Bioforsk Rapport

Bioforsk Report

Vol. 9 Nr. 24 2014

Socio-ecological vulnerability assessment of flood and saline-prone region in rural Bangladesh

Stefanos Xenarios, Golam Wahed Sarker,
Attila Nemes, Udaya Sekhar Nagothu,
Jatish Chandra Biswas, Md Maniruzzaman

Bioforsk

www.bioforsk.no

Hovedkontor/Head office
Frederik A. Dahls vei 20
N-1430 Ås
Tel.: (+47) 40 60 41 00
post@bioforsk.no

Bioforsk Jord og miljø
Frederik A. Dahls vei 20
N-1430 Ås
Tel.: (+47) 40 60 41 00
post@bioforsk.no

Title: Socio-ecological vulnerability assessment of flood and saline-prone region in rural Bangladesh
Author(s): Stefanos Xenarios, Golam Wahed Sarker, Attila Nemes, Udaya Sekhar Nagothu, Jatish Chandra Biswas, Md Maniruzzaman

Dato/Date: 01.02.2014	*Tilgjengelighet/Availability: Open (Public)*	*Prosjekt nr./Project No.:*ClimaRice	*Saksnr./Archive No.:9*
Rapport nr./Report No.:24	*ISBN-nr./ISBN-no: 978-82-17-01233-7*	*Antall sider/Number of pages: 45*	*Antall vedlegg/Number of appendices:*

Oppdragsgiver/Employer: Soil, Water and Environment Division	*Kontaktperson/Contact person: Stefanos Xenarios*

Stikkord/Keywords: Vulnerability, Climate Change, Bangladesh	*Fagområde/Field of work: Social Sciences*

Sammendrag:

Summary:

The current study attempted to quantitatively measure the vulnerability status of selected regions in Bangladesh impacted by climate change. Three upazilas were selected in the drought prone region of Rajshahi, while another three upazilas were assessed in the saline-flood prone Barisal region. The Exposure, Sensitivity and Adaptive capacity of each upazila was measured through socio-demographic, agro-economic and infrastructural indicators inspired by the literature, RiceClima reports but also elicited from a household survey in the examined areas. The technique of Principal Component Analysis was used for the assessment of the indicators while descriptive statistics also helped for a better understanding of the current situation in the two regions.

The findings indicated that the drought prone Rajshahi upazilas (North Bangladesh) are more exposed to inefficient irrigation management and lack of access to household's utilities (water, electricity). The flood and saline prone upazilas of the Barisal region in South Bangladesh lack transportation, agricultural, education and health infrastructure on a regional level. In both regions, the introduction of cash crops and the improvement of market conditions in agriculture are deemed as necessary actions.

Land/Country: *Fylke/County:*	Bangladesh Rajshahi Barisal Regions

Godkjent / Approved	Prosjektleder / Project leader
	Nagothu Udaya Sekhar
Navn/name	Navn/name

Contents

Tables

Figures

1. Introduction

It is predicted that climate change will aggravate the presence of sudden (e.g. cyclones, floods etc.) and chronic (e.g. erosion) hazards to agrarian communities in developing countries. The degree of exposure, sensitivity and adaptive capacity to climate change determines the vulnerability level of a community (Nelson et al., 2010a). The agrarian population in Bangladesh is ranked by many studies to be of the most vulnerable in the world due to the poor socio-economic features, the unique geophysical location and the high exposure to climate change effects (Ramamasy and Bass, 2007).

However, the measurement and interpretation of vulnerability indices is argued to be a rather difficult undertaking (O'Brien et al., 2004). First, it is rather arduous to define the vulnerability of an agrarian community within some administrative boundaries only. The climate change impacts affect larger scale areas - geographical regions (Fussel, 2007) and thus it is difficult to tell the differences between administrative units. Further, there can be multiple threats at various scales occurring simultaneously in social and natural aspects, which makes the identification and impact-value assessment quite dubious. Additionally, an impact from climate change can be instantaneous or may develop slowly over time, and thus the vulnerability assessment may become a rather puzzling process (Nelson et al., 2010b).

Although there may be difficulties in determining the assessment parameters of vulnerability, the biophysical and socioeconomic disciplines seem to adopt two distinctively different approaches. The "end-point" approach is more welcomed among biophysicists while the "start-point" notion prevails in socio-economics. The "end-point" approach may, for example examine future climate scenarios by evaluating - through modeling - its biophysical impacts and suggesting potential adaptive options. The "start-point" deploys the existing inequalities within a society which are deemed to further exacerbate when exposed to climate change (Smit and Wandel, 2006).

In our study, we attempted to borrow elements from both domains for the development of a socio-ecological vulnerability assessment in flood-saline and drought prone areas of Bangladesh. The northern drought prone Rajshahi and the southern flood-saline prone Barisal regions were selected as study areas and three sub-regions (upazilas) were adopted in each region. Demographic, agro-economic and infrastructure related indicators were introduced as assumed signals of social vulnerability, along with the results of climatic and hydrological models as biophysical indicators. Principal component analysis (PCA) was employed for the valuation of the vulnerability levels in each of the examined upazilas. Also, farmers' preferences were elicited for a better clarification of potential adaptation measures to be taken against climate change.

2. Methodology

2.1 Defining the vulnerability concept in a changing climate

According to the definition of the Intergovernmental Panel on Climate Change (IPCC), the leading international body for the assessment of climate change, the vulnerability to climate change could be synopsized as the "degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC, 2001, Glossary).

The vulnerability concept is highly dependent on the exposure, sensitivity and adaptive capacity of a system to cope with weather extremes. There is a multitude of interpretations pertaining to the affecting parameters of vulnerability but we currently borrow the definitions given by the IPCC which stipulates that the *exposure* relates to ―"the nature and degree to which a system is exposed to significant climatic variations"‖ (IPCC, 2001, Glossary). The *sensitivity* on the other hand, reveals the "degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC, 2001, Glossary)". Finally, the *adaptive capacity* is dictated as " the ability (or potential) of a system to successfully adjust to climate change (including climate variability and extremes) to (i) moderate potential damages, (ii) to take advantage of opportunities, and/or (iii) to cope with the consequences (IPCC, 2001, Glossary).

Although the components of vulnerability are well described in IPCC it still remains difficult to define the multifaceted nature of vulnerability. Both natural and social scientists agree that the vulnerability is *multi-dimensional and differential* which means that it is perceived differently across physical space and between various social groups (Cardona et al., 2012). It is also *scale* and *time-dependent* because various socioeconomic and biophysical impacts unequal in magnitude, may appear at the same time. Moreover, it is highly *dynamic* because the impacts may appear instantaneously or aggregated within the years (Vogel and O'Brien, 2004, Devisscher et al., 2012). Although the fuzzy nature of vulnerability is highly acknowledged there is a strong effort to define the boundaries of a vulnerable system. In this report, we have adopted the following diagrammatic concept of vulnerability as presented below:

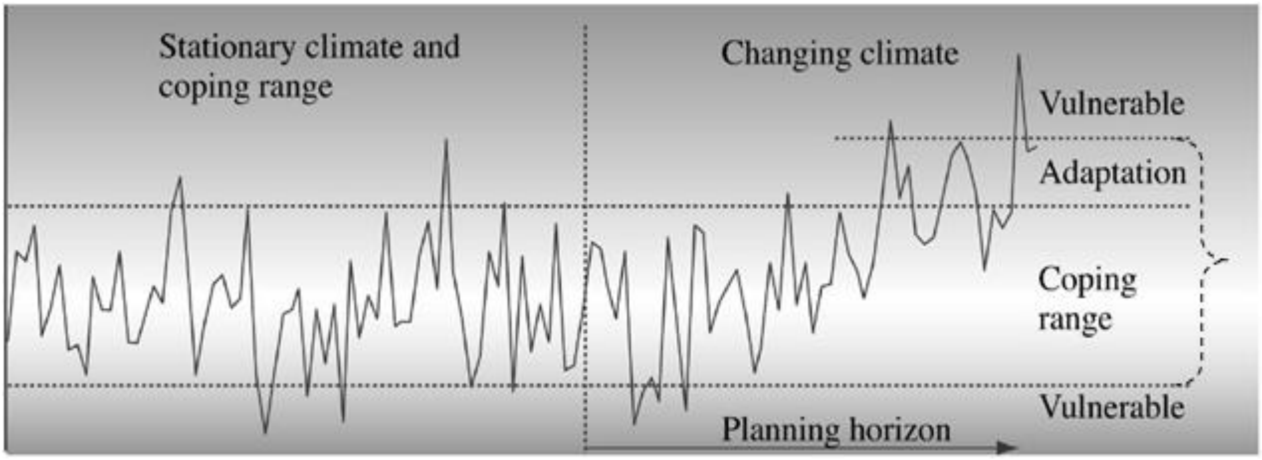

Figure 1. Boundaries of vulnerability and climate change, Source: Fellman, 2012

As shown in Figure 1, when the climate is in a stationary mode (left part of the figure), there are still some weather abnormalities which could be however managed within the coping range of an agrarian community. For example, higher temperatures or heavier rainfalls could be observed for some days in rural Bangladesh even when there is a stationary climate. The farmers have developed the relevant mechanisms to cope with weather fluctuations and overcome the relevant problems occurring from such weather events.

In the case of climate change however, the weather extremes may become more frequent and with higher intensity (right part of figure 1). In this case, the coping rage of a socio-ecological system becomes more limited and it is much dependent on the *exposure* and *sensitivity* to the changing climate. It is then that the *adaptive capacity* should be enhanced which actually represents the potential of a system to better adapt in climate change. In other words, the higher the adaptive capacity, the lower the vulnerability is. On the contrary, the synergy between exposure and sensitivity will augment the vulnerability levels.

In simple mathematical terms, the vulnerability of climate change can be expressed as below:

$V = A - (E + S)$… (1) where

V = Vulnerability, A= Adaptive Capacity, E = Exposure, S = Sensitivity

The operational dimensions of vulnerability often depend on the biophysical and socio-economic perspectives attributed in each case.

2.2 The operational dimensions of vulnerability

2.2.1 The ''starting" and ''ending" points of operational vulnerability

The operational dimensions of vulnerability are differently interpreted by social and biophysical sciences. The social sciences mostly perceive vulnerability as a situation where the existent inequalities between developed and developing regions will further exacerbate (O'Brien et al., 2004). The inherent social and economic differences will make it very hard for communities in developing countries to cope with the external pressures and climate change. As a result, the people from developing regions will be further marginalized and restrained from economic wealth. This vulnerability dimension is mostly acknowledged as a ''starting point'' and as such is nowadays acknowledged from all scientific disciplines. The input data for the ''starting point" perception are mostly indicators pertaining to the areas of socio-demographics, economic wealth, infrastructural facilities and information access.

It is frequent that in developing regions the indicators are processed with operational tools used for poverty analysis. The reason is that a given set of adverse phenomena such as weather extremes could decrease consumption below a minimum poverty level. Hence, a poverty analysis could somehow reflect the vulnerability aspects as well the distributional effects and inequality aspects of an agrarian community in Bangladesh for instance, which is hampered from extensive droughts or floods. It is however noted that the poverty analysis is mostly focused on the consumption levels which can hardly represent the socio-ecological vulnerability by climate change (Brouwer et al., 2007). Instead, statistical exploratory techniques such as components and factor analysis, generalized linear and non-linear models are nowadays introduced to this purpose.

