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A Nationwide Approach on Measuring Households' Resilience by Constructing Climate Resilient Livelihoods Index (CRLI) in Rural Bangladesh

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Abstract

This study developed households' Climate Resilient Livelihoods Index (CRLI) in Bangladesh. CRLI indicators were selected based on the Adequacy of Human livelihood conditions for Well-being and Development (AHEAD) framework and FAO resilience tools. The study was designed on cross-sectional data through a country-wide primary survey of 26,925 rural households. At first, we performed logistic regression to gauge the significance and intensity of different livelihood indicators on any specific livelihood indicator. Secondly, we scored each household with the set criteria of different livelihoods accessibility, if any households fulfill the set criteria was "scored 1" and if not "scored 0". After scoring the households, eight different scores for each household were summed up to construct a composite score of "CRLI". If any household scored 0 - 2 was considered as low resilient, if any household scored 3 - 5 was considered as moderate resilient and if any household scored 6 - 8 was considered as highly resilient. Additionally, we used ArcMap to visualize the percentage of households in districts with different resilience categories. Findings revealed that nationally 1.7% of households were low resilient, 60% of households were moderate resilient and only 11.48% of households were high resilient. More specifically, only 1.7% of households failed to secure any of the climate-resilient livelihood indicators, and only 0.06% of households secured all of them. Findings also revealed that food secured households had better adaptive capacity due to ensuring access to basic services, more financial capabilities, lower dependency ratio, and physical connectivity. In contrast, households with social safety net coverage had food in-

security, less financial ability, higher dependency ratio, lower education, and income sources. Among 64 counties, Cox's Bazar, Bandarban, Chuadanga, Barguna, Bhola, Patuakhali, Narail, Kurigram, Sunamganj, Jamalpur, and Netrokona were the most vulnerable in terms of low CRLI. On the other hand, more than 25% of high resilient households were located in Dhaka, Gazipur, and Munshiganj counties. These findings would propel the government to devise appropriate steps in terms of more investment in area-specific local communities for enhancing regional resilience.

Keywords

Climate Resilient Indicators, Livelihoods Index, Resilience Score, CRLI, Adaptive Capacity, Bangladesh

1. Introduction

According to IPCC Fourth assessment report, "resilience is defined as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change" (IPCC, 2007). "Resilience" also describes "the capacity of people" or "systems" to cope with stresses and shocks by anticipating them, preparing for them, responding to them and recovering from them (Pain & Levine, 2012). Furthermore, "resilience" has been hypothesized as the capacity of a system to absorb the disturbance and still capable to continue its fundamental function and structure (Walter et al., 2006). Similarly, "climate resilience" refers to the capacity of the socio-economic system to absorb stresses and maintain function derived by climate change (Amin et al., 2018). It is a long-term outcome of effective climate change adaptation and that indicates the capacity of social-ecological systems to sustain shocks and maintain the integrity of functional relationships in the face of external forces (Tompkins & Adger, 2004).

The term "livelihoods" is widely being used by different development organizations and agencies which have been taken as a form of "sustainable livelihoods" nowadays (Solesbury, 2003). Livelihoods resilience becomes a globally pressing subject in critical disaster and cultural studies (Roy, 2019). Livelihoods help to comprehend the complex socio-ecological processes that shape adaptive capacity and livelihoods framework supports to comprehend the assessment of adaptive capacity (Clay, 2018). Climate resilient livelihoods refer to the livelihoods that help to adapt, reorganize and evolve to upgrade the sustainability of the existing system to prepare for future climate change impacts (Amin et al., 2018). In this study, the concept of "climate resilient livelihoods" defines the community livelihoods likely to adapt to the future climate change impact by measuring their existing livelihoods strategies. Measuring the existing local livelihoods could anticipate the present vulnerability and future risks. Livelihoods

strategies refer not only to generating income but also include cultural and social phenomena (Sallu et al., 2010). The rural livelihood is a complex and dynamic phenomenon even though the day-to-day uncertainty of survival is constant (Marschke & Berkes, 2006).

Bangladesh is located in between 20˚40'N - 26˚80'N and 88˚10'E - 92˚10'E comprising an area of 147,570 km^2 of deltaic land in South Asia; with a population density of 936 persons/km^2 where more than 20.5% people living below the national poverty line (ADB, 2016), is susceptible to future climate change (IPCC et al., 2007; GoB, 2010). Due to its geographical location this country often experiences different climate related natural events e.g. flood, drought, cyclone, riverbank erosion, salinity intrusion and water congestion that causes a great loss of lives and damages food, water, health and energy security and affects the lives and livelihoods (Alam et al., 2017). Depending on the geographical setting the intensity of the climate risk may differ on influencing the households' resources and resilience (Yohe & Tol, 2002); and may indirectly impact on the adaptation capacities. Assessing adaptation capacities are required for effective development and it varies from country to country, from community to community, from region to region, also among social groups and individuals, and over time (Thathsarani & Gunaratne, 2017). The main objective of this study is to assess the local adaptation capacities based on climate sensitive livelihoods indicators. The hypothesis is if any household can assure sufficient livelihoods, then the adaptation capacity will be enhanced. There is no study has been carried out yet to identify the households' resilience considering the livelihood indicators nationally. In this study, the local adaptive capacity has been assessed by constructing an index of climate resilient livelihoods by aggregating the district level households' index and a comparative geographical visualization of resilient population has been plotted based on the sample households across the country. More specifically, a country wide survey data has been used to explore: 1) the association among the climate resilient livelihoods indicators, 2) the percentages of households with different climatic resilient livelihoods, 3) to construct a climate resilient livelihoods index, and 4) to identify the percentage of households with different resilient categories. Given the geographical settings and different climatic hazards, a responsive adaptive policy is an urge for Bangladesh to adapt with the future adverse climatic impacts. Retorting the need, this research has been identified the local livelihoods resiliency comprehending the climate sensitivity.

