British Journal of Environment & Climate Change
6(4): ………….., 2016, Article no.BJECC.2016.026
ISSN: 2231–4784

SCIENCEDOMAIN *international*
www.sciencedomain.org

Measuring Climate Change Vulnerability and its Adaptive Capacity: Policies and Planning for Bangladesh

M. A. Awal[1*], M. Harun-Ar Rashid[2], A. F. M. Tariqul Islam[3], M. Farouq Imam[4] and M. A. Rouf Sarkar[5]

[1]Department of Crop Botany, Laboratory of Plant Ecology, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
[2]Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
[3]Agricultural Statistics and ICT Division, Bangladesh Agricultural Research Institute (BARI), Gazipur 1701, Bangladesh.
[4]Department of Agricultural Statistics, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
[5]Agricultural Economics Division, Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh.

Authors' contributions

This work was carried out in collaboration between all authors. Author MAA conceived and designed the study, conducted model simulations, and wrote the manuscript. Author MHAR conducted the field visits. Author AFMTI prepared GIS maps. Author MFI conducted statistical analysis. Author MARS conducted literature search. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJECC/2016/27382

Received 31st May 2016
Accepted 11th June 2016
Published 2nd December 2016

Original Research Article

ABSTRACT

Aims: The paper aims to quantify the spatial vulnerability and adaptive capacity to climate change throughout the various regions i.e. divisions of Bangladesh. Another aim was to formulate befitted policies and planning to reduce the climate change vulnerability for the rural poor.
Study Design: A statistical methodology was implemented to quantify vulnerability and adaptive capacity to climate change shocks among all seven divisions of Bangladesh using secondary data sets by the IPCC's integrated vulnerability assessment approach which comprises sensitivity, exposure, and adaptive capacity.
Place and Duration of Study: Desk study: Laboratory of Plant Ecology, Department of Crop

**Corresponding author: E-mail: awalma7@bau.edu.bd*

Botany, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh. Field study: Some extreme climate change shock hot spots throughout Bangladesh including flood, cyclone, drought, salinity, water logging etc; from December 2011 to April 2013.
Methodology: Both socioeconomic and biophysical parameters from Bangladesh Bureau of Statistics (BBS), Household Income and Expenditure Survey (HIES), and other secondary sources are integrated with a statistical tool named Principal Component Analysis. To formulate proper policy for reducing climate change related vulnerabilities, primary data were also collected through focus group discussion with climate poor, and stakeholder consultation with program staffs.
Results: Vulnerability and adaptive capacity to climate change are found different over the divisions of Bangladesh. Households of Barisal division show extreme climate change vulnerability followed by Rangpur and Khulna divisions whereas Rajshahi division shows minimum vulnerability followed by Sylhet or Dhaka division. On the other hand, the households of Khulna region have higher degree of adaptive capacity to climate change followed by Rangpur and Rajshahi divisions whereas the adaptive capacity was found minimum for the households from Sylhet division followed by Chittagong and Dhaka divisions.
Research Limitations/Implications: The biophysical properties of climate and socioeconomic conditions of households are not constant rather changes occur over time. Consequently measured indices would not constant for a longer time. Further analysis may be needed based on the availability of new data sets in future.
Practical Implications: Policy makers often confuse to think too many interacting factors on course of a disaster management plan, however such a single figure as vulnerability index can straightforward the policy intervention towards a direction.
Originality/Value: Although Bangladesh is a worst victim due to the various types of climate change shocks and stresses, its spatial vulnerability and adaptive capacity throughout the various regions of Bangladesh were not previously quantified.
Social Implications: The results are useful to evaluate potential complications for disaster preparedness and planning of the government.

Keywords: Adaptive capacity; climate change; exposure; Principal Component Analysis; sensitivity; vulnerability.

1. INTRODUCTION

Bangladeshi people are already experiencing and responding to the impacts of climate change shocks and stresses as they are highly dependent on the natural environment for their life and livelihoods. As a global problem, climate change affects all aspects of human societal development, especially agriculture, which is closely related to human survival [1]. Due to spatial geo-morphologic setting Bangladesh is one of the worst victims of climate change in the world [2]. Most of the adverse effects of climate change is anticipated to be in the form of climate shocks or extreme weather events like flood and cyclone, while the other known as climate stresses as exemplified as sea-level rising, water logging, salinity, drought etc are likely to be exacerbated due to slow onset course [3] (Map 1), leading to large scale damages to crop, employment, livelihoods and economy of the country. Moreover wide spread poverty as much as 31.5 percent [4] in the population compounds the situation more vulnerable. Therefore, the risks associated with climate change have become a serious threat to the lives, livelihoods and sustainable development of Bangladesh. The extent of vulnerability, however, depends not just on the physical exposure of climate change extremes and population affected, but also on the extent of economic activity of the areas.

Bangladesh is a primarily agrarian economy. About 84 percent of the total population live in rural areas and are directly or indirectly engaged to a wide range of agricultural activities [5]. Agriculture is the single largest producing sector of the economy since it comprises about 21% country's GDP and employs around 48% of the total labor force [6]. Agricultural enterprises are the primary victims of climate shocks and stresses; hence quantification of climate vulnerability is important for proper planning and development of any country like Bangladesh whose economy largely depends on agriculture. Evaluating vulnerability can be helpful in assessing the impact of climate change and analyzing the effectiveness and adaptive degrees of different countermeasures to provide a reliable basis for addressing climate change

[1]. Realizing the facts, some workers have already measured people's vulnerability due to climate change in some parts of the world [7-11]. Scientists and associated policy makers frequently say that Bangladesh is a highly vulnerable to climate change effects, but the expression is entirely qualitative. No effort is noticed yet to scale up the degree of climate change vulnerability quantitatively due to the major weather extremes which spatially strike various regions of Bangladesh.

Quantification of climate change vulnerability is a complex form of risk assessment – accounts for both biophysical and socio-economic components of risk which is concerned to so many variables with diverse characteristics [12]. However, determining how to quantitatively evaluate vulnerability is a difficult problem and a pressing question [1]. A quantitative assessment for vulnerability due to climate change is proposed in this study according to the Intergovernmental Panel on Climate Change's definition of vulnerability and a framework for degrees of sensitivity, adaptive capacity, and exposure [13-17]. These three elements are important indicators to assess the community vulnerability where exposure to the bio-physical effects of climate change in future, sensitivity to the unpredictable weather shocks like cyclone and flood that affected by climate change, and a community's adaptive capacity due to own belongs and accesses to offset negative impacts of climate change. Principal Components Analysis (PCA) was deployed across all seven divisions[1] of Bangladesh to pull up those three types of variables with different units. The assessment method can clarify the effects of climate change on agriculture and effective countermeasures, as well as contribute to the sustainable agricultural development.

2. METHODOLOGY

2.1 Model for Determining Climate Change Vulnerability

Climate change vulnerability was quantified at division level by the integrated vulnerability assessment approach which comprises both the socioeconomic[2] and the biophysical[3] approaches as the definition of vulnerability was given by the Intergovernmental Panel on Climate Change (IPCC). The Intergovernmental Panel on Climate Change, IPCC [22] defines vulnerability to climate change as 'the degree to which a system is susceptible, or unable to cope with adverse effects of climate change, including climate variability and extremes, and vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity'. In brief, vulnerability of a society consist adaptive capacity, sensitivity, and exposure. Although each component has intrinsic properties, the three components are strongly interrelated. Fig. 1 shows the conceptual model for determining climate change vulnerability in Bangladesh.