The biophysical disciplines put much emphasis on the physical affects while the socio-economic aspects tend to be of secondary importance. Future emissions coupled with projected population trends and other technological aspects generate different climate change scenarios (Eakin and Luers, 2006). The adaptive capacity of an ecosystem is determined through the robustness and resilience conditions of an ecosystem to cope with the magnitude of the climate change impacts (Anderies et al., 2004). The biophysical perspective is mostly acknowledged as the ''end point'' approach.

The operational tools applied in such cases are - more often than not - different climatic models. The current models have been much evolved so as to forecast climate change on regional and global scales with a degree of uncertainty (Gallopin, 2006). The most frequent parameters examined are the temperature, precipitation, wind speed, sunshine exposure and humidity. However, there are considerable limitations in our understanding of the climate system and the precision of biophysical parameters especially on a regional level. This becomes more distinctive in the case of developing countries where the biophysical indicators for the regions are scarce and often unreliable. (Basak, 2011).

Our study introduces a mixture of theory and data-driven approaches for the development of a quantitative regional assessment in two regions of rural Bangladesh. In particular, we borrow elements from both the socio-economic and biophysical perspectives for the construction of a vulnerability assessment. To this end, we introduced indicators already applied in a multitude of biophysical and socio-economic studies for the development of vulnerability indexes (Abson et al., 2012; Deressa et al., 2008; Fellman 2012; Piya et al. 2012). These indicators were sourced from published sources of similar projects, RiceClima reports and individual research papers.

However, the agricultural conditions in the flood and drought prone areas of Bangladesh should be also investigated with indicators pertaining to the peculiarities of the case study areas. For this reason, we also had to adapt our vulnerability assessment for the inclusion of representative indicators from the selected areas. A household survey was conducted for this data-driven approach as it is presented in details in the following Section.

Overall, we introduced three groups of vulnerability indicators corresponding to the areas of exposure, sensitivity and adaptive capacity, respectively. The exposure group in Table 1 represents a set of various biophysical and technical indicators originated from RiceClima reports. It should be mentioned that the values of the Exposure indicators represent the weighted mean of a 30-years observations in the selected upazilas.

Table 1. Exposure Indicators

EXPOSURE INDICATORS				
Code	**Abbreviation**	**Unit**	**Explanatory Note**	**TD.-DD**
1	T_annual	Celcius	Mean Temperature for All year	TD
2	P_annual	mm	Mean Precipitation for All year	
3	Yloss_Aus	%	Yield Loss compared to the potential yield without irrigation for T.Aus period	DD
4	Yloss_aman		Yield Loss compared to the potential yield without irrigation for T.Aman period	
5	YL_slight_aus		Indicated level of slight loss in % of years for T.Aus period	
6	YL_mod_aus		Indicated level of moderate loss in % of years for T.Aus period	
7	YL_severe_aus		Indicated level of severe loss in % of years for T.Aus period	
8	YL_slight_aman		Indicated level of slight loss in % of years for T.Aman period	
9	YL_mod_ama		Indicated level of moderate loss in % of	

	n		years for T.Aman period	
10	YL_severe_aman		Indicated level of severe loss in % of years for T.Aman period	
11	NIR_Aus	mm	Net irrigation requirements for T.Aus period	
12	NIR_Aman		Net irrigation requirements for T.Aman period	
13	NIR_Boro		Net irrigation requirements for Boro period	

Note: TD= Theory-Driven Indicators; DD=Data-Driven Indicators

In Table 2, the sensitivity indicators suggested for our study are displayed. As advised by the Bangladesh Rice Research Institute (BRRI), the growing of winter rice (boro) or keeping fallow land in winter time are considered as more sensitive practices to drought conditions than cultivating water resistant crops. Also the small and tenant farmers are suggested by literature reviews to be suitable sensitivity indicators for agricultural vulnerability assessments (Biswas et al., 2009).

Table 2. Sensitivity Indicators

Code	Abbreviation	Unit	Explanatory Note	TD-DD.
1	Cropping Pattern 1	%	Boro- Fallow-T.Aman	DD
2	Cropping Pattern 2	%	Fallow-T. Aus-T.Aman	
3	HYV Boro	tn/ha	Rice variety for dry (winter)period	
4	Small Farm	%	Small Farmers	TD
5	Tenant Farm	%	Tenancy Farming	

Note: Tn/ha= Tonnes per hectare, HYV= High Yield Variety

It is noted that the biophysical indicators used for the sensitivity and exposure measurements are not related to any future climate change predictions but to past observations. Finally, the adaptive capacity indicators are displayed in Table 3 as below:

Table 3. Indicators of Adaptive Capacity

C.	Indicator	Unit	Explanatory Note	TD-DD	C.	Indicator	Unit	Explanatory Note	TD-DD
	SOCIO-DEMOGRAPHIC INDICATORS				12	Access b. house-Electr.	Nos.	Access to brick-made housing-electricity	DD
1	Age	Years	Mean age of adult family members	TD	13	Infr.Health		Community clinics per population	TD
2	Schooling years		Mean schooling years of adult family members		14	Infr.post.		Post services per population	
3	Farm Exp.		Mean Farm experience		15	Infr.veter.		Veterinary centers per population	
4	Family Size	Nos.	Mean Family Size		16	Infr.coop		Cooperatives per population	

5	Own Farm	%	Owning Farmland		17	Infr.agr.ext.		Agricultural extensions per population	
	AGRO-ECONOMIC INDICATORS				18	Infr.finan.		Financial schemes per population	
6	Farm Size	Ha	Mean Farm size per household		19	Infr.school		Schools per population	
7	Crop Intens.	%	Ratio between the gross cropped area and cultivated land	DD	20	Infr.coll.		Colleges per population	
8	BCR All	Nos.	Benefit Cost Ratio crops/ha	TD	21	In-migrat.		People migrating to the upazila per population	
9	Livestock		Livestock amount with weighted averages		22	Local m.	Km	Distance from local markets	
10	Inc. Av.	Tk/hsd	Mean income per household		23	Bigger m.	km	Distance from bigger markets	
	INFRASTRUCTURE INDICATORS				24	Hosp. Km	KM	Distance from Hospitals	
11	Access Tub.-Latr.	Nos.	Access to tubewell and Latrine	DD	25	Town km	km	Distance from towns	

Note : C. = Code; Nos.= Number; TD= Theory-Driven Indicators; DD=Data-Driven Indicators

As presented in Table 3, 6 indicators are attributed to the socio-demographic situation (1-5, 21), 5 indicators describe agro-economic activities (6-10) and 14 (11-20, 22-25) indicators refer to infrastructure access. The relatively small number of agro-economic indicators is due to the summation of individual indicators in some cases. For instance, the Benefit-Cost Ratio of crops per hectare represents the average ratio of all the cultivated crops (e.g. different rice varieties, vegetables etc.) on a per hectare basis. Similarly, the Livestock indicator represents the total amount of livestock (i.e. cows, goat, poultry) given different weights for each animal due to the various economic importance.

It is noted that there were additional meaningful indicators, like the irrigation management, the insect and disease frequency and others to be introduced in the vulnerability assessment. However, the absence of sufficient and appropriate data obstructed their use in the vulnerability assessment. A description of these indicators is presented in Annex 1.

2.2.2 Principal Component Analysis and Farmer's preferences

We employ the Principal Component Analysis (PCA) to identify the potential significance of the adaptive capacity, sensitivity and exposure indicators for the assessment of vulnerability in selected drought and saline-flood prone areas of Bangladesh. The PCA is a technique presented in many applications of statistical and econometric inference. PCA has been also extensively applied in socioeconomic and biophysical vulnerability assessments in regional, national and global level (Deressa et al., 2008; Abson et al., 2012, Piya et al. 2012; Borja-Vega and De la Fuente, 2013).

The objective of PCA is to explain potential relations between a large set of independent variables (in our case indicators) with a latent dependent variable which in our case is the vulnerability level of each upazila. The comparative advantage of PCA over other exploratory techniques is that it can rearrange the independent variables for the simplification of the analysis without losing significant information. This is achieved by lowering the dimensions of the original data to few principal components.

The components are tested for potential correlations with each independent variable (indicator), known as factor loadings which are equivalent to standardized regression coefficients (ß weights) in multiple regressions (Beaumont, 2013). The higher values of the factor loadings (correlation), mean a closer relationship with the principal components. The correlation threshold for a variable to remain as a loading factor is not quite precise. As a rule of thumb though, the correlations, positive or negative, presenting a loading factor lower than +/- 0.7 are often discarded from the analysis. The remaining correlations represent the variables needed to develop the scoring index for the vulnerability assessment.

Also, the number of principal components to interpret the relevant variables is debatable and it mainly depends on the grading of eigenvalues associated with each component. In practical terms, the components presenting eigenvalue higher than 1 are approved for explaining the independent variables (indicators) (Everitt and Hothorn, 2011). More often than not, the principal components should be as many as to explain 60-70% of the variables (Abson et al., 2012).

PCA gives also the potential to understand the overall importance of an independent variable across all the principal components. This is named as Communality for PCA and it is equal to the sum of all the squared factor loadings for all the principal components related to the independent variable (indicator). This value is the same as the R^2 in multiple regression. The value ranges from zero to 1 where 1 indicates that the variable can be fully defined by the factors. The higher the value, the higher the importance of the relevant indicator.

The data to be used in PCA should be initially standardized and checked for potential multicollinearity between the independent variables for the avoidance of biased results.

A potential limitation of the PCA method is the weighting importance in the selected variables. Some authors claim that the PCA may not reflect the higher significance that each variable may possess, by failing to attribute the actual results of a vulnerability assessment. The introduction of experts' judgment (Kaly and Pratt 20009), correlation with past disaster events and use of fuzzy logic (Eakin and Tapia 2008) are some suggestions for the appointment of weighting coefficient. However, there is an allegation that the proportion of variance could also constitute a weighting factor when calculated with the standardized values of each variable (Beaumont, 2013). Moreover, the rotation of the principal components through different techniques (varimax, equamax) could probably offer a better explanation of the results and improve these weighting factors. In our case, we have calculated the variances of each indicator with the standardized values without however considering it as a weighting factor but as a part of the vulnerability assessment. We understand that the appointment of a weighting factor is of major importance but we consider that this demands a thorough research which is beyond the scope of this study.

The PCA can run stepwise for each group of the indicators of exposure, sensitivity and adaptive capacity as presented in Tables 1,2 and 3 or by merging all the indicators of the three groups in one. We have selected the stepwise approach with slight modification in an attempt to better implement Eq.1 in our analysis. To this end, we have run PCA model for adaptive capacity indicators while the sensitivity and exposure indicators were merged in one group since they are represented by a negative signalling in Eq.1.

Below, we present an indicative example of PCA assessment for the case of the Adaptive Capacity Assessment in Godagari upazila (Rajshahi region). As shown in Table 4, all the Adaptive Indicators have been initially standardized. We then run the PCA analysis to identify which of the proposed indicators present a loading factor higher than +/- 0.7 and would be eligible for the vulnerability assessment. In the example, the eligible indicators are highlighted with greyish colour.