1.1. Indicators for Climate Resilience Livelihood Index (CRLI)

In this study, Climate Resilient Livelihood Index (CRLI) has been constructed based on the livelihoods and resilience phenomena. Identifying the indicators within the context of livelihoods; the indicators have been selected from the AHEAD livelihood framework (Adequacy of Human Livelihood Conditions for Well-being and Development) (Lissner et al., 2014). Additionally, we have cross-checked the similar indicators used in the FAO resilience tools (FAO,

2016; Mane et al., 2010). The reason is to construct the CRLI by combining both "livelihoods and resilience" phenomena. In the AHEAD framework, the livelihood has been identified under three broader livelihoods dimension namely subsistence, infrastructure and social structure. Similarly, for selecting the indicators we broadly cover these three livelihoods' dimensions. Household's "food security" and "access to water" have been considered under the broader livelihood dimension of "subsistence". "Access to sanitation and electricity", "physical connectivity", "adaptive capacity", "knowledge and resilience against climate change" are considered under the broader dimension of "infrastructure". "Wealth index", "dependency ratio" and "social safety net" are selected under the broader dimension of "social structure". Consequently, among different resilience indicators considered by the FAO resilience tools (for measuring household food security) this study has considered access to food, access to basic services, asset, dependency ratio, households' adaptive capacity and social safety net. Though, the indicators are selected initially considering the AHEAD livelihoods framework and FAO resilience tools; a justifiable concurrence has been established between chosen indicators and climatic indicators from reviewing a significant number of literatures. The following discussion has emphasized on how the selected indicators are climatically connected and has influenced over livelihoods (**Figure 1**).

1.1.1. Households' Food Security

Temperature and rainfall are the two major indicative climatic variables for climate change. Changing rainfall patterns have significant impacts on the sowing and harvesting times of crops (Hossain et al., 2014). Food production or crop yield is an important component for the national food availability in developing countries (Grace et al., 2012). Agriculture is the main sector which will cause higher poverty due to climate change (Hallegatte et al., 2015). It has been predicted

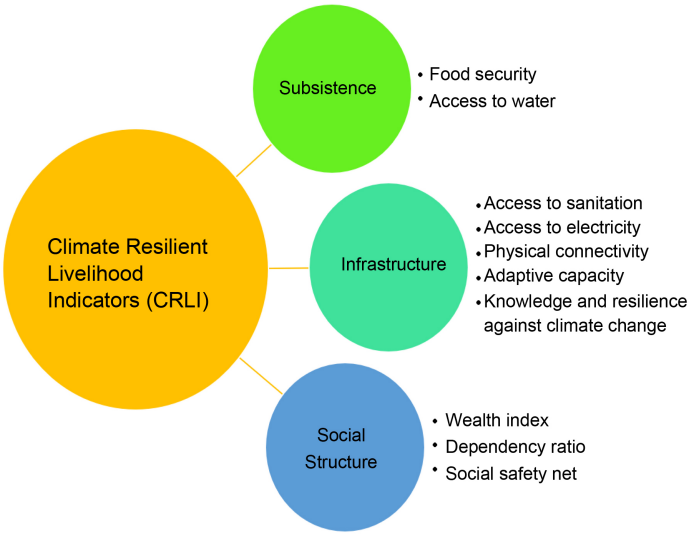

Figure 1. Indicators for climate resilience livelihood index (Lissner et al., 2014; FAO, 2016).

that Bangladesh would experience a net increase in poverty of 15% by 2030 in a low crop productivity scenario (Hertel et al., 2010). Due to climate change, ensuring national food security would be more challenging. Food security has been considered as the prime indicator to identify the households' resilience capacity (Mane et al., 2010). In this study, households' food security has been estimated by measuring the household food insecurity using the Food Insecurity Expenditure Scale (FIES) widely used by Food and Agriculture Organization (FAO, 2020). A total set of 7 questions were asked during the last 12 months to estimate FIES: 1) worried about enough food to eat, 2) unable to eat healthy and nutritious food, 3) eat only few kinds of food, 4) skip a meal, 5) eat less then expectation, 6) run out of food, and 7) starving for a whole day.