2.1.1 Model variables

Adaptive capacity is the ability of a system to adjust to actual or expected climate shocks or to cope with the consequences of those shocks. According to the IPCC [22], the main features determining a community or area's adaptive capacity include economic wealth, technology, information and skills, infrastructure, institution, and equity. Wealth or asset enables households or communities to absorb and recover from losses more quickly. Ownership of major durable household goods include TV, motor cycle, motor car, refrigerator, computer etc, livestock and poultry, fish farming, farm forestry, quality residential house, agricultural assets include tractor, power tiller, power pump, deep tube-well etc, money depositor in bank and nonagricultural income raises from remittance, rent, insurance, gratuity, separation payment, retirement benefit, interest etc are commonly used as indicators of wealth in rural communities of Bangladesh [4]. Most of those items have greater buffer ability against the sensitivity or vulnerability of a shock by getting the liquid money through their sale or value that substantiates their wider adaptive capacity i.e. coping. Literacy rate is often included to approximate the level of skills and education of population, and areas or regions

[1]*Division indicates the biggest administrative unit of government after national. There are only seven divisions like Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur and Sylhet in Bangladesh.*

[2]*Socioeconomic (or internal) vulnerability mainly focuses on the socioeconomic and political status of individuals or social groups [18,19].*

[3]*Biophysical (or natural) vulnerability is a function of the frequency and severity (or probability of occurrence) of a given type of hazard. It is concerned with the ultimate impacts of a hazard event, and is often viewed in terms of the amount of damage experienced by a system as a result of an encounter with a hazard [20]. These two categories of vulnerability may sometimes overlap, for instance in the case of built infrastructure [21].*

with higher levels of stores of human knowledge are considered to have greater adaptive capacity [23]. Other basic services like social safety nets and medical opportunities are also considered as the parameters for determining adaptive capacity.

The level of development and availability of infrastructure and institutions play an important role in adaptation to climate change. Areas with better infrastructures especially road network are expected to have a higher capacity to adapt to climate change [24] because higher density of road not only ensures easy and quick people's communication for marketing, banking, education, and health services but may also facilitate the rapid transportation of necessary agricultural inputs like seeds, fertilizers, pesticides, labours, irrigation etc to the farmers. Proximity to supplies of agricultural inputs is also considered as a good indicator of technology to climate change adaptation (CCA). Availability of microfinance may support farmers by providing credits for technology packages. Health services can assist in the provision of preventive treatments for diseases associated with climatic change, such as diarrhoea.

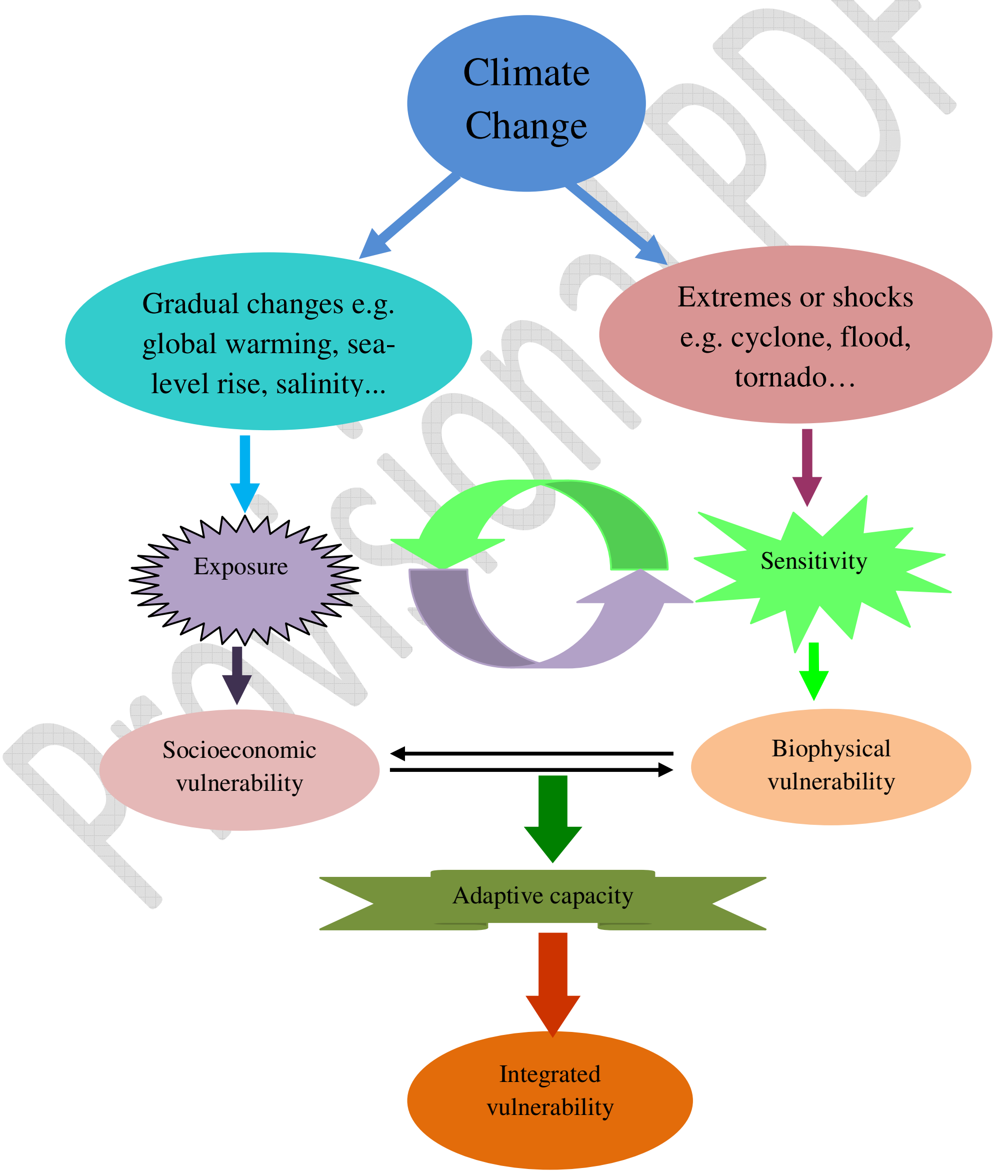
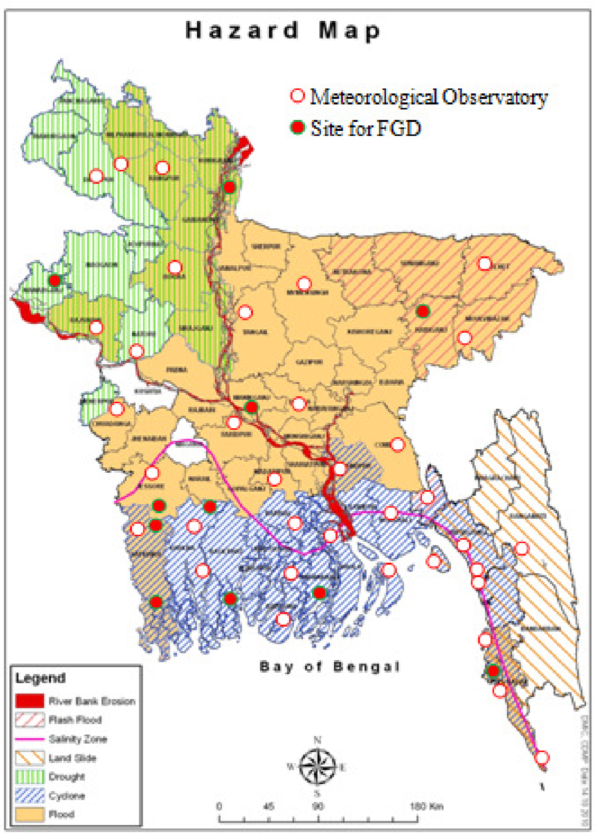


Fig. 1. A conceptual framework/model of vulnerability assessment

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate change stimuli, whereas exposure is the nature and degree to which a system is exposed to climate variations [22]. The sensitivity in agriculture to climate change is represented by the frequency of weather shocks, and it is argued that in places with a greater frequency of cyclones and floods, the agricultural sector responds negatively (i.e., yield is reduced). Thus, agricultural production in cyclone- and flood-prone districts is more sensitive in terms of yield reduction. The frequency of cyclone and flood, two most important climate change shocks for Bangladesh was computed using their past incidences from Sixties of last century by consulting newspaper archives, annual flood reports, hazard maps and records preserved in Bangladesh Meteorological Department (BMD).