Table 4. Example of Standardized Adaptive Indicators

Age	Schooling years	Farm Exp.	Family Size	Own Farm	Farm Size	Crop Intens.	BCR All	Livestock Score	Inc. Av.	Acc. Tubwl. Latrine	Acc. b house Elect.	Acc. health
0.81	-0.41	-0.10	-0.18	-1	1	1	0.02	-1	1	1	1	-1
Infr. post	**infr. health**	**infr.vet**	**Infr.coop**	**Infr.agr.ext.**	**Infr.finan**	**infr.school**	**infr. college**	**in-migrat**	**Local m.**	**bigger m.**	**hosp. Km**	**town km**
1	-0.11	1	-1	-0.17	1	1	0.26	0.17	1	-1	0.14	0.33

In turn, the factor loadings of these indicators are multiplied with the standardized values for the calculation of the Adaptive Capacity levels as below:

= -0.416 (Schooling years) * 0.821 (Loading) + (-0.18)(Family Size)* (-0.862) (Loading)+ (-1) (Own Farm)* 0.876 (Loading) + 1 (Farm Size) * (-0.761) (Loading) + 1 (Crop Intens.)* 0.93 (Loading) + 1 (Invc.Av.)* (-0.9) (Loading) + 1 (Acc.Tubwl- Latrine)* 0.965 (Loading) + 1 (Acc.b.house-Electr.)* 0.967 (Loading) + (-1) (Acc. Health)* (-0.967) (Loading) + (-0.11) (infr.health) * (-0.764) (Loading)+ 1 (infr.vet) * 0.892(Loading) + (-1) (Infr.coop)* (-0.91303)(Loading) +(-0.17) (Infr.agr.ext)* (0.809) (Loading) + 1 (Infr.finan)* (-0.943)(Loading) + 0.267 (infr.college)* (-0.823) (Loading) + 0.178 (in-migrat)* (- 0.816)(Loading) = **1.546,** which is the Adaptive Capacity Score for Godagari upazila in our example.

In the case of indicator's significance as represented through Communality value, we present an example of the Schooling Year's indicator by considering that we have only two principal components (PC) as below:

Schooling Years = $(0.821)^2$ (PC 1) + $(0.499)^2$(PC 2)= **0.924,** Communality Value

It is underlined that the PCA assessment can measure the relative vulnerability between the examined areas and does not suggest some absolute vulnerability grades based upon a global vulnerability index.

For a better clarification of PCA results, we have also attempted to elicit farmers' preferences with regards to the confrontation of weather extremes and improvement of their adaptive capacity. The farmers were not asked to assess the performance of the same adaptive indicators introduced in PCA but to express in a non-determined context their suggestions for a better adaptation to a changing climate.

3. Case Study

3.1 Vulnerability of Bangladesh

Bangladesh has been repeatedly threatened by natural disasters like flood, salinity and droughts mainly influenced by the country's unique geophysical and climatic conditions (Nienke et al, 2006).

In particular, the mountainous ranging of the Tibetan Plateau is drained through a massive river network spreading all over Bangladesh and finally ending up in the Bay of Bengal. The occurrence of intense monsoonal periods often augments the drainage effects by leading to floods mainly in the southern lowland areas (World Bank, 2010). Additionally, saline intrusions are noticed in the south downstream areas, which are attributed to the higher sea level elevation in the coastlands. On the other hand, less rainfall and high evaporating losses in the northwest Bangladesh have entailed seasonal drought events with severe impacts on local communities (Ramamasy and Bass, 2007).

The extreme events are anticipated to get aggravated by climate change as repeatedly noted in the literature (Nguyen, 2006; Biswas et al, 2009; Winston et al, 2010). The snow melting in the mountainous areas of the Tibetan Plateau coupled with erratic and intense monsoons are expected to constitute the driver for increased flooding. Also, the delayed monsoon conditions and the higher sea level intrusion are probable to lead in more frequent drought and salinization effects (MoEF, 2009; Winston et al, 2010). To this end, Bangladesh is struggling to cope with the current adverse weather conditions while national plans and strategies to respond to the impacts caused by climate change are developed.

The threatening situation and the efforts undergone by Bangladesh are well quoted in a recent outcome of the International Institute for Environmental (2013) "…Bangladesh is the most climate vulnerable country in the world and has consistently been a leader in developing solutions around community-based adaptation to climate change, national adaptation planning and offering political leadership as part of the Least Developed Country (LDC) group, which represents the least developed countries at the climate change negotiations."

We have selected the regions of Rajshahi and Barisal in the northern and southern parts of the country, as the most representative areas suffering from drought and flood-saline occurrences respectively. Within each province, three sub-regions (upazilas) were chosen which could best ascribe these opposite weather patterns' impact on a regional level.

3.2 Drought (Rajshahi Region) and flood-saline (Barisal) regions

3.2.1 General Description

In Rajshahi region, the study sites are located in Godagari and Tanore upazilas (lowest administrative unit) under Rajshahi district and Gomostapur upazila under Chapai Nawabganj district. The area is characterized by severe drought and is located in north-western Bangladesh between 88.10^0 to 88.40^0 longitudes and 24.20^0 to 25.00^0 latitudes (Figure 2).

The site area receives lower amount of precipitation (1500 mm) than the rest of Bangladesh, while its cropping intensity of 191-262% is more than the national average (180%). The higher cropping intensity may be attributed to the improved and more widely available irrigation facilities (deep tubewells) developed by the Barind Multipurpose Development Authority (BMDA). The number of deep tubewells (DTW) seems to be proportionate with the cropping intensity in the study location; however, the groundwater table is declining alarmingly due to over exploitation (CEGIS, 2013).

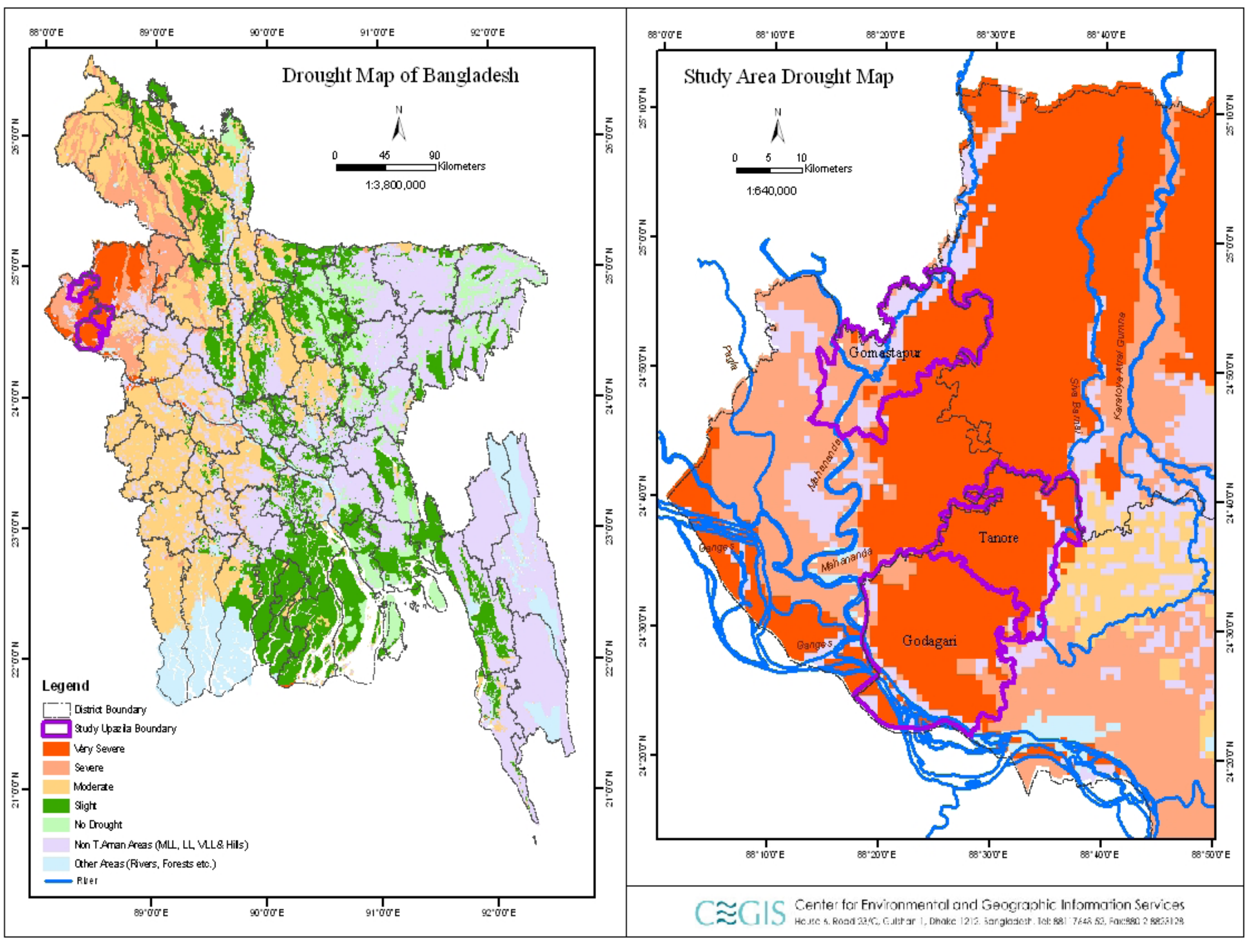

Figure 2. Rajshahi Region, Source: CEGIS (2013)

The government's rules and regulations for irrigation are seldom followed at the field level in Rajshahi. Lack of groundwater reserves, poor quality seeds, high pest prevalence, low soil organic matter content, and extreme temperatures are the major problems for agricultural development. Also, grazing land has decreased tremendously because of increased cropping intensity while insect pests and diseases have made their appearance more frequently. Of late, brick fields have also been established in place of crop fields. The removal of top soil for making bricks is a great concern regarding future agricultural productivity.

In Barisal region, the study sites are located in Amtoli and Patharghata Upazila (lowest administrative unit) under Barguna disrtict and Kalapara Upazila under Patharghata district. The study area lies between 89.50^0 to 90.24^0 longitudes and 21.46^0 to 22.18^0 latitudes (Figure 3). The study areas are mainly bounded by the Bay of Bengal in the South side, Tetulia river in the eastern side of Kalapara upazila, Buriswar river in the western side of the Amtoli upazila, Biskhali and Baleswar river in the eastern and western side of Patharghata upazila, respectively.

