ = 2.013, (0.156)
	Hindu	61.2%	46.9%	
Income		15816.33 (±7284.9)	11234.69 (±5626.48)	t (96) = 3.48, **(0.001 ***)**
Amount paid to buy water (Taka/month)		167.35 (±208.30)	233.67 (±120.93)	t (96) = −1.928, **(0.057 *)**
Number of dependents (number)		3.69 (±1.19)	3.18 (±1.03)	t (96) = 2.26, **(0.026 **)**
Girl child aged 4–16 years (number)		0.53 (±0.71)	0.43 (±0.50)	t (96) = 0.822, (0.413)
House affected by cyclone (number)		1.53 (±0.71)	3.10 (±0.82)	t (96) = −10, **(0.000 ***)**
Number of social safety nets (number)		0.82 (±0.73)	0.80 (±0.65)	t (96) = 0.147, (0.883)
Access to safe water		57.1%	63.3%	$\chi^2(1)$ = 0.383, (0.536)
Adequate water supply		12.2%	16.3%	$\chi^2(1)$ = 0.333, (0.564)
Electricity		83.7%	71.4%	$\chi^2(1)$ = 2.110, (0.146)
Katcha housing		73.5%	83.7%	$\chi^2(1)$ = 2.013, (0.156)

Table A1. *Cont.*

Characteristics	Burirdanga Union (n = 49)	Chila Union (n = 49)	Test Statistics (*p*-Value)
Sanitary latrine	81.6%	87.8%	$\chi^2(1) = 0.708$, (0.400)
Vocational training	30.6%	59.2%	$\chi^2(1) = 8.08$, **(0.004 ***)**
Having inherited property	83.7%	65.3%	$\chi^2(1) = 4.35$, **(0.037 **)**
Have savings in Bank/NGOs	30.6%	24.5%	$\chi^2(1) = 0.460$, (0.498)
Access to information source	67.3%	57.1%	$\chi^2(1) = 1.086$, (0.297)
Access to khas (government) land	77.6%	63.3%	$\chi^2(1) = 2.40$, (0.121)
Preparedness training participation	36.7%	61.2%	$\chi^2(1) = 5.88$, **(0.015 **)**
Affordability of transportation means	83.7%	53.1%	$\chi^2(1) = 10.61$, **(0.001 ***)**
Having assistance from extended family members	85.7%	77.6%	$\chi^2(1) = 1.089$, (0.297)
Having membership in the NGO's microfinance project	36.7%	69.4%	$\chi^2(1) = 10.488$, **(0.001 ***)**

Note: >> χ^2 and t-statistics refers to the chi-square test and mean difference test respectively. **>>** P-values and standard deviation (where applicable) are in parenthesis. >> Bold values are used to highlight the statistical significance.>> Significance codes: 0.1 *, 0.05 **, 0.01 ***.

Table A2. Dimensions and indicators to measure Livelihood Vulnerability Index (LVI).

Major Components	Indicators	Unit of Measurement	Functional Relationship	Explanation
Socio-demographic profile (05)	Dependency ratio [36]	Ratio	Positive	The ratio of the population <15 years and >60 years of age to the population between 15 and 64 years of age.
	Female headed households [36]	Binary	Positive	The primary adult is female. If a male head is away from the home >6 months per year the female is counted as the head of the household.
	Literacy [37]	Count	Negative	Total number of members with formal schooling in the family.
	Existence of women insecurity [51]	Binary	Positive	Women insecurity in terms of violence, safety and security within the household and community.
	Vehicle ownership [52]	Binary	Negative	Availability of vehicles to evacuate people and livestock
Livelihood strategies (04)	Engaged in hazardous and risky activities [53]	Binary	Positive	Involve in activity where household members have chance of injury or death.
	No Child labour in the family [53]	Binary	Negative	Households do not have the members of less the 18 years' age who involved in working activity rather than going to school.
	Mobility and access to remittance [45]	Binary	Negative	Households where at least one adult earning member migrate in the city and send remittances to their families.
	Livelihood diversification index [36]	Index value	Negative	Average agricultural and non-agricultural livelihood diversification index (LDI).