Exposure is represented by the predicted change in temperature and rainfall by 2050. This figure provides the level of climate change to which regions are exposed. It is common that the increase of temperature will increase the frequency of formation of tropical cyclones, and increase of precipitation especially in monsoon season causes flood which often damage livelihood and rural agricultural production in Bangladesh. Thus, divisions with increasing rainfall are identified as divisions more exposed to flood in Bangladesh. The historical data from 1948 to 2010 on air temperature and rainfall recorded in 35 meteorological observatories throughout the country (Map 1) were collected from BMD for assessing the division-wise climate change exposure. It is mentioned from IPCC's Fourth Assessment Report [25] that annual mean rainfall exhibits increasing trends in Bangladesh, and frequency of monsoon depressions and cyclones formation in Bay of Bengal has increased. Table 1 gives the indicators and the hypothesized direction of relationship with vulnerability.



Map 1. Climate shock hot spots of Bangladesh with sites for Meteorological Observatories and primary data collection through FGDs

Map source: Comprehensive Disaster Management Programme (CDMP), Ministry of Disaster Management and Relief, Government of the People's Republic of Bangladesh

Table 1. Vulnerability indicators, units of measurement, and expected direction with respect to vulnerability

Determinants/ indicators of vulnerability	Description of each indicator selected for analysis	Unit of measurement	Hypothesized functional relationship between indicator and vulnerability
1. Adaptive capacity			
i) Household assets or wealth [4]	Ownership of major durable goods, livestock & farming, farm forestry, quality residential house, major agricultural assets, and other assets like stocks, bonds, jewelry etc.; money saver in bank or microfinance system; and nonagricultural income	Percentage of total household or population who own	The higher the percentage of total population with asset ownership, and access to these income sources the lesser the vulnerability.
ii) Incidence of poverty [26]	Head Count Rate (HCR) incidence of poverty (CBN method)	Percentage of total household live below the Upper Poverty Line (UPL)	The higher the percentage of poverty of total population, the higher the vulnerability.
iii) Basic services [4]	Social safety net programs	Percentage of climate-poor household benefitted from SSN	The higher the percentage of climate poor beneficiaries, the lesser the vulnerability.
	School enrollment (>7 yr age)	Percentage of total population who enrolled	The higher the percentage of school enrollment, the lesser the vulnerability.
	Literacy rate age 7 years and older	Percentage of total population	The higher the literacy rate, the lesser the vulnerability.
	Health services/medical facilities	Percentage of total population who get	The higher the percentage of beneficiaries, the lesser the vulnerability.
iv) Infrastructures and institutions [27,28]	Road networks	Division wise density of paved & unpaved road (km km^{-2})	The higher the road density, the lesser the vulnerability.
	Health service centre	Division wise total number of Union sub-centre	Higher the number of health centre, the lesser the vulnerability.
	Primary co-operative society	Division wise total number of primary co-operative societies	Higher the number of primary co-operative societies, the lesser the vulnerability.
2. Sensitivity			
i) Extreme climate i.e. climate shocks (newspaper archive, BMD)	Frequency of cyclones and floods	Percentage of occurrences/year since 1966 to date	The higher the frequency, the more the vulnerability.
iii) Current sensitivity [4]	Households who are affected by weather events like flood, cyclone, heavy rain, drought etc. in 2010	Percentage of household affected by weather events	The higher the percentage of household affected by weather events, the higher the vulnerability.
3. Exposure			
i) Change in climate (Bangladesh Meteorological Department, BMD)	Change in temperature	Percentage change from base value (2010)	Increasing temperature increase cyclonic vulnerability.
	Change in monsoon precipitation	Percentage change from base value (2010)	Increasing precipitation increase flood vulnerability.

2.2 Construction of Vulnerability Index

Households of Bangladesh are commonly exposed to both gradual climate changes like salinity, water logging, temperature rising etc and extreme climatic hazards like cyclones, flood, heavy monsoon downpour etc. Exposure affects sensitivity; which means that exposure to higher frequencies and intensities of climate risk highly affects the livelihood. Exposure is also linked to adaptive capacity. Higher adaptive capacity reduces the potential damage from higher exposure. Exposure could be represented by future gradual changes in climate, and the forecasted values of the probabilities of extreme events like flood or cyclone.

The study used an integrated vulnerability assessment approach which consists of adaptive capacity, sensitivity, and exposure [22]. The vulnerability due to climate change would be parameterised with the following assumptions:

i) People or household with higher adaptive capacity are less sensitive to damages from climate change, keeping the level of exposure constant;
ii) Those divisions with higher frequencies of cyclone or flood are subjected to higher sensitivity due to loss in yield and thus loss of livelihood, given that the main source of livelihood in rural Bangladesh is agriculture;
iii) The divisions with higher changes in rainfall are more exposed to climate change.

A positive value is assigned to the variable related to adaptive capacity except percentage of poverty. Adaptive capacity along with climate sensitivity and exposure add up to total vulnerability. Therefore, vulnerability is calculated as the net effect of adaptive capacity, sensitivity, and exposure [14]:

$$\text{Vulnerability} = \frac{\text{Climate Sensitivity} \times \text{Exposure}}{\text{Adaptive Capacity}} \quad (1)$$

The weights of the different variable (Table 1) were attached to the vulnerability indices through employing the method of Principal Components Analysis[4], PCA [29,30]. A similar type of programme was run to compute the adaptive capacity. The computed climate vulnerability and adaptive capacity indices were presented with GIS mapping using GIS software like ArcView GIS 3.3/ArcGIS 9.2.

2.3 Collection of Primary Data and Survey Tool

Primary data have been collected to formulate the probable measures for reducing climate change vulnerability in Bangladesh. The underlying principle is that if some actions that reduce climate sensitivity and exposure but strengthen adaptive capacity, the said actions would reduce vulnerability, and vice versa. For this purpose, both primary and secondary stakeholders were selected. Primary stakeholders indicate the rural villagers whose livelihoods are affected by the climate change stimuli. The views and opinions of climate victims and their thinking to reduce climate vulnerability were recorded with qualitative survey tool like Focus Group Discussion (FGD). The surveys from affected villagers were done from climate shock hotspots like flood, cyclone, water logging, salinity, drought etc throughout all the seven administrative divisions of the Bangladesh. Initially the affected areas were selected from freely available climate and poverty maps in the web (http://www.dmb.gov.bd/gis.html; http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/LatestReports/UpdatingPovertyMaps of Bangladesh.pdf; etc) where climate shocks matched with higher level of poverty. Thereafter more specific survey areas were selected with the consultation with Department of Agricultural Extension (DAE)'s officials working at central and grassroots' levels. Awal [31,32] has documented details of the survey areas along with the survey tools of primary data collection of the study.

The secondary stakeholders include relevant Programme Staffs or Officers at public (government organization i.e. GO) and private (non-government organization i.e. NGO) sectors. The official stakeholders concerned to agricultural production like crops, livestock,

[4] *Principal component analysis (PCA) is a statistical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called principal components. The number of principal components is less than or equal to the number of original variables. The transformation is defined in such a way that the first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. PCA is sensitive to the relative scaling of the original variables. The goal of principal components analysis is to explain the maximum amount of variance with the fewest number of principal components. Principal components analysis is commonly used in the social sciences, market research, and other industries that use large data sets.*

fisheries etc and disaster management and water development were consulted. Therefore the consultations with those stakeholders at local and central level officials from Ministry of Disaster Management and Relief (MoDMR), Ministry of Agriculture (MoA), Ministry of Environment and Forests (MoEF), Ministry of Fisheries and Livestock (MoFL), Ministry of Water Resources (MoWR), and Ministry of Local Government, Rural Development and Cooperatives (MoLGRDC) as well as NGO programme staffs were conducted to know their opinions for reducing climate vulnerability for each of climate shock like flood, cyclone, water logging, salinity and drought [3,31]. In addition of collection of primary data published and unpublished reports from print and electronic media were also consulted.

3. PROGRAMMING: PRINCIPAL COMPONENT ANALYSIS (PCA)

3.1 Computation of Variable

The variables related to adaptive capacity, climate sensitivity and exposure are mentioned in Tables 2-4. The sources of the data are shown in Table 1.