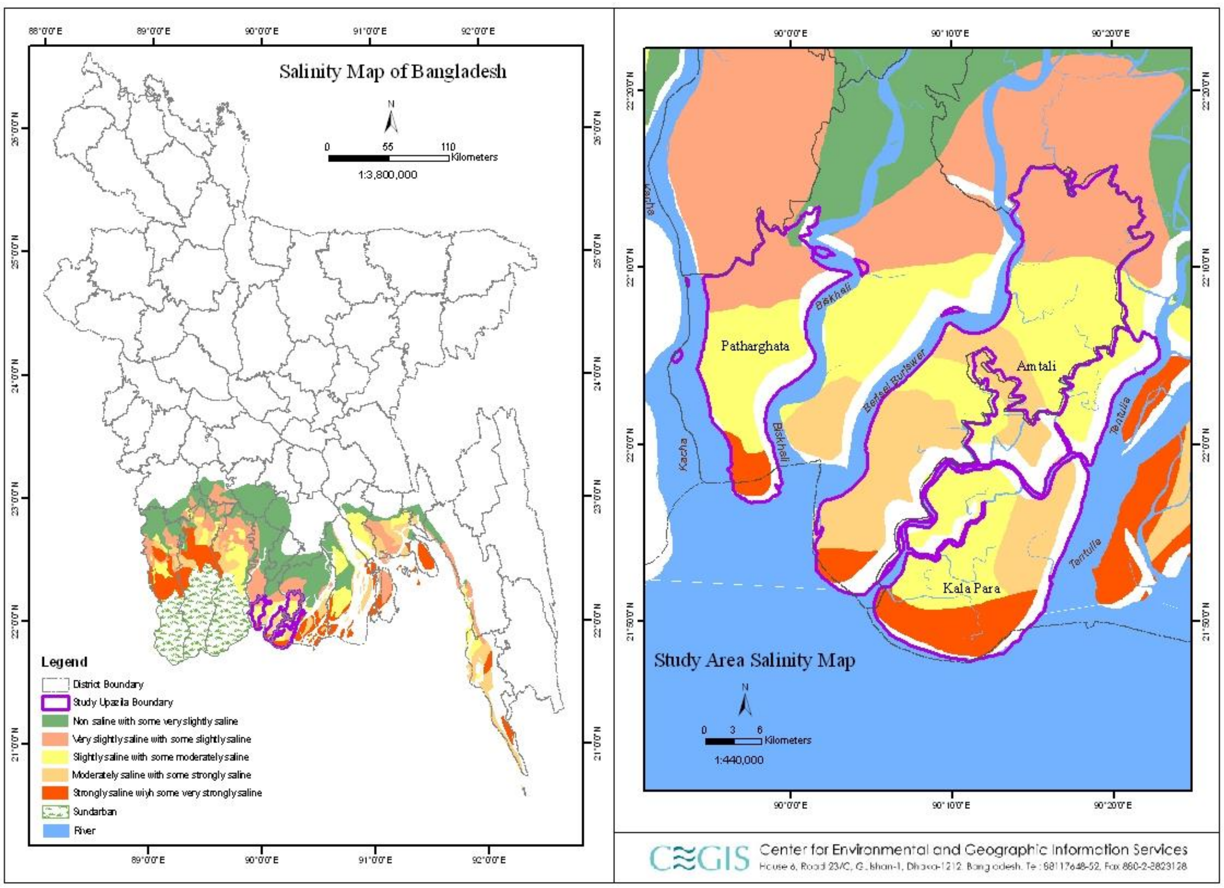

Figure 3. Barisal Region, Source: CEGIS (2013)

The area is characterized by an intermediate amount of rainfall (about 2000 mm) and with a cropping intensity of 173-199%, which is around the national average (180%).

The land type of this area is medium low to medium high land, where maximum flooding depth is about 90 cm during the monsoon season.

The study areas are within a polder system, which was constructed mainly for flood protection and to prevent the area from saline water intrusion as presented in Figure 4. At present, the sluice gates are not properly maintained and many of them are out of order. Moreover, sedimentation near the sluice gates is increasing day by day, which causes drainage congestion in the study areas.

Figure 4. Sluice gate in Amtoli upazila (Source: Field Trip in Barisal region, February 2012)

Seasonal intrusion of saline water is damaging the ecological and hydrological balance of the studied upazilas. Additionally, inadequate saline tolerant varieties, high pest prevalence, lack of farm machinery, and lack of training on modern crop production technologies are some of the other bottlenecks of agricultural development (Biswas, 2009).

3.2.2 Agricultural practices in Rajshahi and Barisal regions

The major crops grown in Rajshahi are rice and wheat. However, currently increasing areas of rice fields are being replaced by mango orchards due to the lower water demand and higher profitability of the mango fruit. This may have significant implications for the future rice production in Bangladesh. The minor crops are potato, tomato, gram, maize, and eggplant.

The major cropping patterns in Godagari was the Boro – Fallow – T. Aman (42%) followed by Boro – T. Aus – T. Aman (38%). Similar patterns were also observed in Tanore area. However, in Gomostapur area the highest coverage was the Boro – Fallow – T. Aman pattern (40%) followed by Boro – fallow – T. Aman (34%).

During the last 15 years, the amount of rainfall and its distribution pattern, temperature and drought duration, has changed unfavorably to growing traditional rice variaties. In the mid-90s farmers mostly cultivated Kalokuchi, Shaitta, Dharial, Sonasail, Mugi, Raghusail, Magusail, Jhingasail, BR10, BR11 and IR20 rice varieties. At present, Pariza, Sada Sawrna, Guti Sawrna, BINA dhan7, BRRI dhan28, BRRI dhan36 and BRRI dhan39 are mostly grown.

Farmers also grow short duration rice varieties in attempt to reduce the effect of drought conditions. Moreover, they are growing tomato, mustard, and potato to minimize the need for irrigation water in the dry season.

In the case of Barisal, rice is the major crop. The minor crops are pulses, potato, chili, mustard, sunflower, watermelon, groundnut and spices, etc. Pulse-Fallow-T. Aman (55%) is the major cropping pattern followed by Winter Crops-Fallow-T. Aman (20%) in Kalapara upazila. In the case of Amtoli upazila, Grass pea-T. Aus-T. Aman (48%) is the major pattern followed by Fallow-T. Aus-T. Aman (24%). The dominant cropping pattern in Patharghata upazila is Fallow-Fallow-T. Aman (40%) followed by Grass pea-Fallow/T. Aus-T. Aman pattern (25%).

Alike Rajshahi, change in climate conditions in the past few years have adversely affected rice growing via changes to the rainfall and its distribution pattern, temperature, and drought duration. Farmers earlier cultivated rice varieties such as Kajalsail, Sadamota, Lalmota, Laxmibilash, Rajasail, Shaitta, Brindamoni, Rangalaxmi, Shitabhog, Kutiagni, Betichikon, Jhingasail, Matichak etc and a few HYV rice varieties such as BR11, BR22. At present, Sadamota, Vajan, BR11, BR22, BR23, BRRI dhan27, BRRI dhan40, BRRI dhan41 and BRRI dhan49 are commonly grown, which cover 60-99% of the land in the T. Aman season and about 90% of the land in the T. Aus season.

The growth periods of different rice and non-rice crops in Rajshahi and Barisal are shown in Figure 5. As presented, the boro rice needs longer growth period than the T. Aman rice. Mustard, potato and tomato need comparatively short growth duration. It is further presented that not exactly the same crops are cultivated in both regions due to different geophysical and weather conditions.

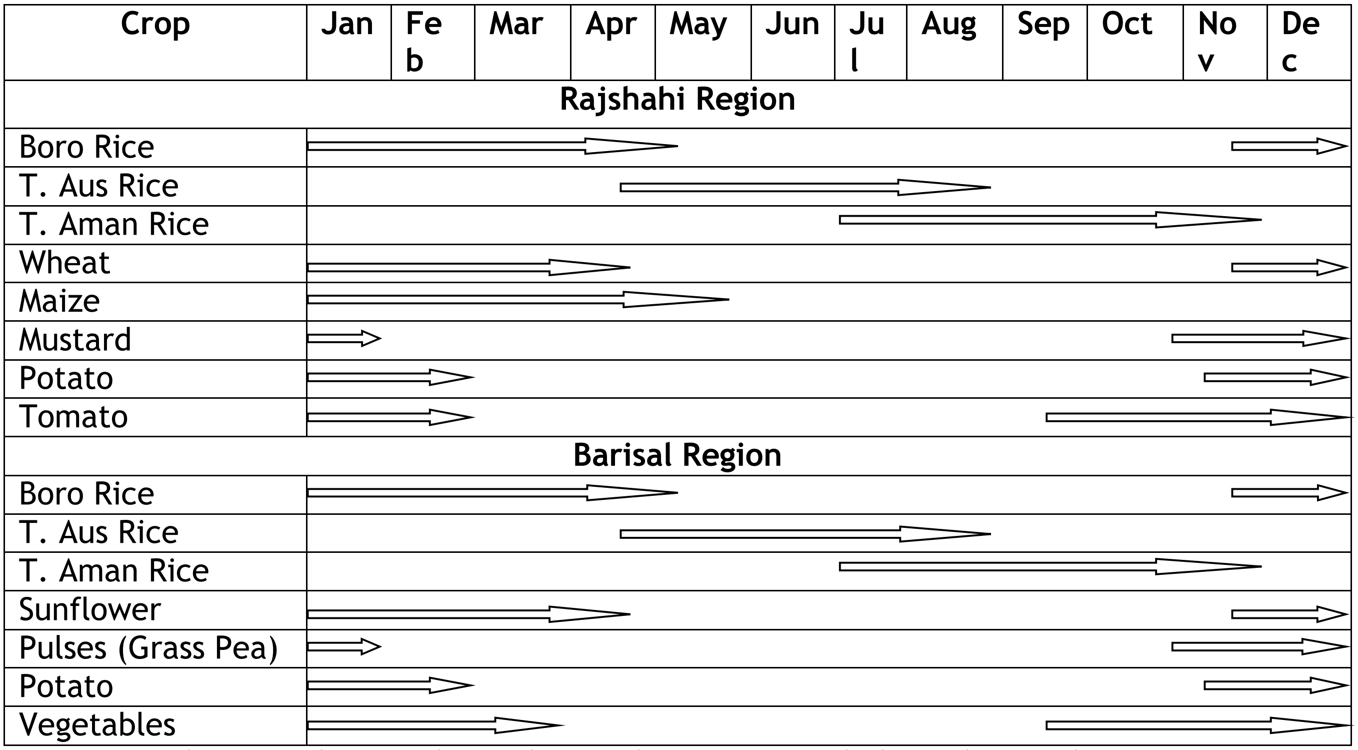

Figure 5. The growth period of cultivated crops in Rajshahi and Barisal regions

3.3 Primary and Secondary Data

The primary data was elicited from a household survey analysis conducted in the two regions. In each region, 100 farmers from different farm sizes (small, medium and large) were queried through a random sampling method. The collection of the survey responses was carried out from February to March 2013.

The survey period covered 3 agricultural crop seasons. These are: i) Kharif-I: 16 March to 30 June); ii) Kharif-II: 01 July to 15 October and iii) Rabi: 16 October to 15 March. The survey data covered Rabi/Boro, 2011; Kharif-I, 2012 and Kharif-II, 2012 seasons. The crops cultivated in these seasons are boro rice in October-November to harvesting time April-May, then the aus rice during March-April to July-August and lastly the aman rice in July-August to November-December.

The secondary data was originated from the following sources:

- Scientific publications on socioeconomic and biophysical indicators.
- Bangladesh Meteorological Office (BMO), the Directorate of Agricultural Extension (DAE) and other government publications.
- Internal project reports of the RiceClima project on climate change scenarios, hydrological and crop modelling.

4. Results

4.1 Descriptive results

The amount of respondents in the household survey were rather well balanced among the upazilas and the villages situated in each area as presented in Table 5.

Table 5. Sampling distribution

Drought prone study area (Rajshahi region)			Flood-Saline prone study area (Barisal region)		
Upazila	**Block/Village**	**Farmer (Nos.)**	**Upazila**	**Block/Village**	**Farmer (Nos.)**
Godagari	**All**	**30**	Kalapara	**All**	**32**
	Nabagram	7		Nilganj	10
	Iyhy	11		Tiakhali	12
	Bidirpur	12		Chokomoya	12
Tanore	**All**	**34**	Amtoli	**All**	**34**
	Kalma	8		Uttar Tiakhali	13
	Kaliganj	11		Choto Nilganj	9
	Mandomala	15		Nalbania	12
Gomastapur	**All**	**36**	Patharghata	**All**	**34**
	Zinarpur	11		Char Doani	12
	Chotodadpur	14		Char Lathimara	12
	Rohanpur	11		Kalomega	10
Total		**100**	**Total**		**100**

Source: Field Survey, 2013

Further, some descriptive statistics of agronomic and economic interest are presented for a better understanding of the socio-economic situation in the study areas. It is noted that these descriptive results are not necessarily presented as well in the PCA assessment in the form of indicators. In particular, many of the descriptive results just provide a better understanding of the study sites but they would not be meaningful as indicators for the vulnerability assessment. In few cases, as indicatively in the irrigation and pest and disease descriptive results, vulnerability indicators could be shaped. However, the data was provided only on a regional level and thus the indicators would be meaningless for a vulnerability assessment on a upazilla level.