1.1.2. Access to Basic Services

Access to basic services refers to the three basic or public services inevitable for the well-being of human livelihood condition. It is one of the resilience tools that is determined by the FAO resilience framework (Mane et al., 2010). Human health risk burden has increased in Bangladesh and climatic factors such as temperature, rainfall and flooding are associated with different vector borne diseases (HNAP, 2018) along with the non-climatic factors such as access to safe drinking water, sanitation and power supply (Smith et al., 2015). Therefore, identifying the households' resilience; access to water, sanitation and electricity has been considered in this study.

1.1.3. Wealth Quintile

Poverty has been considered as one of the major causes derived from the climate change-driven phenomena. It has been counted as a threat multiplier and the poverty aspects would worsen in terms of income poverty and overall well-being (Olsson et al., 2014). To identify the household poverty, "wealth quintile" has been measured in this study. Based on the wealth quintile, the households are classified into five quintiles-lowest, low, middle, high and highest. In our study the wealth quintile has been calculated by considering the households' cultivable lands, livestock and trees, number of rooms, housing condition and asset value calculation of a list of different households' items.

1.1.4. Demographics

It has been estimated that climate change threatens the lives and futures of more than 19 million children in Bangladesh (UNICEF, 2019). Households with more children are more vulnerable to climate threats; therefore, in this study we have considered the households' demographics as a resilience tool. Demographics define the dependency ratio or the number of working people. The dependency ratio in this study has been referred not only for children in a household but also it has considered the ratio between the numbers of working people with the number of dependent people in a household. Therefore, this study has undertaken the number of persons in a households' with less than 15 years and greater than 65 years old.

1.1.5. Social Safety Net

Social Safety Net (SSN) is a domain to develop an adaptive social protection along with disaster risk management and climate change adaptation (Awal, 2013). Social safety has also been used as the households' social security in the FAO resilience tool. In this study, households covered with the government social safety net e.g. VGF (Vulnerable Group Feeding), VGD (Vulnerable Group Development), old age allowance, allowances for the widow, deserted and destitute Women, disabled allowance and child allowance have been taken under consideration.

1.1.6. Physical Connectivity

Physical connectivity refers to the ownership of television or cell phone for escalating connections. Access to information on early warning, response strategies, coping, adaptation mechanisms and science enhance the adaptive capacity (Thathsarani & Gunaratne, 2017). Also, these indicators are commonly being used for identifying the households" resilience on food security (Ciani & Romano, 2014).

1.1.7. Adaptive Capacity

In this study, we have considered the highest level of education in a household with different income sources. The education level has been considered as education enhances knowledge, which plays a vital role in increasing the adaptive capacity. It has been established within several research frameworks that knowledge is a powerful determinant and closely associated with many other determinants of adaptive capacity (Williams et al., 2015). However, following the FAO resilience tools diversity of income sources has been considered as an indicator for adaptive capacity. It has been also evident that farmers with more diverse sources of income have a higher adaptive capacity than farmers with less diverse sources of income (Abdul-Razak & Kruse, 2017).

1.1.8. Knowledge and Resilience against Climate Change

Apart from the following indicators, this study has additionally considered "knowledge and resilience against climate change" as an indicator for constructing the CRLI. Household's having knowledge on climate change, have experienced any impact of climate change on their livelihoods for the last 10 years and have received any training on climate change and strategies are considered for this indicator. It has been identified that strategic and systematic capacity building among the local people is required to cope with future climate change (Fahey et al., 2016).

2. Methods

2.1. Study Location

This study has been conducted in 64 districts in Bangladesh which covers the entire country. Bangladesh is placed in the boundary of the Bay of Bengal to its South and the Himalayas to its North. The location is in between 20˚40'N -

26˚80'N and 88˚10'E - 92˚10'E comprising an area of 147, 570 km^2. Most of the country is flood plain, flat and alluvial land at the mouth of Ganges-Meghna-Brahmaputra (GMB) basins which possess an identical tropical climate with high sensitivity to climate variability (seasonal variations in rainfall, high temperature and humidity) (Moniruzzaman, 2015). Currently, Bangladesh is divided into 8 administrative divisions namely Dhaka, Chottogram (Chittagong), Khulna, Rajshahi, Barisal, Sylhet and Rangpur and these divisions are sub-divided into 64 districts (**Figure 2**).