3.2 Principal Component Analysis (PCA) for Determining Climate Change Vulnerability

The PCA is a variable reduction technique which maximizes the amount of variance accounted for in the observed variables by a smaller group of variables called *components* or *factors*. It is a process for extracting from a set of variables those few orthogonal linear combinations of variables that most successfully capture the common information. It allows reducing the number of variables down to their *principal components*. Factor analysis attempts to identify underlying variables, or factors, that explain the pattern of correlation within a set of observed variables.

For example, we have a set of *y*-variables (y_1, y_2, y_3, ……….. y_{21}) of each division of Bangladesh. Therefore PCA will generate *w*-principal components like w_1, w_2, w_3, ……….. w_{21} (lets the first principal components) irrespective the divisions i.e. do not vary across divisions. The PCA starts by specifying each variable normalized by its mean and standard deviation. The *z*-score (standard or normalized values) of the variable can be considered as z_{y_1}, z_{y_2}, z_{y_3}, ………… $z_{y_{21}}$ for each division.

The *z*-scores of the variables were determined using the formula-

$$z = \frac{Variable - Mean\ of\ Variables}{Standard\ Deviation\ of\ Variables}$$

z-scores of the all variables y_1 to y_{21} are shown in Appendix 1.

Now the principal components and *z*-scores for a division are to be integrating as per formula for computing the climate vulnerability (Eq 1) like-

$$\text{Vulnerability} = \frac{[\{(w_{17}\times z_{y_{17}})+(w_{18}\times z_{y_{18}})+(w_{19}\times z_{y_{19}})\}\times\{(w_{20}\times z_{y_{20}})+(w_{21}\times z_{y_{21}})\}]}{\{(w_1\times z_{y_1})+(w_2\times z_{y_2})+(w_3\times z_{y_3})+ \ldots\ldots\ldots + (w_{16}\times z_{y_{16}})\}} \quad (2)$$

where, the variables from y_1 to y_{16}, y_{17} to y_{19}, and y_{20} to y_{21} in this study represent the parameters used for adaptive capacity, climate sensitivity and exposure, respectively.

The results in Eq (2) indicate the vulnerability originated due to first principal components with maximum variance. Similarly, vulnerability can be computed for second principal components, third principal components, and so on. The variances are gradually decreased towards the descending order of principal components until zero.

For combining maximum variance, a composite index can be calculated as

Integrated index = (Vulnerability due to 1st Principal components × Respective variance/Total variance considered)+(Vulnerability due to 2nd Principal components × Respective variance/Total variance considered+(Vulnerability due to 3rd Principal components × Respective variance/Total variance considered)+(Vulnerability due to 4th Principal components × Respective variance/Total variance considered) + …… so on.

Table 2. Variables related to household assets or wealth

Division/ Variable	Percentage of household or population have owned/accessed/engaged to							
	Durable goods[a]	Livestock or poultry/ fish farming/ forestry	Quality residential house[b]	Cultivable land	Agricultural assets[c]	Money depositor in Bank/ MFI/ informal org	Modern house hold facilities[d]	Other asset & income[e]
	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8
Barisal	17.87	43.733	7.8	46.9	1.95	6.6	30.451	5.307
Chittagong	21.404	45.067	11.9	43.2	1.961	7.367	33.126	8.736
Dhaka	19.093	36.7	7.7	48.1	2.022	6.633	31.363	5.886
Khulna	16.359	46.967	27	52.8	3.578	15.3	29.663	5.221
Rajshahi	20.296	43.367	16.5	47.8	2.378	6.5	30.901	5.186
Rangpur	16.704	52.1	10.7	49.2	2.367	14.533	23.237	3.286
Sylhet	21.626	44.8	21.8	38.6	2.411	5.3	29.027	5.764
MEAN	19.050	44.676	14.771	46.657	2.381	8.890	29.681	5.627
STDEV	2.155	4.596	7.364	4.556	0.566	4.167	3.129	1.617

[a]*Include radio, camera, bicycle, motor cycle, refrigerator, TV, mobile, computer, washing machine, sewing machine etc.*
[b]*Wall of main living house is composed of brick or other higher quality materials.*
[c]*Tractor, thresher, power tiller, plough, deep tube well shallow tube well, sprayer, husking machine, ginning machine etc.*
[d]*Include sanitary latrine, tube well, electricity, e-mail etc.*
[e]*From rent, insurance, profit and dividend, lottery/prize bond, royalty, remittance, gratuity, interest etc.*

Table 3. Variables related to poverty and basic services

Division/ Variable	Percentage of rural household live below UPL[a]	Percentage of rural climate-poor household benefitted from SSN[b]	Percentage of rural school enrolment (7-24 yr)	Percentage of rural literacy rate (≥ 7 years)	Percentage of rural household sought medical treatment
	y_9	y_{10}	y_{11}	y_{12}	y_{13}
Barisal	39.2	25.00	63.3	55.23	21.6
Chittagong	31.0	40.00	56.6	55.14	18.2
Dhaka	38.8	35.48	59.3	49.00	16.9
Khulna	31.0	72.58	62.4	57.68	24.8
Rajshahi	30.0	22.22	62.5	55.50	22.5
Rangpur	47.2	44.16	59.2	52.66	21.2
Sylhet	30.5	33.33	50.6	52.46	14.5
MEAN	35.386	38.967	59.129	53.953	19.957
STDEV	6.546	16.720	4.447	2.821	3.568

[a]*UPL= Upper Poverty Level;* [b]*SSN = Social Safety Net*

Table 4. Variables related to infrastructures and institutions, climate sensitivity and exposure

Division/ Variable	Road density (km/ km^2)[a]	Union heath sub-centre (2006)/ million people	Primary cooperative society (2009-2010)/ thousand household	Percentage of flood frequency	Percentage of cyclone frequency	Percentage of household currently affected by climate shocks	Percentage changes in annual mean temperature on 2050	Percentage changes in summer rainfall on 2050
	y_{14}	y_{15}	y_{16}	y_{17}	y_{18}	y_{19}	y_{20}	y_{21}
Barisal	0.127	8.592	7.22	17.021	26.241	3.91	0.272	6.054
Chittagong	0.134	8.868	4.67	34.043	15.281	1.774	1.541	-7.857
Dhaka	0.168	8.753	19.22	44.305	2.628	5.43	1.976	-8.876
Khulna	0.122	8.417	5.65	18.511	12.128	11.568	1.533	1.278
Rajshahi	0.179	11.894	6.50	47.606	0.000	3.103	0.119	-18.437
Rangpur	0.126	12.257	4.18	48.67	0.000	15.012	0.282	8.210
Sylhet	0.119	8.565	7.06	56.383	1.064	4.767	3.865	8.679
MEAN	0.140	9.621	7.786	38.077	8.192	6.509	1.370	-1.564
STDEV	0.024	1.686	5.172	15.381	10.062	4.880	1.329	10.363

[a] *Includes paved and unpaved roads*

Table 5. Climate change vulnerability as NSI and SI

Division	Vulnerability index				Composite vulnerability	
	Factor 1	Factor 2	Factor 3	Factor 4	NSI	SI[a]
Barisal	0.247226	0.396783	-0.0428	1.304063	0.3600	0.9138
Chittagong	-0.11258	-0.01579	0.009971	-0.14509	-0.06794	0.5000
Dhaka	-0.03762	-0.03419	0.005522	-0.40426	-0.07789	0.3620
Khulna	0.047577	-0.04023	0.002434	0.094696	0.024224	0.6380
Rajshahi	-0.65184	-0.35113	-0.05745	-0.42938	-0.42389	0.0862
Rangpur	0.198502	-0.07889	-0.14479	0.268433	0.069937	0.7759
Sylhet	0.228171	-0.26861	0.069358	-0.99571	-0.08784	0.2241

[a] *NSIs are proportionally converted to 0 to 1 by SPSS Editor*

All the 21 variables were included in the factor analysis. The number of factor extracted can be defined by the user. One of the most commonly used techniques is the *Eigen* value rule. Under this rule, only those factors with an *Eigen* value (the variances extracted by the factors) of 1.0 or more are retained (Appendix 2).

Varimax rotation was carried out to minimize complexity of factors by maximizing the variance of loading on each other (Appendix 3). The rotation attempts to minimize the number of indicators that have high loading on one other. The percentage of variation explained by the first factor is more than the second factor and that of second factor is more than that of third factor and so on.