Farm size and landholders

The average farm size and cultivated land of sample farmers are shown in Table 6. As presented, the total area of cultivated land in Godagari, Tanore and Gomostapur in Rajshahi region is nearly identical to the cultivated land of the upazilas in the Barisal region. In all the Rajshahi upazilas, the share of owned land was greater than that of the rented/mortgaged land. Conversely, the share of rental farming lands is greater in the Barisal region, except in Patharghata upazila. The average farm size in both regions is relatively similar between the six upazilas although with some variations.

Table 6. Farm ownership status (ha)

Location	Farmer (No.)	Own land (ha)	Rented/ Mort. in land (ha)	Rented/M ort. out land (ha)	Total cultivated land (ha)	Average. farm size (ha)
	a	b	c	d	e=b+c-d	e/a
Rajshahi Region						
Godagari	30	29.07	21.33	1.07	49.33	1.64
Tanore	34	38.47	7.80	1.20	45.07	1.33
Gomostapur	36	28.67	16.00	-	44.67	1.24
Total	**100**	**96.21**	**45.13**	**2.27**	**139.07**	**1.39**
Barisal Region						
Kalapara	32	24.67	25.60	-	50.27	1.57
Amtoli	34	23.80	24.47	0.40	47.87	1.40
Patharghata	34	35.33	4.27	-	39.60	1.16
Total	**100**	**83.80**	**54.34**	**0.40**	**137.74**	**1.38**

Source: Field Survey, 2013

Table 7 gives a more precise allocation of farm size per landholder by dividing them between small, medium and large farmers. The number of large and small farmers seems to be higher in Rajshahi than in Barisal.

Table 7. Farm sizes based on cultivated land (ha)

Location	Small Farm (0.61 - 1.0 ha)		Medium Farm (1.01 - 3.0 ha)		Large Farm (3.01ha and above)	
	Number	Percent	Number	Percent	Number	Percent
Rajshahi Region						
Godagari	8	26.67	19	63.33	3	10.00
Tanore	15	44.12	17	50.00	2	5.88
Gomostapur	20	55.56	14	38.89	2	5.55
Average	**14.33**	**42.12**	**16.67**	**50.74**	**2.33**	**7.14**
Barisal Region						
Kalapara	8	25.00	22	68.75	2	6.25
Amtoli	13	38.24	20	58.82	1	2.94
Patharghata	15	44.12	19	55.88	-	-
Average	**12.00**	**35.79**	**20.33**	**61.15**	**1**	**3.06**

Source: Field Survey, 2013

Crop Cultivation

Tables 8 shows the major crops in Rajshahi grown in the selected sites with their existing yield level. Different types of crops are grown between regions and their yield also varies depending upon location. The major rice varieties grown in the study sites were Local T. Aus (Pariza), HYV T. Aus (BRRI dhan48), HYV T. Aman BRRI dhan49 and 56), Sawrna (Guti Sawrna, Ranjit Sawrna and Lal Sawrna), HYV Boro (BRRI dhan28 and BINA-7) etc. The major non-rice crops were Chick Pea, Mustard, Tomato and Wheat.

Table 8. Major crops grown and yield level in Rajshahi region

Crops	Popular varieties	Area (ha)	Average yield (t/ha)	Yield range (t/ha)
A. Godagari site				
Local T. Aus	Pariza	12.20	4.28	3.90 – 5.85
HYV T. Aus	BRRIdhan48	1.33	4.80	4.25 – 4.90
HYV T. Aman	BRRIdhan49 and BRRIdhan56	1.80	4.54	4.10 – 5.40
Sawrna (aman)	Guti Sawrna, Ranjit Sawrna and Lal Sawrna	35.20	5.13	4.80 – 5.55
HYV Boro	BRRIdhan28 and BINA7	14.54	5.30	3.90 – 6.30
Chickpea		5.53	1.16	0.90 – 1.80
Mustard		6.33	1.07	0.90 – 1.31
Tomato		5.94	21.16	16.50 – 30.00
Wheat		12.20	3.66	3.08 – 4.80
Total Cropped Area		**95.07**		
B. Tanore site				
HYV T. Aman	BRRIdhan49	6.47	5.45	4.80 – 6.00
Sawrna (aman)	Guti Sawrna, Ranjit Sawrna and Lal Sawrna	25.93	5.26	4.50 – 5.63
HYV Boro	BRRIdhan28 and BINA7	26.53	4.98	3.90 – 6.00
Chickpea		0.53	1.80	1.3 – 2.00
Maize		4.20	5.40	4.90 – 6.10
Mustard		6.20	1.04	0.90 – 1.20
Potato		6.20	17.84	16.05 – 18.00
Wheat		4.13	3.53	3.15 - 4.80
Total		**80.20**		
C. Gomastapur site				
Local T. Aus	Pariza	12.40	5.24	4.89 – 5.70
Local Aman	Fine and aromatic variety	5.87	2.25	1.95 – 2.55

HYV T. Aman	BRRIdhan34/36	0.27	5.62	5.40 – 5.85
Sawrna (aman)	Guti Sawrna, Ranjit Sawrna and Lal Sawrna	38.80	5.36	4.50 – 5.70
HYV Boro	BRRIdhan28 and BINA7	3.47	5.39	4.80 – 6.00
Chickpea		1.07	1.65	1.05 – 1.80
Mustard		4.00	1.11	1.05 – 1.80
Wheat		12.80	3.51	3.00 – 3.60
Total		**78.67**		

Source: Field Survey, 2013

Respectively, in Barisal region the major rice varieties were Local T. Aus (Mala China), Local T. Aman (Kazal Shail, Sadamota, Lalmota, Vajan and Tepu), HYV T. Aman (BR11/23 and BRRIdan40/41), HYV Boro (BRRI dhan28). The major non-rice crops were pulses and vegetables. Table 9 shows the average yield and range of yield of each crop in Barisal, which reveals that, minimum and maximum yield differences were high in each crop.

Table 9. Major crops grown and yield level in Barisal region

Crops	Popular varieties	Area (ha)	Average yield (t/ha)	Yield range (t/ha)
A. Kalapara site				
Local T. Aman	Sadamota, Lalmota, Vajan,Tepu	36.27	2.81	2.40 – 3.60
HYV T. Aman	BR11 and BRRIdan41	15.20	3.37	3.00 – 3.60
HYV Boro	BRRIdhan28	11.73	4.20	3.90 – 4.80
Pulses (Grass Pea)		1.80	1.09	0.98– 1.20
Vegetables		2.53	12.18	10.75 – 13.50
Total		**67.53**		
B. Amtoli site				
Local T. Aus	Mala China	9.60	3.30	3.00-3.60
Local T. Aman	Sadamota, Lalmota	27.33	2.70	2.40-3.00
HYV T. Aman	BR11, BRRI dhan40/53	16.37	3.80	3.10-4.50
HYV Boro	BRRI dhan28	2.30	4.27	3.90 – 4.80
Pulses (Grass Pea)		6.40	1.18	1.00-1.75
Vegetables		1.00	12.08	11.05– 13.25
Total		**63.00**		
C. Patharghata site				
Local T. Aman	Kajalsail, Sadamota,	32.53	3.45	2.40-4.50

	Lalmota			
HYV T. Aman	BR11, BR22 and BRRI dhan44	4.33	4.60	3.40-5.80
Potato		2.47	9.75	9.00-10.50
Sunflower		1.20	1.80	1.65-1.95
Pulses (Grass Pea)		19.87	1.24	0.98-1.50
Vegetables		1.27	10.75	9.50-12.00
Total		**61.67**		

Source: Field Survey, 2013

Crop profitability

The profitability of crop production was examined through the Benefit-Cost ratio indicator as presented in Tables 10 and 11. In Rajshahi region, non-rice crops were more profitable (BCR ranged from 1.37 to 2.28) than rice crops (BCR ranged from 1.15 to 1.25). Among rice crops HYV boro rice were less profitable than aus or T.Aman rice due to the high irrigation and fertilizer costs associated with boro rice production (Table 10).

Table 10. Location wise crops grown and gross margin (Tk/ha) in Rajshahi region

Crops	Yield (t/ha)	Sale price (Tk/kg)	Total Variable cost (TVC) (Tk/ha)	Gross return (GR) (Tk/ha)	Gross Margin (GM = GR-TVC) (Tk/ha)	Undiscoun-ted BCR = GR/TVC
Godagari site						
T. Aus (Pariza)	4.28	16.25	61,525	73,830	12,305	1.20
T. Aman	5.13	16.25	70,794	88,493	17,699	1.25
HYV Boro	5.30	16.12	77,552	90,736	13,184	1.17
Mustard	1.07	45.06	33,756	49,284	15,528	1.46
Tomato	21.16	8.25	76,566	1,74,570	98,004	2.28
Wheat	3.66	18.80	52,896	72,468	19,572	1.37
Tanore site						
T. Aman	5.45	16.25	77,060	94,013	16,953	1.22
HYV Boro	5.70	16.12	84,856	97,584	12,728	1.15
Maize	5.40	12.50	41,657	72,900	31,243	1.75
Mustard	1.04	45.06	31,935	47,902	15,967	1.50
Potato	17.84	9.40	78,362	1,67,696	89,334	2.14
Wheat	3.53	18.80	49,924	69,894	19,970	1.40
Gomastapur site						
T. Aus (Pariza)	5.24	16.25	73,488	90,390	16,902	1.23
T. Aman	5.42	16.25	74,202	93,495	19,293	1.26

HYV Boro	5.60	16.12	85,600	95,872	10,272	1.12
Mustard	1.11	45.06	35,753	51,127	15,374	1.43
Wheat	3.51	18.80	47,930	69,498	21,568	1.45

Source: Field Survey, 2013

In Barisal region, non-rice crops were also more profitable (BCR ranged from 2.10 to 2.75) than rice crops (BCR ranged from 1.18 to 1.30). Among rice crops HYV T. Aman rice was more profitable (BCR1.30) than aus rice (BCR 1.20) or boro rice (BCR 1.8) (Table 11b). This was happened due to rain fed cultivation practice and use of low doses of fertilizer, which incurred low costs associated with T. Aman rice production.