Table A2. *Cont.*

Major Components	Indicators	Unit of Measurement	Functional Relationship	Explanation
Social and Political network (09)	Access to food relief in disaster time [52]	Binary	Negative	Self-explanatory.
	Access to early warning system (Independent/ Conventional) [27,36]	Binary	Negative	Self-explanatory.
	Support from extended family members [54]	Binary	Negative	Households getting hazard or post-hazard time support from extended family members e.g. friends, relatives etc.
	Connected with vertical network (i.e. community network) [27]	Binary	Negative	Whether the household connected with the community network for social, political, or religious purposes.
	Access to social safety nets programme [55]	Binary	Negative	Household is a part of government or NGOs operated social safety net programmes.
	Access to housing project after disaster [27]	Binary	Negative	Household received building materials as rehabilitation aid.
	Mobility in community activities [56]	Binary	Negative	HH heads and adult members participate in the community activities.
	Political violence in the community [57]	Binary	Positive	Self-explanatory.
	Tenure insecurity [45,56,58]	Binary	Positive	Tenure insecurity due to living in *khas* land and other political and social issues.
Income and food access (06)	Living below poverty line [45]	Binary	Positive	If total consumption per adult equivalent per day is less than $1.9 then the household is registered as poor whether non-poor as according to World Bank.
	Seasonality effect on household income and consumption [45,56]	Binary	Positive	Having time series when household have nothing to do and consumption became limited.
	Impact of government physical development [52]	Binary	Positive	Government physical development activities fail or have minimal effects on minimizing impacts of climate induced hazards.
	Political influence in rehabilitation programmes [57]	Binary	Positive	Biasness of political leaders for the selection of beneficiaries for rehabilitation programmes implemented by the government and NGOs.
	Amount of loan [57]	Taka	Positive	Current loan status of the household.
	Food insecurity [45]	Count	Positive	Average number of months households struggle to find food (range: 0–12).
House, water, and sanitation services (04)	Households living condition [27,52]	Likert	Negative	Condition of dwelling units & other sheds such as kitchen, cattle sheds in a scale of 1 to 5 (the higher the better).
	Condition of sanitary latrines [52,57,59]	Likert	Negative	Household's sanitation status in a scale of 1 to 5 (the higher the better).

Table A2. *Cont.*

Major Components	Indicators	Unit of Measurement	Functional Relationship	Explanation
	Amount paid to buy water [52]	Taka	Positive	Money that household spent to get water from private /NGOs developed water plant.
	Drinking water sources frequently affected by natural hazards [52]	Binary	Positive	Water sources affected by hazards such as drought, heavy rains and sudden storms, cyclone & storm surge.
Health (02)	Distance to health centre [36]	Minute	Positive	Average time to reach the nearest health centre from each household's location (walking distance in minutes).
	Disability/chronically illness in the family [59]	Count	Positive	Number of members having disability/chronically illness in the family.
Natural disasters and climate extremes (06)	Number of natural disasters during the last 10 years [52,59]	Count	Positive	Disaster frequency in last 10 years where natural disasters includes flood, draught, cyclone, tornedo, surge, etc.
	Inundation of the house [60]	Days	Positive	Average days (in a year) homesteads remained inundated due to cyclone or flooding.
	Duration of waterlogging in the agriculture field [60]	Days	Positive	Average days (in a year) agriculture field remained inundated due to cyclone or flooding.
	Frequency of flash flood [59,61]	Count	Positive	Number of flash floods experienced by a household in a year.
	Height of flood water [61]	Feet	Positive	Average height of water during flood.
	River erosion [60]	Binary	Positive	Chance of losing land due to river erosion.

Table A3. Dimensions and indicators comprising the resilience index (RI) measured for Mongla Upazila.

Dimensions	Indicators	Unit of Measurement	Functional Relationship	Explanation
Economic Adaptation (11)	Regular savings from family income [62]	Binary	Positive	Regularly save money from family income for hazard time and post-hazard response.
	Raised platforms used for cowsheds [62]	Binary	Positive	To save the animals from waterlogging and being their habitats muddy.
	Poultry: kept inside houses during hazard [62]	Binary	Positive	To save them from being stolen and injured.
	Move the animals to elevated platforms or land [62]	Binary	Positive	Move the animals to open and elevated platform for their daily consumption and to reduce the pressure on homemade or commercial animal food.
	Relocating fish cultivation area [62]	Binary	Positive	Relocation from hazard prone area to the less hazard facing area.