To compute the vulnerability for a given factor (Factor 1, for example), the cases *z*-score on each variable is multiplied by the corresponding factor loading of the variable for the given factor, and integrate these product following the Eq (2). The first four factors explained near to 87% variation with first, second, third and fourth (*Eigen* value>1; (Scree plot in Appendix 2), explaining 36, 20, 19 and 12 percent, respectively. Therefore the importance of the factors in measuring vulnerability is not the same (Table 5). Using the proportion of these percentages as weights on the vulnerability, a Non-standardized Index (NSI) was developed for each division, using the following formula [33]:

NSI = (36.189/86.717) (Vulnerability due to Factor 1) + (19.806/86.717) (Vulnerability due to Factor 2) + (19.045/86.717) (Vulnerability due to Factor 3) + (11.677/86.717) (Vulnerability due to Factor 4).

This index measures the vulnerability of one division relative to the other on a linear scale. The value of the index may be positive or negative, making it difficult to interpret. Therefore, a Standardized Index (SI) was developed, the value of which can range from 0 to 1, using the SPSS Editor. The higher the SI, the greater the vulnerability. A similar procedure was adopted by Krishnan [33] and Antony and Rao [34].

3.3 Principal Component Analysis (PCA) for Determining Adaptive Capacity

A similar procedure for determining the climate vulnerability was conducted but with utilizing the first 16 variables such as $y_1,\ y_2,\ y_3,\ \ldots\ldots\ldots.\ y_{16}$. The first four factors explained near to 90% variation with first, second, third and fourth (whose *Eigen* values are also found greater than one), explaining 40, 22, 17 and 11 percent, respectively (Scree plot in Appendix 4). Therefore the importance of the factors in measuring adaptive capacity (AC) is not the same (Table 6). Varimax rotation was also carried out to minimize complexity of factors by maximizing the variance of loading on each other (Appendix 5).

In order to find out the factor score for a given case for a given factor, the case's normalized score on each variable is multiplied by corresponding factor loading of the variable for the given factor, and integrated these products. Using the proportion of the percentages as weights on the AC, a Non-standardized Index (NSI) was developed for each division, using the formula [33]:

NSI = (39.744/89.607) (AC due to Factor 1) + (22.039/89.607) (AC due to Factor 2) + (16.768/89.607) (AC due to Factor 3) + (11.056/89.607) (AC due to Factor 4).

The value of the index may be positive or negative, making it difficult to interpret.

Table 6. Adaptive capacity as NSI and SI

Division	Adaptive capacity				Composite adaptive capacity	
	Factor 1	Factor 2	Factor 3	Factor 4	NSI	SI[a]
Barisal	1.213827	-1.16256	-1.91056	0.279081	-0.0706	0.5000
Chittagong	-3.29483	-3.54633	-1.36676	0.655598	-2.5085	0.2241
Dhaka	-1.82589	-1.99702	-2.1819	-6.09703	-2.4616	0.3621
Khulna	6.943549	1.938111	5.593034	2.841957	4.95365	0.9138
Rajshahi	0.846215	0.454162	-0.95668	0.397705	0.35708	0.6379
Rangpur	2.669056	5.379031	1.047088	2.291813	2.98553	0.7759
Sylhet	-6.55192	-1.0654	-0.22422	-0.36912	-3.2556	0.0862

[a]NSIs are proportionally converted to 0 to 1 by SPSS Editor

Therefore, a Standardized Index (SI) was developed, the value of which can range from 0 to 1, using the SPSS Editor. The higher the SI, the greater the adaptive capacity.

4. RESULTS AND DISCUSSION

4.1 Adaptive Capacity *versus* Climate Change Vulnerability

The households of Khulna region have higher degree of adaptive capacity to climate change followed by Rangpur and Rajshahi divisions whereas the adaptive capacity was found minimum for Sylhet division followed by Chittagong and Dhaka divisions (Fig. 2; Map 2). The Barisal division ranked intermediate in this regard. Higher adaptive capacity of Khulna division is ascribed for higher factor loading due to the quality residential house, cultivable land, agricultural assets, microfinance activities, SSN services, literacy rate, and medical facilities etc. It is evident that the people of higher climate-disadvantaged regions are more adaptive than that from less stressed one. The people under climate change are being prepared to adapt with climate exposure day by day whereas poor households do not find any suitable adaptive options to struggle with sudden climate disasters like cyclone or massive flood.

The extremely higher degrees (>0.9) of climate change vulnerability of Barisal division (Fig. 2, Map 3) are associated with higher frequency of cyclone, and that of higher degrees of vulnerability of Rangpur division due to recurrent flood events. Khulna division is also expected as extremely vulnerable due to frequent cyclonic hit but higher adaptive capacity has made it as vulnerable next to extreme. Lower vulnerability of Rajshahi region might be explained due to its no cyclone sensitivity along with strong adaptive capacity.

In addition to the degree of vulnerability as mentioned in Map 3, low-lying coastal zone of southern Bangladesh comprising Khulna, Barisal and Chittagong divisions is facing a slow onset but longer term serious problem like sea level rising (SLR) which would be gradually increased to the coming days. The SLR creates the other vulnerabilities like salinity and water congestion or water logging in the locality. Moreover, north-western parts of Rajshahi and Rangpur divisions' often experience drought events which may carry extra load on the predicted vulnerability.

4.2 Application of Climate Vulnerability and Adaptive Capacity Indices in Government Planning

Vulnerability index represents a single numerical result which is a composite of multiple quantitative indicators via some formulae where diverse issues like climatic, physical, social etc can be combined into a standardized framework by which some comparisons are possible to make within the regions like divisions in Bangladesh. Policy makers often confuse to think too many interacting factors on course of a disaster, however such a single figure can straightforward the policy intervention towards a direction. It can be utilized-

i) To evaluate potential complications for disaster preparedness and planning of the government. In disaster events the higher vulnerable divisions are more likely to be adversely affected by climate shocks, i.e. they are less likely to recover and more likely to uncertain. Effectively addressing vulnerability decreases both human suffering and the economic loss related to social services and public assistance like delivery of safety net goods aftermath of a disaster.
ii) As an ideal tool to help government decision-makers to take proper plan and strategy as well as to assist in adaptation strategy or mitigating the impacts of climate change. Based on the degree of vulnerability climate change threats can additionally be translated into national action plan that would help to take proper care to move for reducing those impacts.
iii) To allocate the climate fund based on the degree of vulnerability. It is recently claimed that the climate fund is not disbursed properly as per the magnitude of vulnerability in the various regions of Bangladesh. For example less vulnerable Chittagong division received the maximum share of climate fund 21 percent whereas highly vulnerable Khulna region received only 11 percent [35].
iv) To disburse the public funds associated with agriculture rehabilitation programme of the government.

Degree of adaptive capacity is also important in policy formulation. It is reciprocally paradigm to vulnerability index in some cases. In case of lower adaptive capacity for a region like division in Bangladesh, one can think that the ecosystem as a whole is so fragile to cope with climate change without larger support from outside.

4.3 Strategy to Reduce Climate Change Vulnerability

For reducing vulnerability due to climate change, strategies which promote adaptive capacity but reduce sensitivity and exposure should be taken. For rural Bangladesh the measures that should have to address towards underlying directions are mentioned in Tables 7-9 (based on perceptions from FGDs, consultation with related stakeholders, published and unpublished reports etc). The GO and NGOs authorities of Bangladesh may follow those measures as they are extensively working to minimize the climate change threats at various levels of the country. Therefore, proper polices and laws are to be enacted or existing ones should be revised. Households and community people are also responsible to come forward.