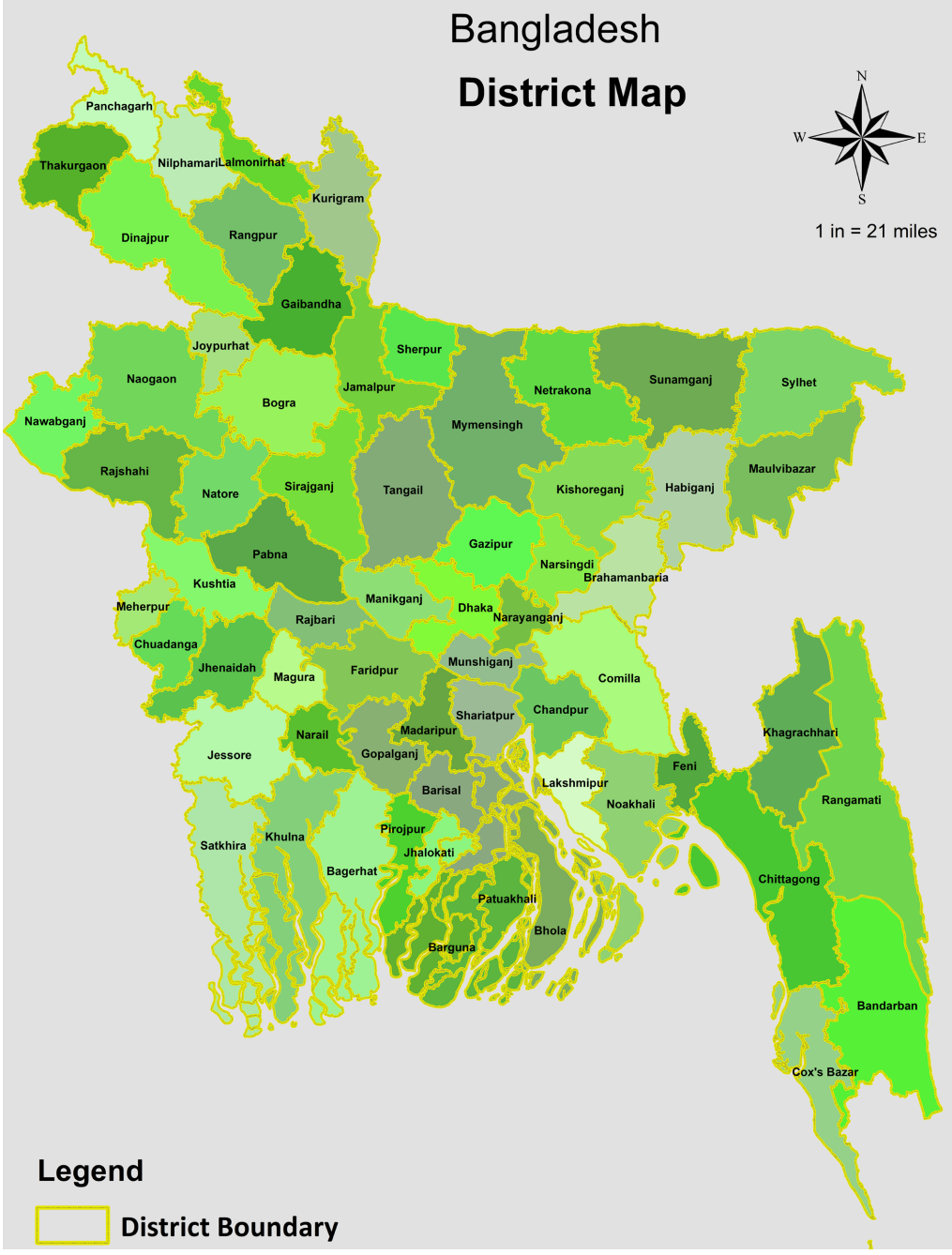

Figure 2. Map of Bangladesh.

2.2. Study Design

A cross-sectional study was designed employing a primary survey of 26,925 rural households located in different districts of Bangladesh. Following the Primary Sampling Unit (PSU) used in Population and Housing Census 2011 in Bangladesh, a multi-stage random sampling was used to select the households. Therefore, this study chose 1077 PSUs representing 64 districts. Considering 80% power, a 5% significance level and a design effect of 1.6×, the total sample size was calculated to be 26, 925 households following Equation (1); where n is the required sample size, expressed as number of households, z is the two sided z-value at $(1-\alpha)$% level of confidence, r is the predicted or anticipated value of specific indicator, expressed in the form of a proportion, $deff$ is the design effect for the indicator when cluster random sampling is implemented, e is the margin of error to be tolerated at the $(1-\alpha)$% level of confidence, pb is the proportion of the total population upon which the indicator r, $AveSize$ is the average household size (number of persons per household), RR is the predicted response rate. For the purpose of this study each village was considered as PSU and from each PSU 25 households were selected and considered accordingly.

$$n = \frac{z_{1-\alpha/2}^2 \times r \times (1-r) \times deff}{e^2 \times pb \times AveSize \times RR} \quad (1)$$

2.3. Data

A pre-tested and semi-structured questionnaire was designed in Comcare, a mobile based data collection application. Face to face interviews were conducted with 26,925 respondents using both open ended and closed questions. The questionnaire encompassed the socio-demographic characteristics including household's income, number of income sources, households' food security, access to water, sanitation and electricity, access to television and cell phone, dependency ratio, social safety net and knowledge and resilience against climate change. The study was conducted from October 2017 to January 2018. A total of 120 experienced field enumerators were recruited and trained to collect data through mobile app-based survey.