Table A3. *Cont.*

Dimensions	Indicators	Unit of Measurement	Functional Relationship	Explanation
	Build embankment to reduce the risk of flooding [62]	Binary	Positive	Build embankment to reduce risk of being flooded shrimp farm and open water aquatic resources.
	Fishing ponds protected with nets and barriers [62]	Binary	Positive	To protect the fish from being flooded.
	Adopt crop varieties [54]	Binary	Positive	Adopt verities of crop types for household consumption, nutrition, and economic gain.
	Adopt climate resilient crop types [54]	Binary	Positive	Adopt saline and flood resilient crop types to reduce the chance of damage.
	Changing irrigation techniques [62]	Binary	Positive	Transition from traditional to modern irrigation techniques.
	Use of canals for irrigation [62]	Binary	Positive	Using canals as an easy and affordable source of irrigation.
Physical Adaptation (21)	Renovation of ponds [62]	Binary	Positive	Renovation of ponds for freshwater and aquaculture.
	Build rainwater reservoir in the house/ community [62]	Binary	Positive	Reservoir in both household and community level to harvest the rainwater.
	Involving with community-based water supply system [62]	Binary	Positive	Households involve with the community-based water supply system.
	Establish tube well in newly built houses [62]	Binary	Positive	Newly built tube well in the house as an easy and affordable source of water.
	Making houses on raised plinths [62]	Binary	Positive	Making house in high elevation from the ground to be saved from waterlogging and being the house muddy.
	Elevated courtyard [62]	Binary	Positive	Elevated courtyard to cope with the flood events and waterlogging.
	Tree plantation around the house [62]	Binary	Positive	Planting trees around house to reduce the impact of cyclone, floods, tornados etc.
	Repair or rebuild houses with hardy materials [59,62]	Binary	Positive	To deal with the worst event of natural calamity.
	Climate proofing construction [62]	Binary	Positive	Building climate resilient infrastructure such as, rooftop with Nipa Palm (*Golpata)* or providing shade of wooden trunk under the rooftop to deal with extreme heat and building pucca (brick or concert build) housing.
	Change of housing location [62]	Binary	Positive	Relocation house from hazard prone area to the less hazard facing area.

Table A3. *Cont.*

Dimensions	Indicators	Unit of Measurement	Functional Relationship	Explanation
	Special techniques for hazard mitigation [62]	Binary	Positive	Use of thunderstorm protector, planting tree around the house, binding house corners with the adjacent trees and pillar (specially the rooftops) and unplugged electronic equipment in hazard time.
	Elevated latrines [62]	Binary	Positive	Elevated latrines to avoid spread of diseases.
	Cooking on elevated platforms [62]	Binary	Positive	As an arrangement to be safe from waterlogging, rainwater, and flood.
	Regular repair and maintenance of infrastructure in the village [62]	Binary	Positive	For emergency response and quick evacuation.
	Canal rehabilitation through channelization [62]	Binary	Positive	To drain out water naturally.
	Removal of obstacle in drainage system to reduce congestion [62]	Binary	Positive	For quick outflow of rainwater and water due to tidal surge.
	Collective maintenance of common facilities [62]	Binary	Positive	Collective maintenance of common facilities such as schools, mosques so that villagers could use these to take shelter during emergency.
	Construction of new cyclone shelter/ Construction of robust infrastructure [62]	Binary	Positive	Construction of new/robust infrastructure for multiple use.
	Raise elevation of the dykes [62]	Binary	Positive	To protect the water resource and increase water bearing capacity of the *gher** and ponds.
	Planting tree near the riverbed [62]	Binary	Positive	To reduce river erosion and to getting firewood for cooking.
	Conservation of mangrove plantation [62]	Binary	Positive	Conservation of mangrove forest as a protector against the cyclones, tornedos, floods etc.
Social Adaptation (07)	Adoption of weather information product for real time weather information [62]	Binary	Positive	Adoption of TV, Radio etc. for real time weather information for hazards time response.
	Attending capacity building training provided by GO/NGO [54]	Binary	Positive	NGO/GO capacity building training on livestock, agriculture, fishing, handicrafts, forest management, co-production etc.
	Household making coalition with NGO's/Donor's organizations [54]	Binary	Positive	Household making partnership to co-produce services or membership in the project with NGO's/ Donor's organizations.
	HH Engaging in community-based organization [62]	Binary	Positive	Household have engagement with CBOs activity.

Table A3. *Cont.*

Dimensions	Indicators	Unit of Measurement	Functional Relationship	Explanation
	Participating in social convention [54]	Binary	Positive	Member of the household participates in different social (religious and traditional) convention.
	Having membership of the political party [59]	Binary	Positive	Engage with the activity of a political party.
	Maintaining networks with political leaders [63]	Binary	Positive	Household have friendship or connection with political leaders.

*A traditional agricultural system in Bangladesh. A shallow depth pond which is dug into a rice field for fish farmin.

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