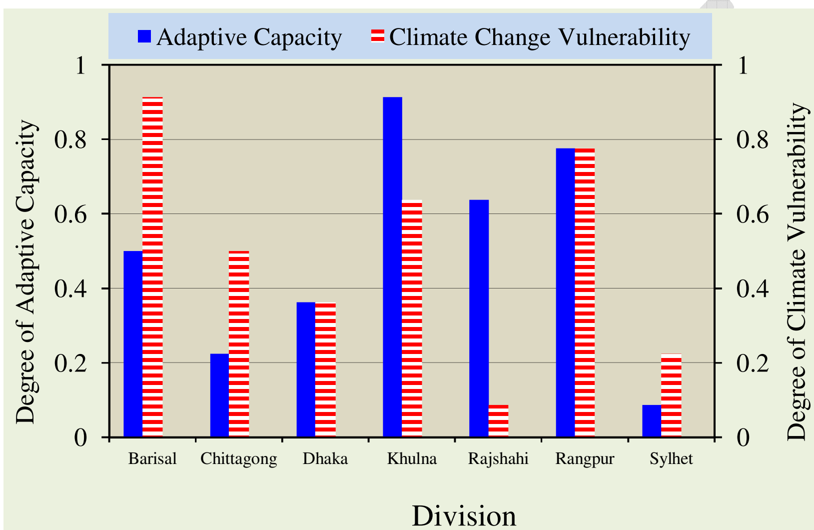
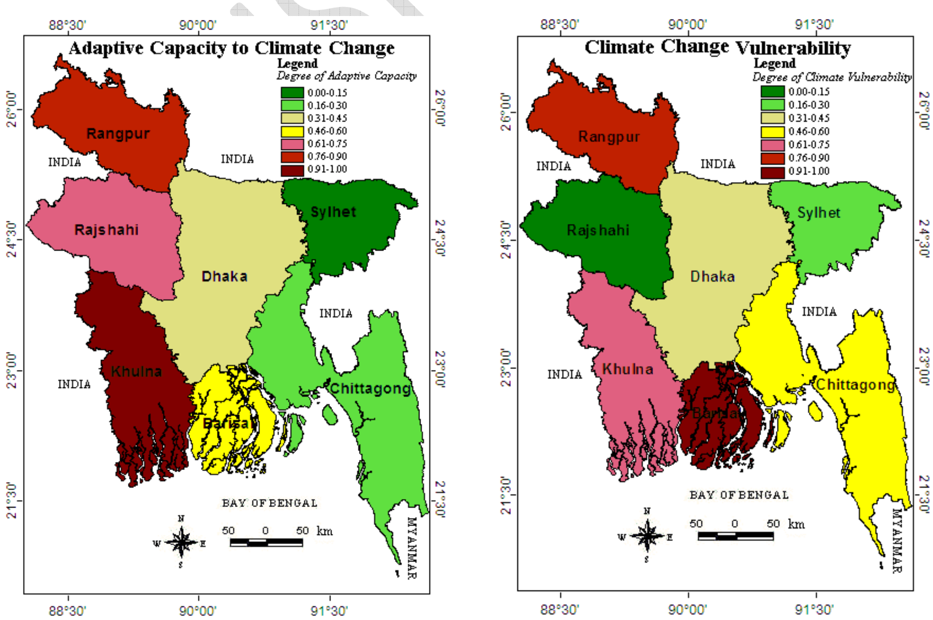


Fig. 2. Degree of adaptive capacity and climate change vulnerability in rural Bangladesh



Maps. 2-3. Adaptive capacity (left, map 2) and climate change vulnerability (right, map 3) in rural Bangladesh

Table 7. Improvement of adaptive capacity

Level of responsibility	Promotion of
Household	Income, house quality, remittance, microfinance activity, school enrollment, literacy rate, alternative livelihood options (handicrafts, poultry/cattle rearing, plant nursery, aquaculture etc.), on standby during disastrous time with food, fuel and saving etc.
Community	Awareness to disaster and its preparedness training, security of livestock and food storage system, cooperative society, protection of dam/embankment, and cottage industries at local level like tailoring, bamboo and cane, jute goods, earth goods, jewelries etc.
State	Road, bridge, culvert, public transportation, educational institutes, hospital/health service, cyclone/flood protection centre or boat shelter for fisher man, poverty reduction, social safety net service etc.

Table 8. Reduction of sensitivity to climate change

Climatic shocks	Means of reduction of climate sensitivity
Flood	Construction of strong embankment with adequate sluice gate and modern flood protection centre, river or canal dredging/de-siltation etc.
Cyclone	Establishment of strong embankment with adequate sluice gate, modern cyclone centre with coastal design, multi-layered green belt with monocotyledons trees like palmyra palm, coconut, date palm etc.
Water logging	Elevating the *beels* (low land) through Tidal River Management (TRM) plan. Roads, homestead, institutes etc should also be raised (details found in Awal [31]).
Salinity	Inhibit the intrusion of saline water from sea by strong coastal embankment, proper management of sluice gates, rain water harvest etc.
Drought	Construction of water reservoirs, excavation or re-excavation of ponds, channels/canals, ditches, mini-pond, rain/flood water harvest etc.

Table 9. Reduction of exposure to climate change

Climatic shocks	Means of reduction of climate exposure
Flood	Introduction of early/short duration (e.g. BR28 and BRRI Dhan 45 etc as rice varieties) and submergence tolerant (e.g. BRRI Dhan 51, BRRI Dhan 52, BINA Dhan 11, BINA Dhan 12 etc as rice varieties) or tall statured/deep water (e.g. *floating* rice, *broadcast aman*[a], *jolidhan*, *poushdhan* rice etc) crop varieties, floating agriculture (e.g. vegetable production, seedling production etc), encourage of swamp forest species or water tolerant tree species like hizal (*Barringtonia acutangula*), tamal (*Diospyros cordifolia*), barun (*Crataeva nurvala*), madar (*Erythrina variegata*), gab (*Disopyros peregrine*), dumur (*Ficus hispida*), chalta (*Dillenia indica*), dehua (*Artocarpus lacucha*), paniphal (*Trapa bispinosa*) etc.
Cyclone	Early harvest with early planting or with short duration varieties (BRRI Dhan 33, BRRI Dhan 39, BINA Dhan 7, BINA Dhan 8 etc as rice varieties), plantation of water and storm resistant tree like coconut, palmyra palm, date palm etc.
Water logging	Alternation in livelihood (i.e. from crop to fish or ducks), floating agriculture, encourage of existing water-logged tree species etc (details found in Awal [31]).
Salinity	Coastal zoning especially based on degree of salinity e.g. rice and/or shrimp or crab production zone, adjustment of crop rotation, cultivation of salinity tolerant crops (cowpea, mung bean, sunflower, water melon etc) or varieties (e.g. BRRI Dhan 47, BINA Dhan 8 etc for rice) etc.
Drought	Cultivation of C4 crops with high water-use efficiency (hence little water user like maize, sugarcane, sorghum, oat etc), cultivation of wheat or pulses instead of *Boro*[b] rice in dry season, introduction of drought/heat resistant or drought escaping (BRRI Dhan 33 for rice; short duration 118 days, hence drought escaper) varieties etc.

[a]Rice varieties that are cultivated during rainy season extended from June to November in Bangladesh.
[b]The Boro rice is commonly known as winter rice. The term boro is Bengali originated from the Sanskrit word "Boro" which refers to a cultivation from November to May under irrigated condition

5. CONCLUSIONS

Climate change vulnerability has been quantified across all the seven administrative divisions of Bangladesh following the IPCC's definition of vulnerability, which explain it as a function of adaptive capacity, sensitivity and exposure. An integrated assessment approach was adopted to combine the data on biophysical and socioeconomic parameters with employing principal component analysis to give weights to those factors. Policy makers often confuse to think too many interacting factors on course of a disaster, hence such a single figure like vulnerability index can straightforward the policy intervention towards a direction. Households of Barisal division show extreme climate change vulnerability followed by Rangpur and Khulna divisions whereas Rajshahi division shows minimum vulnerability followed by Sylhet or Dhaka division kept Chittagong division in middle. On the other hand, the households of Khulna region have higher degree of adaptive capacity to climate change followed by Rangpur and Rajshahi divisions whereas the adaptive capacity was found minimum for the households from Sylhet division followed by Chittagong and Dhaka divisions. The reduction strategies of climate change vulnerability have been documented.