2.4. Analysis

Statistical Analysis

At first, we used the Pearson's correlation to identify the correlation among the eight climate resilient livelihoods indicators. The coefficient of Pearson's correlation ranges −1 through 0 to +1, if the sign of the correlation coefficient is positive, then a positive correlation would exist between the indicator and if the sign of the correlation coefficient was negative, then a negative correlation would exist between the livelihood's indicators (Sedgwick, 2012). Secondly, we tested the multicollinearity among the independent variables (Murray et al., 2012) and we included the variables that have the Variation Inflation Factor (VIF) less than 5. We performed logistic regression to gauge the significance and intensity of other

livelihoods indicators on any specific livelihood indicator. Logistic regression model is a maximum likelihood method identifies the regression coefficients that maximize the probability of the observed data (Tripepi et al., 2008). In logistic regression the binary dependent variable is a dummy for considering each livelihoods indicator where, Yi has only two possible values, 0 or 1; where 1 for either positively scored and 0 for negatively scored according to the scoring criteria (Table 1).

Table 1. Scoring criteria of households.

Indicators	Measurement scale	Scored 1	Scored 0
Household food security (HFS)	Food Insecurity Expenditure Scale (FIES)	Food secured	Moderate secured and severely insecure
Access to basic services (ABS)	Access to water, sanitation and electricity	Access to all basic services	Absence of any basic services
Wealth quintile (WQ)	Wealth index	Middle, high and highest quintile	Lowest and Low quintile
Demographics (DGS)	Dependency ratio	Dependency ration less than 51%	More than 51%
Social safety net (SSN)	Any government social safety net programme	At least one member under any programme	Absence of any safety net programme
Physical connectivity (PC)	Access to television and cell phone	Access to both	Without any access
Adaptive capacity (AC)	Level of education and diverse sources of income	At least one household member completed secondary education level and more than two income sources	Absence of both criteria
Knowledge and resilience against climate change (KRCC)	Knowledge about climate change, impact on income and livelihoods, received livelihoods training and support	Have knowledge about climate change and have no impact on income and livelihoods, have received livelihoods training and aid for livelihoods	Absence of any of the criteria

After scoring the households, eight different score for each household are summed up to construct a composite score. Based on the composite score we classified the CRLI index into three categories. If any household scored 0 - 2 is considered as *low resilient*, if any household scored 3 - 5 is considered as *moderate resilient* and if any household scored 6 - 8 is considered as *high resilient*. Additionally, we used ArcMap to visualize the percentage of households in districts with different resilience categories, using the following equation:

$$\text{Percentage of resilience category in a district} = \frac{\text{Total number of sample in any category}}{\text{Total number of sample in a district}} * 100$$

3. Result and Discussion

3.1. Household Demographics

Table 2 represented the household's demographics. A total of 26, 925 households were interviewed. In respond to the household food security, result showed that 73% households were found to be food secured and 27% households were found to be food unsecured. Considering the similar indicators, a study conducted in Bangladesh, has been identified that approximately 20 percent of the population was food insecure in 2011 according to nutrition balance approach (Broussard & Tandon, 2016). According to our study, about 97% of households had access to water; verified the findings identified by UNICEF (UNICEF, 2016). Findings also identified that about 50% of households had access to improved sanitation and 89% households had access to electricity. Similarly, the national demographic survey of Bangladesh reported that 53% households had access to improved sanitation and 87% households had access to electricity (GoB & USAID, 2016). Only 38% households had access to television, however, more than 96% households had at least one cell phone. However, the national demographic survey reported that 48.5% households belongs television and 94% households had mobile phone access (GoB & USAID, 2016). Among all households, only 15% households had social safety net coverage. According to World Bank survey, it had been identified that the social safety net coverage in Bangladesh was 12% in 2005 which had been increased 13% in 2010 (https://www.ceicdata.com). Our study had identified that the social safety net coverage reportedly increased by 2% in 2017. Identifying the demographics, more than 80% households were found with dependency ratio > 51. Nearly forty percent households were from lower and lowest wealth quintile, 20% households were from middle wealth quintile and the rest 40% household were from high and highest wealth quintile. Each 20% fell into each national wealth quintile which indicated that there is no difference of target population distribution with wealth quintile of the national population. Regarding knowledge about and resilience against climate change, result showed that 77% households had knowledge about climate change, however, a local study conducted in 7 vulnerable districts in 2016, has identified that 54.2% people had heard of climate change

Table 2. Household's demographics.

Indicators	Yes	No
	N = 26,925	
Household food security	72.95	27.05
Access to basic services		
Access to water	97.09	2.91
Access to sanitation	50.59	49.41
Access to electricity	89.13	10.87
Wealth quintile		
Lowest quintile	20.00	--
Lower quintile	20.00	
Middle quintile	20.00	--
High quintile	20.00	--
Highest quintile	20.00	
Demographics		
Dependency ratio > 51	82.72	17.28
Physical connectivity		
Access to television	38.11	61.89
Access to cell phone	96.01	3.99
Social safety net	15.12	84.88
Adaptive capacity		
>2 income sources	40.04	59.96
>Secondary education	31.12	68.88
Knowledge and resilience against climate change		
Households received training on climate change	5.13	94.87
Knowledge about climate change	77.75	22.25
Have impact of climate change on income	45.90	54.10
Have impact on livelihoods	56.23	41.00
Received support for livelihoods and income generation	2.37	97.63