Table 11. Location wise crops grown and gross margin (Tk/ha) in Barisal region

Crops	Yield (t/ha)	Sale price (Tk/kg)	Total Variable cost (TVC) (Tk/ha)	Gross return (GR) (Tk/ha)	Gross Margin (GM = GR-TVC) (Tk/ha)	Undiscoun-ted BCR = GR/TVC
Kalapara site						
Local T. Aman	2.81	16.15	39,502	48,192	8,690	1.22
HYV T. Aman	3.37	15.75	43,422	56,448	13,026	1.30
HYV Boro	4.20	15.50	58,729	69,300	10,571	1.18
Pulses	1.09	35.42	18,385	38,608	20,223	2.10
Vegetables	12.18	10.14	44,911	1,23,505	78,594	2.75
Amtoli site						
Local T. Aus	3.30	16.10	47,025	56,430	9,405	1.20
Local T. Aman	2.70	16.15	37,646	46,305	8,659	1.23
HYV T. Aman	3.80	15.75	50,516	63,650	13,134	1.26
HYV Boro	4.27	15.50	58,713	70,455	11,742	1.20
Pulses	1.18	36.30	19,122	42,834	23,712	2.24
Vegetables	12.08	11.50	52,423	1,38,920	86,497	2.65
Patharghata site						
Local T. Aman	3.45	16.25	48,385	59,513	11,128	1.23
HYV T. Aman	4.60	16.50	64,919	80,500	15,581	1.24
Potato	9.75	12.10	49,989	1,17,975	67,986	2.36
Sunflower	1.80	30.50	22,941	58,500	35,559	2.55
Pulses	1.24	38.67	19,572	47,951	28,379	2.45
Vegetables	10.75	10.75	44,108	1,15,563	71,455	2.62

Source: Field Survey, 2013

Irrigation management

In turn, Table 12 shows the main source of irrigation water along with the common type of distribution systems. In Rajshahi, groundwater is the main sources for crop irrigation and the supply is conducted with buried pipe systems. Both Deep Tube wells (DTW) and Mini DTW are used for irrigation. In few cases, surface water is used for irrigation purpose in some areas adjacent to the pond and canals.

Conversely, in Barisal surface water is the main sources for crop irrigation. Irrigation water is distributed with open canal systems. However, recently the irrigated agriculture has not become a common practice. The sea intrusion has increased the salinity of the surface waters to that extend that is not suitable for irrigation purposes. Low lift pumps (LLP) are used for pumping surface water usually from small ponds where the salinity is rather low.

Table 12. Source-wise irrigation coverage under study sites

Locations	Irrigation coverage (%)		Irrigation Device	Distribution system
	Surface water	Ground water		
Rajshahi Region				
Godagari	8	92	DTW and Mini DTW	Buried pipe
Tanore	5	95		
Gomastapur	6	94		
Barisal Region				
Kalapara	93	7	LLP	Open canal
Amtoli	95	5		
Patharghata	96	4		

Note: DTW = Deep Tubewell (forced mode pump); Mini DTW = Low capacity submergible pump; and LLP = Low Lift Pump (suction mode pump)

Source: Field Survey, 2013

Rice diseases and insects

The respondents were also asked about the impact of rice diseases and its incidence level as presented Table 13. In both Rajshahi and Barisal regions sheath blight was the most common disease followed by blast. The present incidence level of rice blast was almost similar compared to last 15 years incidence but presently, sheath blight emerged as a major disease for rice because of climatic and ecological variations occurred over this time period.

Table 13. Information about rice disease incidence level

Name of Disease	Season	Variety	Yield Loss (%)		Control Measures
			15 Years Back	Present	
Rajshai Region					
Sheath blight	T. Aman	BR11	-	20-25	Chemical control (Nativo, Hexa) and Biological Control (Drainage Water from field)
		BRRI dhan52			
		Sawrna		25-30	
Blast	T. Aman	Arometic rice (Including HYV and Local)	15-20	15-20	Nothing
	Boro	BRRI dhan29	-	10-12	Chemical control (Trooper, Nativi, Zeel etc.)
		BRRI dhan28		4-5	
Bacterial blight	T. Aman	BRRI dhan52		5-6	Nothing
	Boro	BRRI dhan28		5-6	
Bakanae	Boro	BRRI dhan29		2-3	Uprooting of Infected Tillers
Barisal Region					
Sheath blight	T. Aman	BR11	-	20-25	Chemical Control (Nativo, Hexa) and Biological Control (Drainage Water from Field)
		Sadamota		12-15	
Blast	T. Aman	All Arometic rice (BRRI dhan34, Sakkorkhorai, Kalizira)	15-20	15-20	Nothing
	Boro	BRRI dhan29	-	10-12	Chemical control (Trooper, Nativi, Zeel)
		BRRI dhan47		20-25	
Bacterial blight	T. Aman	BR11		5-6	Nothing
	Boro	BRRI dhan28		5-6	

Source: Field Survey, 2013

The respondents were also asked about the rice insects and its incidence level. As presented in Table 14, the farmers' views were almost identical between the two regions. Brown plant hopper (BPH) was the most common insect followed by goll midge. Table 14 also shows that the incidence level of rice hispa was higher in the past but nowadays has been drastically reduced because of unfavourable ecosystem for its development.

Table 14. Information about rice insect's incidence level

Name of Insects	Season	Variety	Yield Loss (%)		Control Measures
			15 Years Back	Present	
Rajshahi and Barisal Regions					
Brown plant hopper (BPH)	Boro	BRRI dhan29	-	25-30	Chemical control (Mipsin) and Biological control (Drainage Water from Field)
Yellow stem borer	All seasons	All variety	5-10	5-10	Chemical control (Furadan) and Biological control (Parching)
Rice Hispa	T. Aman		10-20	-	Chemical control (Diazinon) and Biological control (Leaf Clipping)
Goll midge			15-20	15-20	Chemical control (Diazinon/Furadan) and Biological control (Drainage Water from Field)

Source: Field Survey, 2013

4.2 PCA Results

The results of PCA suggest that a large amount of the indicators enclosed in the Adaptive Capacity group are satisfactorily explained (66.4%). In particular, 16 out of the 25 adaptive variables are statistically significant and can be identified as potential drivers for the vulnerability levels of each upazila (see Table 1, Annex 2). The crop intensity, the access to housing facilities and the presence of financial institutions are given the highest importance.

In the case of the Exposure and Sensitivity indicators, 14 out of the 19 variables could be well explained (84%) by the PCA analysis as potential determinants (see Table 2, Annex 2). Also, the standardized values of all the variables from each group are presented in Annex 3.

We then assess the overall significance of each indicator through the communality values as presented in Table 15. The five most important ones are presented for the Adaptive capacity group while an equal amount is also denoted for the Exposure and Sensitivity groups. For the case of Adaptive indicators, the household's livelihood conditions are most noticeable. It is then, the health and veterinary access as of almost equal importance while the farm ownership is also signified. In the case of Exposure and Sensitivity group, an almost equal merit of significance is attributed to the five most important indicators. Particularly, the indicators related to the yield loss and the irrigation requirements of T.Aus rice crop season are noticed while the annual precipitation and temperature indicators are hinted.

Table 15. Significance of Vulnerability Indicators

Adaptive Capacity	Communality Value	Exposure-Sensitivity	Communality Value
Access Tubewell_Lartrine	0.986	Yloss_Aus	0.999
Access Pacca_Electricity	0.986	YL_severe_aus	0.997
Access health	0.986	NIR_Aus	0.997
infr.vet	0.976	P_annual	0.997
Own Farm	0.965	T_annual	0.995

The scoring of the vulnerability levels for each upazilla is derived by the subtraction of the exposure and sensitivity indicators from the adaptive capacity as presented in Figure 6. When each group of indicators is separately examined for each upazila, the lowest adaptive capacity is given to **Amtoli** while further aside follows the **Kalapara**, both situated in Barisal region. This could be probably attributed to the **low mean annual income** and the **poor performance of infrastructural indicators** in these two upazilas which seem to hamper the adaptive potential. The **poor infrastructure** could be also in part responsible for the low adaptive capacity score in **Patharghata** upazila while also the **small farm experience** seems to be a contributor. However, the other demographic and agro-economic indicators perform much better in Patharghata than in the two other upazilas of Barisal region and thus there is a better adaptive capacity scoring.

In the case of adaptive capacity indicators in Rajshahi region, **Godagari** upazila seem to score remarkably lower than the other two upazilas but still in higher levels than the Barisal region. This low score seems to be rendered on the **limited access to household facilities (latrine, water, electricity)** while also the **education and crop intensity indicators** perform comparatively lower than the two other Rajshahi upazilas. The high scoring of Tanore and more distinctively Gomastapur appears to be the result of a satisfactory performance in most of the **demographic and agro-economic indicators.**

Reversely, all the **Rajshahi** upazilas attain a remarkably low scoring in the exposure and sensitivity indicators which counterbalances the positive performance of the adaptive capacity. This is much attributed to the **unfavorable climatic conditions for irrigated agriculture** recorded for the last 30 years in Rajshahi which have hindered the potential of higher agricultural production. On the contrary, the **milder climatic conditions** in **Barisal** region and the much lower need on irrigation have resulted in lower production loss.

Overall, the less vulnerable areas are shown in Barisal firstly by **Patharghata** while closely behind follows **Kalapara** upazila. Unlikely, **Amtoli** upazila although belonging to Barisal region, seems to perform worse than **Tanore** and **Gomastapur** in Rajshahi. The scoring of **Godagari** vulnerability is noticeably the lowest among all other upazilas.

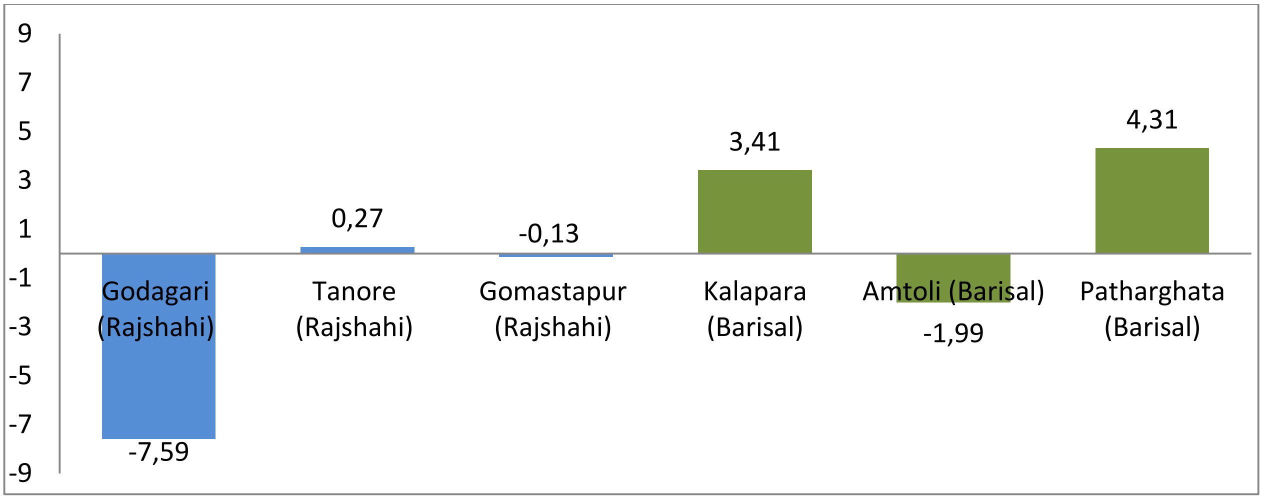

Figure 6. PCA Assessment Results

It is mentioned that the vulnerability scoring between upazilas does not represent an absolute value index but the relevant performance between the areas.

4.3 Farmers' preferences

The farmers' preferences for the improvement of their adaptive capacity indicate a strong inclination to the agricultural activities. As presented in Table 16 there is a clear indication of intertwinement between the need for farming improvement and the concept of adaptation in a changing climate. Most of the suggestions pertaining to the pricing of agricultural inputs and products while the technological support is also of major importance. Another area of interest is the improvement of infrastructure in irrigation systems on surface water conservation and provision of better groundwater systems. Finally, the access to better seeds and the arrangement of educational seminars in technologies are also suggested as priorities for a better adaptation to climate change.