ACKNOWLEDGEMENTS

This paper is based on a study financed under the Research Grants Scheme (RGS) of the National Food Policy Capacity Strengthening Programme (NFPCSP). The purpose of the RGS was to assist in improving research and dialogue within civil society so as to inform and enrich the implementation of the National Food Policy. The NFPCSP is implemented by the Food and Agriculture Organization (FAO) of the United Nations and the Food Planning and Monitoring Unit (FPMU), Ministry of Food, Government of the People's Republic of Bangladesh with the financial support of EU and USAID.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dong Z, Pan Z, An P, Wang L, Zhang J, He D, Han H, Pan X. A novel method for quantitatively evaluating agricultural vulnerability to climate change. Ecological Indicators. 2015;48:49-54.
2. Awal MA. Vulnerability to disaster: Pressure and release model for climate change hazards in Bangladesh. International Journal of Environmental Monitoring and Protection. 2015;2(2): 15-21.
3. Awal MA. Vulnerable population to climate change in Bangladesh: Livelihood constraints and adaptation strategies. American Journal of Social Sciences. 2015;3(4):87-95.
4. HIES. Household Income and Expenditure Survey. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh; 2010.
5. Golder PC, Sastry RK, Srinivas K. Research priorities in Bangladesh: Analysis of crop production trends. SAARC Journal of Agriculture. 2013;11(1):53-70.
6. CIA. The World Factbook. Central Intelligence Agency. 2011. Archived from the original on 29 June 2011. Retrieved 8 August 2011.
7. Yoo G, Hwang JH, Choi C. Development and application of a methodology for vulnerability assessment of climate change in coastal cities. Ocean & Coastal Management. 2011;54(7):524-534.
8. Fraser EDG, Simelton E, Termansen M, Gosling SN, South A. Vulnerability hotspots: integrating socio-economic and hydrological models to identify where cereal production may decline in the future due to climate change induced drought. Agricultural and Forest Meteorology. 2013; 170:195-205.
9. Shah KU, Dulal HB, Johnson C, Baptiste A. Understanding livelihood vulnerability to climate change: applying the livelihood vulnerability index in Trinidad and Tobago. Geoforum. 2013;47:125-137.
10. Larroudé P, Oudart T, Daou M, Robin N, Certain R. Three simple indicators of vulnerability to climate change on a Mediterranean beach: A modeling approach. Ocean Engineering. 2014;76: 172-182.
11. Bär R, Rouholahnedjad E, Rahman K, Abbaspour KC, Lehmann A. Climate change and agricultural water resources: A vulnerability assessment of the Black Sea catchment. Environmental Science & Policy. 2015;46:57-69.

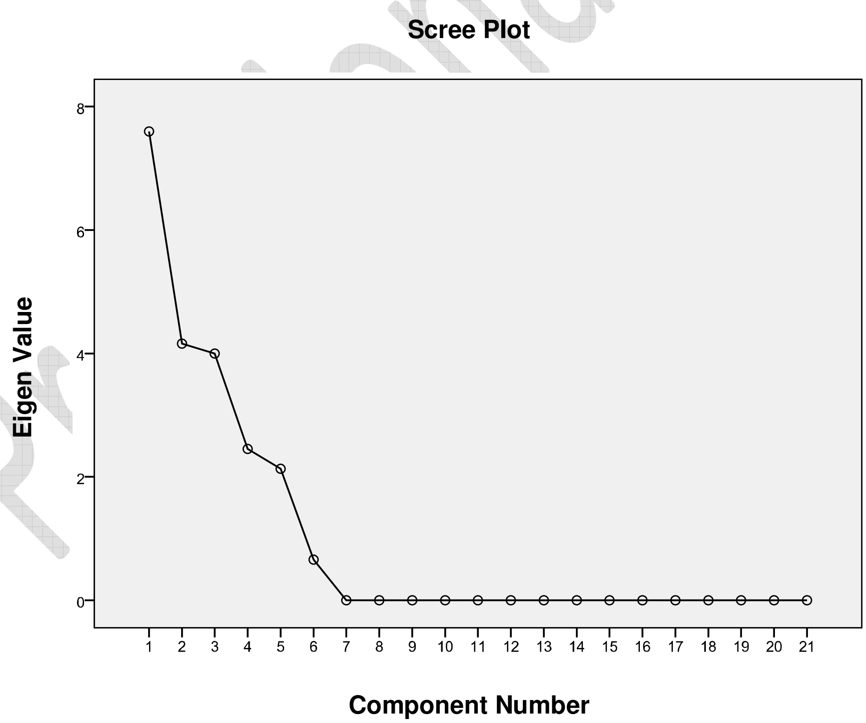
12. El-Zein A, Tonmoy FN. Assessment of vulnerability to climate change using a multi-criteria outranking approach with application to heat stress in Sydney. Ecological Indicators. 2015;48:207-217.
13. Deressa T, Hassan RM, Ringler C. Measuring Ethiopian farmer's vulnerability to climate change across regional states. IFPRI Discussion Paper 00806. International Food Policy Research Institute; 2008.
14. Cinner JE, McClanahan TR, Graham NAJ, Daw TM, Maina J, Stead SM, Wamukota A, Brown K, Bodin O. Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Global Environmental Change. 2012; 22(1):12-20.
15. Skjeflo S. Measuring household vulnerability to climate change—why markets matter. Global Environmental Change. 2013;23(6):1694-1701.
16. Mamauag SS, Aliño PM, Martinez RJS, Muallil RN, Doctor MVA, Dizon EC, Geronimo RC, Panga FM, Cabral RB. A framework for vulnerability assessment of coastal fisheries ecosystems to climate change—Tool for understanding resilience of fisheries (VA–TURF). Fisheries Research. 2013;147:381-393.
17. Reed MS, Podesta G, Fazey I, Geeson N, Hessel R, Hubacek K, Letson D, Nainggolan D, Prell C, Rickenbach MG, Ritsema C, Schwilch G, Stringer LC, Thomas AD. Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options. Ecological Economics. 2013;94:66-77.
18. Adger WN. Social vulnerability to climate change and extremes in coastal Vietnam. World Development. 1999;27(2):249-269.
19. Füssel H. Vulnerability: A generally applicable conceptual framework for climate change research. Global Environmental Change. 2007;17(2):155-167.
20. Brooks N. Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre for Climate Change Research. 2003; Working Paper No. 38.
21. Füssel H. Vulnerability in Climate Change Research: A comprehensive conceptual framework. International and Area Studies. Breslauer Symposium. University of California; 2005.
22. IPCC. Climate Change 2001. IPCC Third Assessment Report (TAR). Contribution of working groups I, II and III to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK. 2001.
23. Smith J, Lenhart SS. Climate change adaptation policy options. Climate Research. 1996;6(2):193-201.
24. O'Brien K, Leichenko R, Kelkar U, Venema H, Aandahl G, Tompkins H. et al. Mapping vulnerability to multiple stressors: Climate change and globalization in India. Global Environmental Change. 2004;14(4):303-313.
25. IPCC. IPCC Fourth Assessment Report (AR4): Climate Change 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK; 2007.
26. BBS. Report of the Household Income & Expenditure Survey 2010. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning (MoP), Government of the People's Republic of Bangladesh; 2011a.
27. BBS. Statistical Yearbook of Bangladesh 2009. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning (MoP), Government of the People's Republic of Bangladesh; 2010.
28. BBS. Statistical Yearbook of Bangladesh-2010. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning (MoP), Government of the People's Republic of Bangladesh; 2011b.
29. Filmer D, Pritchett LH. Estimating wealth effects without expenditure data— or tears: An application to educational enrollments of India. Demography. 2001;38(1):115-132.
30. Vyas S, Kumaranayake L. Constructing socio-economic status indices: How to use principal component analysis. Health Policy and Planning. 2006;21(6):459-468.
31. Awal MA. Water logging in south-western coastal region of Bangladesh: local adaptation and policy options. Science Postprint. 2014;1(1):e00038.
DOI: 10.14340/spp.2014.12A0001
Available: www.spp-j.com
32. Awal MA. Scale-up potentialities of some social safety net programmes to climate

change shocks in Bangladesh. International Journal of Social Sciences and Management. 2015;2(2):78-92. DOI: 10.3126/ijssm.v2i2.11618
33. Krishnan V. Constructing an area-based socioeconomic status index: A principal components analysis approach. Early Child Development Mapping Project (ECMap), University of Alberta, Edmonton, Alberta, CANADA; 2012.
34. Antony GM, Rao KV. A composite index to explain variations in poverty, health, nutritional status and standard of living: use of multivariate statistical methods. Public Health. 2007;121:578-587.
35. Hossain E. Question regarding climate fund: Donors observation" Daily Ittefaq, 3 February 2013, Dhaka, Bangladesh; 2013.
36. Fisher LD, Belle GV. Biostatistics. A Methodology for the health sciences. John Wiley & Sons. Inc; 1993.