(Kabir et al., 2016). This indicated that the knowledge of climate change was widely familiarized to the national level in comparison to the selective vulnerable communities. Findings also revealed that about 56% households reported that climate change had impact on their livelihoods. The climate change perception study also identified that 58% of the respondents reported climate change had direct impact on their livelihoods and the intensity would be worse in their locality (Marchal et al., 2012). Similarly, the study identified that 30% respondent reported climate change had impact on their income. However, in this study findings showed that about 45% households reported that climate change had

impact on their income. Interestingly, a swapping of reported percentage is observed between climate change perception study and our study. The difference showed that nationally 58% of population reported climate change had impact on their livelihoods in 2012 which decreased 56% in 2017; however, 30% of population reported that climate change had impact on their income in 2012 which increased to 45% in 2017. This finding justified that the percentage of population whose income had affected by the impact of climate change had been increased from earlier by 15%, in spite of not having clear idea whether climate change had impact on their livelihoods or not. It corresponds with the findings from the climate change perception study, where it had showed that almost 59% of respondents were not sure about the impact of climate change on their livelihoods (Marchal et al., 2012). Our findings also revealed that only 2% households have received support for livelihoods and income generation from different organizations and only 5% households have received any training on climate change.

3.2. Association among the Climate Resilient Livelihood Indicators

Table 3 presented the result of logistic regression where each livelihood indicator had considered as dependent variable. Result showed that one unit increase in food security yields significantly a positive change in log odds of 1.8 for access to basic services, 2.45 for wealth quintile, 1.25 for adaptive capacity, 1.1 for demographics and 1.58 for physical connectivity. Findings justified that increasing household's food security might enhance access to basic services, wealth, physical connectivity, adaptive capacity. Findings also showed that one unit increase in household food security might contribute on demographics (reduce dependency ratio and increase work force) with a log odd of 1.11. Result also showed

Table 3. Association among the climate resilient livelihoods indicators.

Dependent variables / Independent variables	ABS	WQ	SSN	AC	DGS	PC	HFS	KRCC
ABS		2.33*	0.84*	1.18*	1.11*	1.84*	1.79*	1.05
WQ	2.33*		0.82*	1.72*	1.18*	24.41*	2.44*	1.24*
SSN	0.84*	0.81*		1.09	0.72*	0.81*	0.50*	1.04
AC	1.18*	1.70*	1.08		3.50*	0.89	1.24*	1.31*
DGS	1.12*	1.16*	0.73*	3.51*		1.26*	1.11*	1.05
PC	1.84*	24.46*	0.80*	0.88	1.25*		1.59*	1.11*
HFS	1.79*	2.45*	0.50*	1.25*	1.11*	1.58*		1.01
KRCC	1.05	1.24*	1.04	1.32*	1.05	1.10*	1.02	

Household food security (HFS), access to basic services (ABS), wealth quintile (WQ), demographics (DGS), social safety net (SSN), physical connectivity (PC), adaptive capacity (AC), knowledge and resilience against climate change (KRCC).

that one unit increase in access to basic services in households yields a significant positive change with a log odd of 2.33 for wealth quintile, 1.18 for adaptive capacity, 1.84 for physical connectivity. This finding justified that enhancing financial abilities allowed households to access more services or better services. Findings revealed that one unit increase in wealth quintile enhanced the physical connectivity (both access to television and mobile) with a log odd of 24.41. Wealth quintile also had significant positive influence on household food security, access to basic services, demographics, adaptive capacity. However, increasing wealth quintile reduced the social safety net coverage with a log odd of 0.82. Remarkably, the interesting thing to note that among eight indicators, social safety net had a significant negative association with household's food security, access to basic services, wealth quintile, demographics and physical connectivity. This indicated that households with sufficient food security, financial ability, lower dependency ration, higher education level and more income sources tend to less reliance on social safety net coverage. Eventually this findings justifies that social safety net programme aimed for insecure poor and vulnerable people (Badhan et al., 2019). Result also showed that adaptive capacity might be driven significantly by the access of basic services, household's food security, wealth quintile, demographics and knowledge and resilience against climate change. In this study, adaptive capacity was defined by the number of income sources and highest education level of the households, both indicators contributed on securing household's food security and enhancing financial wealth as well as physical connectivity. Households demographic also contributed on enhancing the adaptive capacity as the dependency ratio decreased and contributed on increased income source by engaging household workforce. Findings also revealed that wealth quintile, adaptive capacity and physical connectivity had significant positive association with knowledge and resilience against climate change. This indicated that households lead to an increase in wealth, adaptive capacity and physical connectivity increase the knowledge and resilience against climate change as well.

3.3. Households with Resilience Score

Findings revealed that almost 73% households were food secured, 46% households had access to basic services, 60% households had better financial capacities, 83% households had lower dependency ration, 38% households had physical connectivity, 15% households had coverage under social safety net programme, 12% households had adaptive capacity and lastly, 31% households had knowledge and resilience against climate change, which were eventually scored 1. In contrast, result showed that almost, 27% households were food insured, 54% households were failed to meet any of the basic services, 40% households were financially vulnerable, 17% households were occupied with more dependents and had less work force, 62% households failed to meet the physical connectivity (access to both television and cell phone), more than 80% households failed to

assure social safety net programme and had low adaptive capacity and almost 70% households had failed to have knowledge and resilience against climate change; eventually scored 0 (Figure 3).