When the preferences are allocated on an upazila level, it appears that the respondents of Patharghata upazila are in the highest desire of the suggested initiatives and especially the freshwater conservation measures. Broadly, the upazilas belonging to Barisal region are much more interested than Rajshahi in participating to all the relevant suggestions but for water infrastructure. The highest grades amongst upazilas are shaded with greyish color.

Table 16. Suggestions for improvement of adaptive capacity

Areas	Suggestions	Rajshahi Region (%)				Barisal Region (%)			
		God.	Tan.	Gom.	Mean Values	Kal.	Amt.	Path.	Mean Values
Market	Availability of agricultural inputs at reasonable / subsidized price (seed, fertilizer, water, pesticides etc.)	65	68	63	**65**	75	68	70	**71**
Market	Ensure reasonable output prices and profitability of agricultural commodities	82	78	84	**81**	82	80	84	**82**
Market	Availability of farm machineries at subsidized price or on rental basis (power tillers, pumps, sprayer, reaper, thresher etc.)	60	63	58	**60**	60	62	68	**63**
Water Facilities	Irrigation infrastructure development (setting of pumps, ensure electricity, improved canal system etc,)	85	82	90	**86**	75	78	80	**78**
Water Facilities	Conservation of water (rain water harvest, embankment, sluice gate, canals etc.)	55	52	65	**57**	95	92	96	**94**
Seeds	Availability of new high yielding and short duration rice varieties	75	72	78	**75**	85	82	88	**85**
Education	Intensive farmers' training on agricultural production technologies	75	78	72	**75**	75	88	72	**78**

5. Discussion

The descriptive statistics gave an overall impression of the agricultural conditions in both regions. Not major differences are presented between the two sites except for the irrigation practices. The irrigation factor appears to play a major role in the production costs of Rajshahi region which is anticipated to get more important in the future because of the decreasing water reserves and the higher drought frequency. Further, the need to confront with the emerging disease and insects' incidences seems to be commonly shared between the two regions.

The PCA results have demonstrated the significance of the adaptive capacity, sensitivity and exposure indicators for the attribution of the vulnerability assessment. In particular, the higher scoring of Rajshahi in adaptive indicators seemed incapable of signifying a better vulnerability status of Rajshahi over Barisal region. The average production loss of Rajshahi in the last 30 years has offset any comparative advantage emerging from the adaptive capacity performance.

There are some methodological limitations of PCA use in the current study. Initially, there is a considerable uncertainty on the appropriateness and relevance of the suggested indicators. This is a broader issue standing on most of the vulnerability assessments irrelevantly to the suggested measurement approach. There is a common understanding that many indicators might enclose a degree of subjectivity in an effort to portray case-specific conditions of vulnerability. We acknowledge these potential biases and as a mitigation effort, we have introduced indicators spotted in other similar vulnerability assessments by attempting to reduce the case-specific ones.

It is also argued that the vulnerability is a dynamic concept and a static assessment like PCA could hardly explain any future changes. To this end, it is firmly explained that we have estimated the present vulnerability levels in each upazila based on the current demographic, agro-economic and infrastructural indicators and past observations of biophysical parameters. Although it is understood that any future observations may not highly deviate from the assessed ones, it is explicitly mentioned that the vulnerability assessment does not represent any future status of the selected upazilas.

However, there is the potential to provide some future vulnerability scenarios based on the performance of the examined indicators. For instance, we have tried to increase the performance of three out of the five most significant indicators presented in Table 15 for Barisal region only. Namely, the performance of Access to Health, Veterinary and the farm ownership was improved by 30% for each of the three Barisal upazilas. As presented in Figure 7, the Vulnerability has been now slightly to moderately improved in the three Barisal upazilas. Such scenario analyses could greatly help the policy makers to understand in which particular indicators should pay attention and invest for a better vulnerability performance.

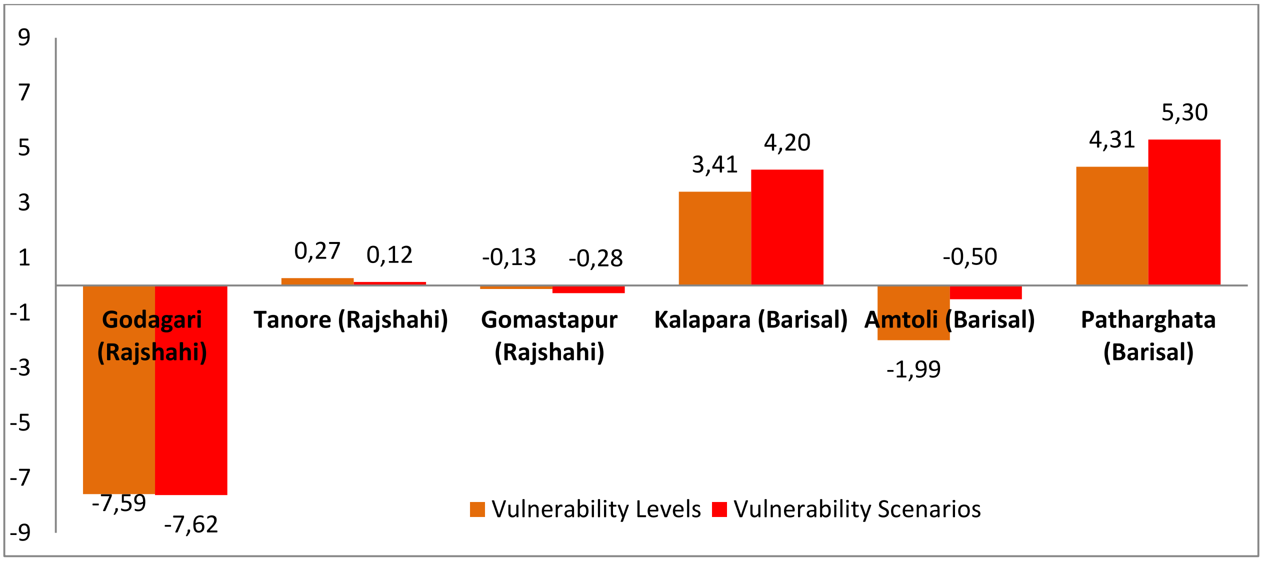

Figure 7. Vulnerability Scenarios for Barisal region

The aforementioned methodological and policy relevant concerns were also met in many similar vulnerability assessment studies. A regional vulnerability assessment in Ethiopia notes the lack and unreliability of primary data (Deressa, 2008). Another vulnerability analysis of rural households in Nepal signifies the importance of scenarios for the identification of agro-economic and infrastructural areas to be improved (Pyia et al., 2012). Other applications of PCA in national trans-national level were enriched with Geographical Information Systems (GIS) in an attempt to overcome the static nature of the results (Abson et al. 2012; Borja-Vega and De la Fuente, 2013).

The farmers' preferences came to signify the need of both regions to invest on agricultural market mechanisms, irrigation facilities, seeds and educational seminars for a better adaptation to climate change. These elements were coincidentally also represented as statistically significant indicators in PCA analysis. For instance, the Mean Annual Income indicator is highly related and affected by the market mechanisms which are suggested by farmers. In turn, the suggested improvements in irrigation facilities are well represented by the Net Irrigation requirements in the Exposure group of indicators. It is mainly that the farmers pointed out some broader interventions that could help in better adaptation while the PCA indicators were focused on specific aspects of these interventions.

It is noted that the suggested improvements by farmers on market conditions seem to mostly target on the increase of their welfare, an objective which is better viewed through a poverty analysis.

6. Concluding remarks

Climate change impacts are already occurring in Bangladesh and is likely to continue with greater severity in future. Those who are most vulnerable to the adverse impacts of climate change are generally the agrarian regions. Therefore, the development of tools to assess socio-ecological vulnerability, such as in this report, could help to identify measures to create resilience and mitigate the impacts of climatic vagaries.
The current study attempted to describe in a quantitative manner the vulnerability status of the drought and saline-flood prone selected upazilas in Bangladesh. Also, some descriptive results and farmers' preferences attempted to better clarify and cross-check the vulnerability assessment.

The findings for the drought prone regions in Rajshshi signified the need to improve the access to household facilities and moreover the urgency for better groundwater management so as to meet the current production loss. In particular, as the groundwater availability is gradually diminishing, HYV boro rice cultivation could be hardly irrigated in the following years. More efficient irrigation schemes should be developed to meet the current demand while better water resistant rice varieties should be introduced. Also, cash crops like wheat, maize, mustard, potato, tomato should be better promoted as a promising response to water scarcity and a more profitable alternative to rice cultivation.

The introduction of cash crop is also encouraged in Barisal region for the improvement of the agricultural income. Moreover, the need for better infrastructure and sound water conservation measures are also prioritized in Barisal region. Also, the education on new technologies in cultivation through training, demonstration and field days is highly desired.

The current vulnerability assessment is a context-specific approach and the data, methods and results cannot be transferred without any proper adjustments to other similar studies.

7. References

Abson D.J., Dougill A.J.and Stringer L.C (2012) Using Principal Component Analysis for information-rich socio-ecological vulnerability mapping in Southern Africa, *Applied Geography* (2012) 1-10

Anderies, J., Janssen, M., Ostrom, E., (2004). A framework to analyse the robustness of socio-ecological systems from an institutional perspective. *Ecology and Society* 9, 1–18

Basak, (2011) *Climate Change Impacts on Rice Production in Bangladesh: Results from a Model*, Unnayan Onneshan-The Innovators, Bangladesh

Borja-Vega C. and De la Fuente A., (2013) *Municipal Vulnerability to Climate Change and Climate-Related Events in Mexico*, Policy Research Working Paper 6417, The World Bank, Washington

Biswas J.K., Ali M.A., Mahbub, A.M., Ansari, T.H., Raghib Hassan A.W. and Islam, M.S. (2009) Results and Findings from BRRI-FAO Collaboration under Project Improved Adaptive Capacity to Climate Change for Sustainable Livelihoods in the Agricultural Sector (LACC II), BRRI, Joydebpur, Gazipur-1701 & DAE, Khamarbari, Dhaka-1207

Brouwer R., Akter, S., Brander, L. and Haque, E. (2007) Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh, *Risk Analysis*, 27(2):313-26.

Beaumont. R., (2012) *An introduction to Principal Component Analysis & Factor Analysis Using SPSS 19 and R*, *http://www.floppybunny.org/robin/web/virtualclassroom/stats/statistics2/pca1.pdf* [accessed 2/12/2013]

Cardona, O.D., M.K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R.S. Pulwarty, E.L.F. Schipper, and B.T. Sinh, (2012) Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach,G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. *A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)*. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65-108

Center for Environmental and Geographic Information Systems (CEGIS), 2013, *Report on Water Availability Assessment using SWAT Model*, *www.riceclima.com* [accessed 12/09/2013]

Deressa T., Hassan R.M. and Ringler, C., (2008) *Measuring Ethiopian Farmers' Vulnerability to Climate Change Across Regional States*, Environment and Production Technology Division, IFPRI Discussion Paper, 00806

Devisscher, T. Bharwani, S., Tiani, A.M., Pavageau, C., Kwack, N.E., Taylor R. (2012), *Baseline Assessment of Current Vulnerability and Adaptive Capacity*, COBAM Project – 2011, *http://www.cifor.org/cobam/home.html*, [accessed 12/11/2013]

Eakin, H. and Luers, A.M. (2006) Assessing the Vulnerability of Social-Environmental Systems, *Annu. Rev. Environ. Resour*. 2006. 31:365–94, doi: 10.1146/annurev.energy.30.050504.144352

Eakin, H., and B. Tapia (2008) Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change* 18(1): 112–127.