APPENDIX

Appendix 1. *z*-scores of the variables used in the analysis

Variable	Division						
	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Rangpur	Sylhet
y_1	-0.54765	1.092115	0.019819	-1.24875	0.578007	-1.08867	1.195122
y_2	-0.20523	0.085008	-1.7354	0.49839	-0.28486	1.615174	0.026916
y_3	-0.94671	-0.38994	-0.96029	1.660631	0.234739	-0.5529	0.954475
y_4	0.05331	-0.75889	0.316726	1.34844	0.250872	0.558191	-1.76865
y_5	-0.76093	-0.74151	-0.63381	2.113291	-0.0053	-0.02472	0.052965
y_6	-0.54964	-0.36558	-0.54172	1.538129	-0.57364	1.354069	-0.86161
y_7	0.246065	1.10106	0.537562	-0.0058	0.389896	-2.0597	-0.20908
y_8	-0.1976	1.922619	0.16041	-0.25077	-0.27241	-1.44722	0.084975
y_9	0.582658	-0.66995	0.521555	-0.66995	-0.8227	1.804712	-0.74633
y_{10}	-0.83536	0.061774	-0.20856	2.010343	-1.00163	0.310578	-0.33715
y_{11}	0.938113	-0.56865	0.038553	0.735712	0.758201	0.016064	-1.91799
y_{12}	0.452688	0.420787	-1.75556	1.321099	0.54839	-0.45826	-0.52915
y_{13}	0.460462	-0.49249	-0.85686	1.357362	0.712715	0.348349	-1.52953
y_{14}	-0.51106	-0.21987	1.194455	-0.71905	1.652033	-0.55266	-0.84384
y_{15}	-0.61017	-0.44649	-0.51469	-0.71396	1.348109	1.563389	-0.62619
y_{16}	-0.10937	-0.60239	2.2107	-0.41292	-0.24858	-0.69713	-0.14031
y_{17}	-1.36900	-0.26228	0.404927	-1.27213	0.619549	0.688727	1.190205
y_{18}	1.793757	0.704541	-0.55293	0.391192	-0.8141	-0.8141	-0.70836
y_{19}	-0.53264	-0.97037	-0.22115	1.036714	-0.69802	1.742494	-0.35702
y_{20}	-0.82578	0.128853	0.45609	0.122835	-0.94087	-0.81825	1.877126
y_{21}	0.735143	-0.60725	-0.70559	0.274264	-1.62821	0.943195	0.988453

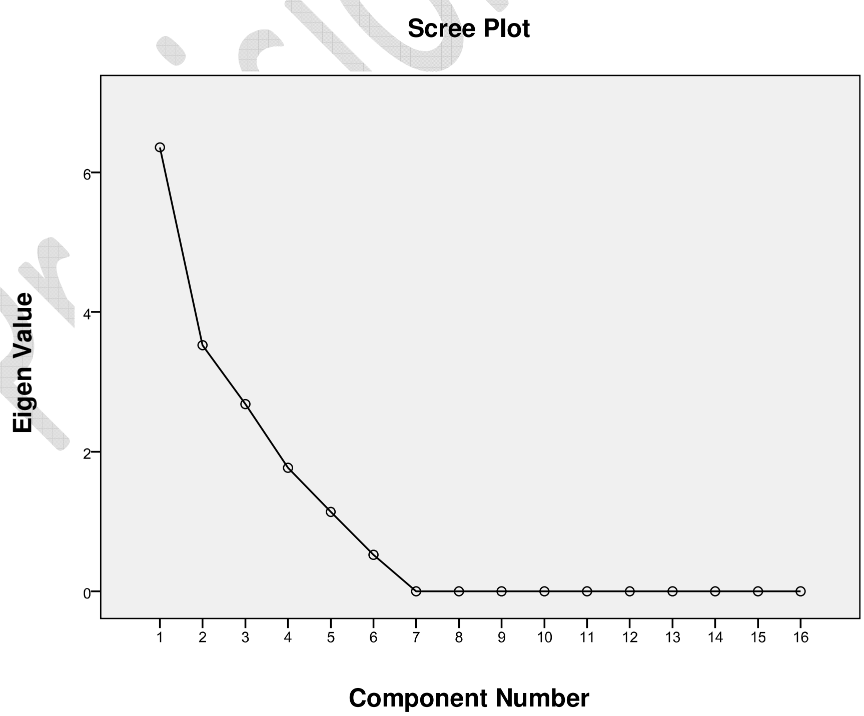


Appendix 2. Scree plot of *Eigen* values for the variables of climate vulnerability

Appendix 3. Rotated Component Matrix[a] for the first four factors for determining climate change vulnerability

Variable	Factor 1	Factor 2	Factor 3	Factor 4
y_1	-0.700	-0.610	-0.276	0.000
y_2	0.556	0.000	0.000	0.000
y_3	0.000	0.000	0.896	0.000
y_4	0.324	0.861	0.341	0.000
y_5	0.000	0.000	0.946	0.000
y_6	0.637	0.387	0.562	0.000
y_7	-0.912	0.000	0.000	0.303
y_8	-0.757	-0.276	0.000	0.342
y_9	0.852	0.000	-0.448	0.000
y_{10}	0.304	0.000	0.843	0.263
y_{11}	0.000	0.982	0.000	0.000
y_{12}	-0.277	0.436	0.397	0.284
y_{13}	0.000	0.877	0.315	0.000
y_{14}	-0.450	0.402	-0.253	-0.598
y_{15}	0.313	0.345	-0.250	-0.775
y_{16}	0.000	0.000	0.000	0.000
y_{17}	0.000	-0.560	0.000	-0.802
y_{18}	0.000	0.275	0.000	0.905
y_{19}	0.870	0.000	0.421	0.000
y_{20}	0.000	-0.878	0.357	0.000
y_{21}	0.707	-0.418	0.000	0.452
Eigen values	7.600	4.159	3.999	2.452
% of variance	36.189	19.806	19.045	11.677
Cumulative variance (%)	36.189	55.995	75.040	86.717

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization. [a]Rotation converged in 8 iterations.
Loadings less than 0.250 have been omitted or replaced by zero [36]



Appendix 4. Scree plot of *Eigen* values for the variables of adaptive capacity

Appendix 5. Rotated Component Matrix[a] of the first four factors for determining adaptive capacity

Variable	Factor 1	Factor 2	Factor 3	Factor 4
y_1	-0.757	-0.519	0.000	0.000
y_2	0.000	0.562	0.000	0.770
y_3	0.000	0.000	0.949	0.255
y_4	0.929	0.260	0.000	0.000
y_5	0.339	0.000	0.904	0.000
y_6	0.518	0.539	0.418	0.000
y_7	0.000	-0.970	0.000	0.000
y_8	-0.282	-0.855	0.000	0.000
y_9	0.000	0.752	-0.541	0.000
y_{10}	0.331	0.000	0.680	0.000
y_{11}	0.966	0.000	0.000	0.000
y_{12}	0.441	-0.330	0.349	0.749
y_{13}	0.884	0.000	0.000	0.380
y_{14}	0.000	0.000	0.000	-0.463
y_{15}	0.000	0.642	0.000	0.294
y_{16}	0.000	0.000	0.000	-0.981
Eigen values	6.359	3.526	2.683	1.769
% of variance	39.744	22.039	16.768	11.056
Cumulative variance (%)	39.744	61.784	78.551	89.607

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
[a]Rotation converged in 7 iterations.
Loadings less than 0.250 have been omitted or replaced by zero [36]