3.4. Percentage of Households with CRLI Score

Finally, a composite index had been constructed combining the scores. Findings revealed that only 1.7% households scored 0, which indicated that 1.7% households failed to secure any of the livelihood's indicators, eventually defined as low resilient. In addition, about 8.6% households scored 1 and 16.7% households scored 2, also fell into low resilient categories. Nevertheless, 20% households scored 3, 4 and 5 discretely fell into moderate resilient categories, therefore, 60% households were moderate resilient. On the contrary, findings also revealed that only 11.48% households were high resilient where only 10% households scored 6, 1.41% households scored 7 and 0.06% households scored 8 (Figure 4).

3.5. Mapping of the Climate Resilient Livelihoods Index in Districts

Figure 5 showed a clear pattern of spatial distribution of resilient livelihoods in Bangladesh. In our study, the spatial distribution showed that most of the low resilient households were mostly located in the south-east and some parts of the north-east hilly and *haor* basin. More than 40% low resilient households were located in *haor* regions (Sunamgonj, Sylhet, Netrokona, Kishorgonj and Jamalpur), flooding regions (Kurigram, Lalmonirhat and Sirajgonj) and Khagrachhari. Remarkably, more than 50% low resilient households were located in Cox's bazar and more than 45% low resilient households were located in Bandarban. These districts were located mostly in disaster prone zones where poverty rate was high (Bangladesh Bureau of Statistics, 2009) and livelihoods pattern was very poor as well. On the other end, less than 10% low resilient households were

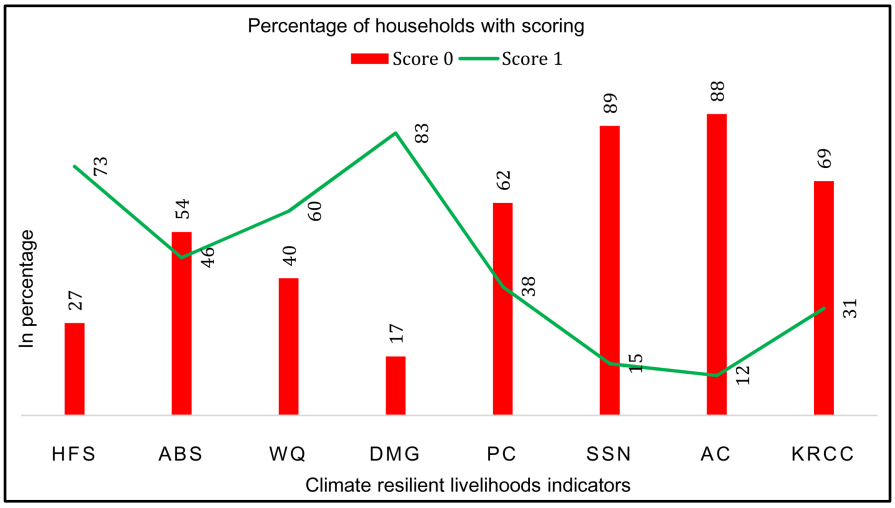

Figure 3. Households with climate resilient livelihoods indicators (in %).

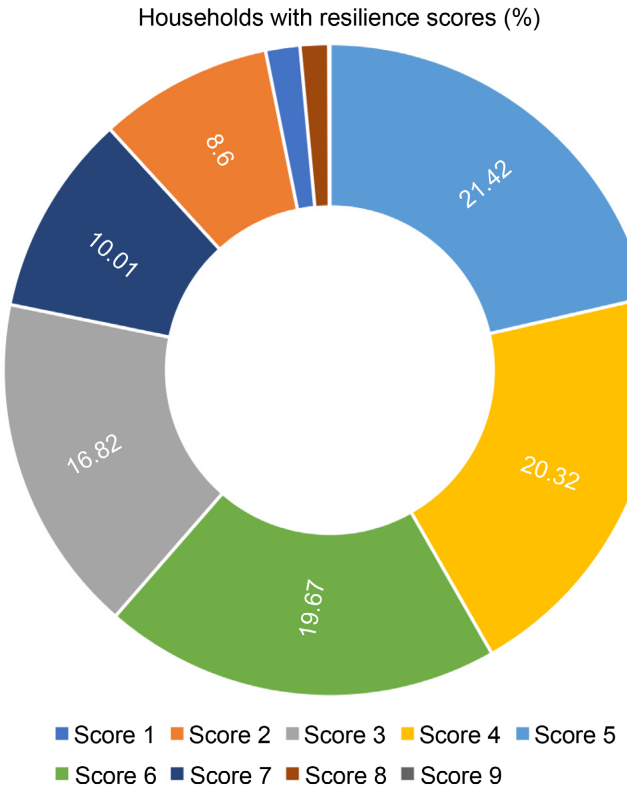

Figure 4. Households with resilience score.