Everitt B S and Hothorn T. (2011) *An introduction to applied multivariate analysis with R.*, Springer

Fellmann, T., (2012) *The assessment of climate change related vulnerability in the agr sector: Reviewing conceptual frameworks* in FAO/OECD Workshop on Building Resilience Adaptation to Climate Change in the Agriculturel Sector, 23-24 April 2012, RedRoom, FAO

Fisher, S. (2013) Bangladesh: from adaptation to low carbon resilience?, *http://www.iied.org/bangladesh-adaptation-low-carbon-resilience* [accessed 07/01/2014]

Fussel, H.S. (2007) Vulnerability: A generally applicable conceptual framework for climate change research, *Global Environmental Change*, Volume 17, Issue 2, Pages 155–167

Gallopin, G.C., 2006. Linkages among vulnerability, resilience, and adaptive capacity. *Global Environmental Change* 16, 293–303.

Intergovernmental Panel on Climate Change (IPCC) (2001) *Annex B. Glossary of Terms*, *http://www.ipcc.ch/pdf/glossary/tar-ipcc-terms-en.pdf* [accessed 07/02/2013]

Kaly, U., and C. Pratt (2000) *Environmental vulnerability index: Development and provisional indices and profiles for Fiji, Samoa, Tuvalu and Vanuatu*. Phase II report for NZODA. SOPAC Technical Report 306.

Nelson, R., Kokic, P., Crimp S., Meinke, H., Howden, S.M.,(2010a) The vulnerability of Australian rural communities to climate variability and change: Part I—Conceptualising and measuring vulnerability, *Journal of Environmental Science and Policy* 13 (210) 8-17

Nelson, R., Kokic, P., Crimp S., Meinke, H., Howden, S.M.,(2010a) The vulnerability of Australian rural communities to climate variability and change: Part II—Integrating impacts with adaptive capacity, *Journal of Environmental Science and Policy* 13 (210) 18-27

Nienke, M. Beintema and Wais Kabir (2006) *Bangladesh,* Agricultural Science and Technology Indicators, ASTI Country Brief No. 34, July 2006

Nguyen, N.V. (2006), *Global climate changes and rice food security*, International Rice Commission, FAO, Rome,Italy

O'Brien, K., Eriksen,S., Schjolden, A., Nygaard,L.,(2004) What's in a word? Conflicting interpretations of vulnerability in climate change research, *CICERO Working* Paper 2004:04, P.B. 1129 Blindern, 0318 Oslo

Piya L., Maharjan, K. L. and N.P. Joshi (2012) *Vulnerability of rural households to climate change and extremes: Analysis of Chepang households in the Mid-Hills of Nepal,* Selected Paper prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012.

Ramamasy, S. and Bass S. (2007) Climate variability and change: adaptation to drought in Bangladesh, A resource book and training guide, Food and Agricultural Organization of the United Nations, Rome, ISBN 978-92-5-105782-7

Smit, B. and Wandel, J., (2006) Adaptation, adaptive capacity and vulnerability, *Global Environmental Change* 16 (2006) 282–292

Vogel, C.H. and Karen O'Brien, 2004. Vulnerability and global environmental change: Rhetoric and reality. *AVISO*, 13 (March)

Winston, Y. , Mozaharul, A., Ahmadul, H., Abu Saleh, K., Ruane, A., Rosenzweig, C., Major, D., Thurlow, J. (2010) *Climate Change Risks and Food Security in Bangladesh*, ISBN 9781849711302, 176pp. EarthScan, London

World Bank (2010) *The Economics of Adaptation to Climate Change* : Synthesis Report, World Bank, Washington DC 20433, United States

Annex 1. Excluded indicators in vulnerability assessment

Code	Indicator	Unit	Reason for exclusion
1	Crop variety replacement within the last 15 years	Nos.	No differentiation between upazillas
2	Irrigation coverage under study sites	%	
3	Device-wise irrigation cost	Tk	Poor information
4	Crop-wise irrigation number, times and depth of water applied for crop production	Nos.	
5	Rice disease incidences		No differentiation between upazillas
6	Rice insect incidences		
7	Perceptions on climate changes and its impacts on agriculture		
8	Problems encountered in agriculture due to climate change		
9	Mean Precipitation for Oct.-Nov.		
10	Climatic and environmental variation in last 15 years		
11	Environmental concerns in the surveyed area		
12	Effects of major agricultural and societal issues on livelihood in surveyed area		
13	Mean Temperature for Dec.-Jan-Feb.	(C)	High Correlation
14	Mean Temperature for March-Apr-May		
15	Mean Temperature for June-July-Aug-Sep.		
16	Mean Temperature for Oct.-Nov.		
17	Mean Precipitation for Dec.-Jan-Feb.	(mm)	
18	Mean Precipitation for March-Apr-May		
19	Mean Precipitation for June-July-Aug-Sep.		
20	Mean Precipitation for October – Non.		

Annex 2. Factor Analysis in PCA

Table 1. Factor Analysis for Adaptive Capacity Indicators

	Factor	Factor
Age	-0.60673	-0.493516
Schooling years	0.82118	0.499806
Farm Exp.	-0.57051	-0.170434
FamilySize	-0.86289	0.173527
Own Farm	0.44348	0.876551
Farm Size	-0.08718	-0.761755
Crop Intens.	0.93086	-0.187183
BCR All	-0.35366	-0.466762
Livestock Score	-0.68483	0.565911
Inc. Av.	-0.02209	-0.901198
Access Tubewell_Lartrine	0.96757	-0.225128
Access Pacca_Electricity	0.96757	-0.225128
Infr.post	0.35122	0.101852
infr.health	-0.76437	-0.293278
infr.vet	0.89280	-0.423456
Infr.coop	-0.91303	0.027316
Infr.agr.ext.	0.80956	-0.066638
Infr.finan	-0.07238	-0.943837
infr.school	0.59102	-0.208836
infr.college	-0.30124	-0.823146
in-migrat	-0.81679	-0.174353
Local m.	0.50491	-0.429069
bigger m.	0.47677	0.142531
hosp. Km	0.27963	-0.459243
town km	0.17976	0.315068
Expl.Var	11.28531	5.876386
Prp.Totl	0.43405	0.226015

Note: The statistically significant variables are presented with red font color while the variables attaining highest values are framed with greyish shade.

Table 2. Factor Analysis for Sensitivity and Exposure Indicators

	Factor	Factor
Crop Pattern 2	-0.88827	-0.348879
Crop Pattern 3	0.68340	0.290611
Small Farm Size	-0.43364	0.780922
Tenant Farmer	0.34344	-0.638966
HYV Boro yield	-0.58322	-0.692499
T_annual	0.98831	0.135129
P_annual	0.98271	0.178196
Yloss_Aus	-0.99655	-0.079465
Yloss_aman	-0.72608	0.569433
YL_slight_aus	0.99064	0.100983
YL_mod_aus	-0.42021	0.390647
YL_severe_aus	-0.98791	-0.147803
YL_slight_aman	0.91794	-0.237036
YL_mod_aman	0.76440	-0.000306
YL_severe_aman	-0.96482	0.198452
NIR_Aus	-0.99517	-0.084552
NIR_Aman	-0.91925	0.384395
NIR_Boro	-0.92324	-0.290180
Expl.Var	12.54443	2.603757
Prp.Totl	0.69691	0.144653

Note: The statistically significant variables are presented with red font color while the variables attaining highest values are framed with greyish shade.

Annex 3. Standardizes Values

Table 1. Adaptive Capacity

Age	Schooling years	Farm Exp.	FamilySize	Own Farm	Farm Size	Crop Intens.	BCR All	Livestock Score	Inc. Av.	Acc.Tub. _Latr.	Acc.B. H._Elect .	Access health
0.81	-0.42	-0.11	-0.18	-1.00	1.00	1.00	0.03	-1.00	1.00	1.00	1.00	-1.00
-1.00	1.00	-1.00	-0.50	1.00	-0.29	0.48	-0.06	-0.92	-0.25	1.00	1.00	-1.00
0.14	0.51	0.92	-1.00	0.36	-0.67	0.45	0.17	-0.25	-1.00	1.00	1.00	-1.00
1.00	-0.87	0.89	0.81	-0.27	0.71	-0.92	1.00	0.22	-0.25	-1.00	-1.00	1.00
0.71	-1.00	1.00	0.46	-0.99	0.00	-1.00	0.81	0.02	0.25	-1.00	-1.00	1.00
0.34	-0.06	0.11	1.00	0.50	-1.00	-0.22	-1.00	1.00	-1.00	-1.00	-1.00	1.00
Infr.post	**infr.health**	**infr.vet**	**Infr.coop**	**Infr.agr.ext.**	**Infr.finan**	**infr.school**	**infr.college**	**in-migrat**	**Local m.**	**bigger m.**	**hosp. Km**	**town km**
1.00	-0.11	1.00	-1.00	-0.17	1.00	1.00	0.27	0.18	1.00	-1.00	0.14	0.33
0.63	0.06	0.09	-1.00	-0.33	-1.00	0.18	-1.00	-1.00	-0.60	-1.00	-0.71	-0.20
-0.19	-1.00	0.62	-0.83	1.00	-0.77	0.01	-0.66	-0.09	-0.20	1.00	1.00	0.47
0.90	0.40	-1.00	-0.20	-1.00	-1.00	0.32	-1.00	1.00	-1.00	-1.00	-1.00	1.00
-1.00	1.00	-1.00	1.00	-1.00	0.58	-1.00	1.00	0.62	-0.80	-1.00	0.43	-1.00
0.48	-0.14	-1.00	0.25	-1.00	-1.00	-0.11	-1.00	0.50	0.00	-1.00	-0.71	0.47

Table 2. Exposure - Sensitivity

Crop Pattern 2	Crop Pattern 3	Small Farm Size	Tenant Farmer	HYV Boro yield	T_annual	P_annual	Yloss_Aus	Yloss_aman
0.90	-0.41	-0.89	1.00	0.97	-1.00	-0.99	0.74	-0.43
0.75	-1.00	0.25	-1.00	0.85	-1.00	-1.00	0.81	0.14
1.00	-0.35	1.00	-0.36	1.00	-1.00	-0.99	1.00	1.00
0.00	-0.41	-1.00	0.27	0.56	1.00	0.85	-1.00	-1.00
-1.00	1.00	-0.13	0.99	0.58	1.00	0.85	-0.94	-0.43
-1.00	0.47	0.25	-0.50	-1.00	1.00	1.00	-0.94	-0.14
YL_slight_aus	**YL_mod_aus**	**YL_severe_aus**	**YL_slight_aman**	**YL_mod_aman**	**YL_severe_aman**	**NIR_Aus**	**NIR_Aman**	**NIR_Boro**
-1.00	1.00	0.88	-1.00	0.00	0.71	0.71	0.17	1.00
-1.00	0.00	1.00	-1.00	0.00	0.71	0.78	0.52	0.80
-1.00	0.00	1.00	-1.00	-1.00	1.00	1.00	1.00	0.39
1.00	-1.00	-0.88	1.00	1.00	-1.00	-1.00	-1.00	-0.91
1.00	-1.00	-0.88	1.00	0.00	-0.71	-0.87	-0.68	-0.67
0.88	1.00	-1.00	-0.20	1.00	-0.14	-0.96	-0.11	-1.00