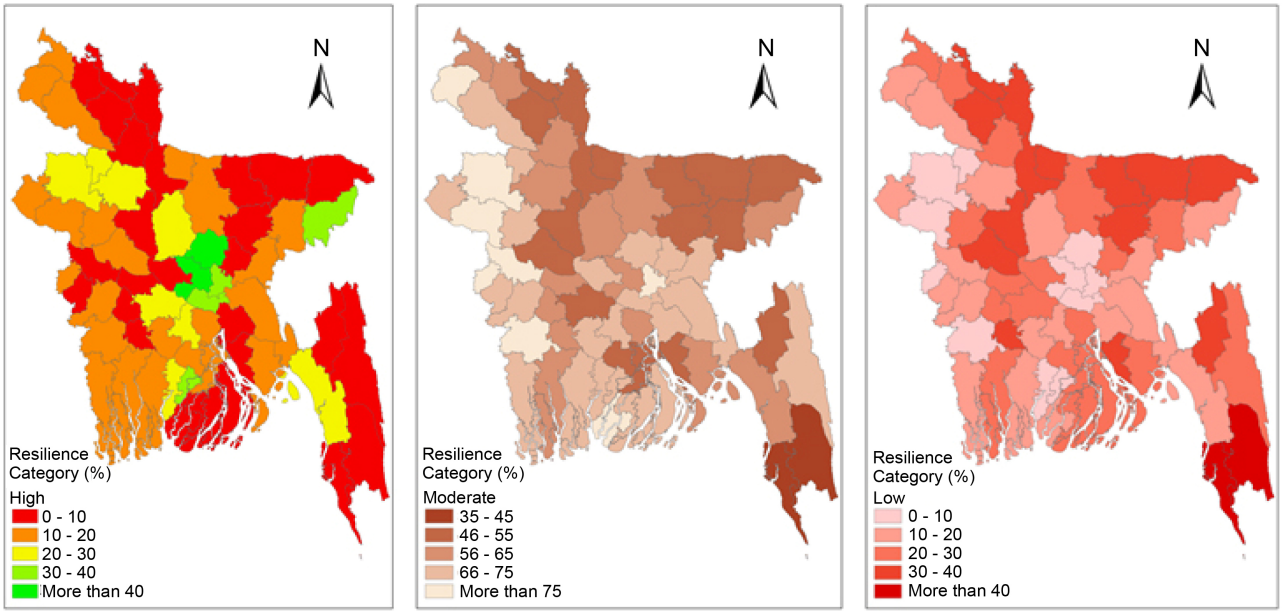

Figure 5. Percentage of households with different resilience categories in Bangladesh.

located in Dhaka, Gazipur, Munshiganj, Narayangonj and Naogaon. This indicated that centrally located districts had sufficiency on accessing the livelihoods indicators that eventually reduce the number of low resilient households. Findings from another study also justified our results which revealed that Gazipur

and Naryanganj districts had high adaptive capacity (Islam et al., 2019). The percentage of moderate households was higher in compare to low and high resilient households, except Bandarban and Cox's bazar. In the high resilience category, the situation was grim. At the best possible situation, only Dhaka had a population percentage of more than 30% with high resilience, while Gazipur and Munshiganj reported more than 25% high resilience. Every other district falls below this threshold, with an astounding 52 districts having less than 15% high resilience population. Of these, 11 districts have less than 5% high resilience, indicating significant livelihood challenges and changes in the case of a natural disaster affecting these areas. Once again, Cox's Bazar and Bandarban feature in this unfortunate list, along with Chuadanga, Barguna, Bhola, Patuakhali, Narail, Kurigram, Sunamganj, Jamalpur and Netrokona.

4. Conclusion

This research identifies that considering the geographical settings and different climatic hazards, a responsive adaptive policy is a crucial urge for Bangladesh to adapt to the future adverse climatic impacts. Empirical understanding of this study demonstrates the regional variation of climate resilient livelihoods is varied in local context depending on the social variables. Meticulous exploration of the aforementioned crucial issues would enhance better management of different climate-induced risks and vulnerabilities in future. Undoubtedly, it is pertinent to articulate the national mapping of regional livelihoods that could serve as a beacon for the concerned authorities to contrive region specific policies and strategies to prevent, control or reduce the impacts of climate change.

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Consent for Publication

All authors have read and approved the submission.

Availability of Data and Material

Data are publicly available; however, interested researcher may contact the corresponding author rabbi@pik-potsdam.de. Data and materials may be shared with the qualified researchers after considering of all aspects.

Conflicts of Interest

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

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Supplementary

Table S1. Collinearity among the CRLI indicators.

	ABS	WQ	SSN	AC	DGS	PC	HFS	KRCC
ABS	1							
WQ	0.3	1						
SSN	−0.1	−0.1	1					
AC	0.1	0.1	0.0	1				
DGS	0.1	0.1	−0.1	0.1	1			
PC	0.3	0.6	−0.1	0.0	0.1	1		
HFS	0.2	0.3	−0.1	0.1	0.1	0.2	1	
KRCC	0.0	0.1	0.0	0.0	0.0	0.1	0.0	1