Impact of major climate variables on crop agriculture and local adaptation strategies in southeast coastal region of Bangladesh

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1. Introduction

Agricultural sector is particularly vulnerable to climate change and it has been estimated that climate change will impact negatively on agricultural production in the 21st century through higher temperatures, more variable rainfall and extreme climatic incidents such as floods, cyclones, droughts and rising sea levels (IPCC, 2007). Despite the condition of Bangladesh as a country that is highly vulnerable to climate change, the impact of climate change on crop agriculture has secured recent attention due to the contribution of agriculture sector on Bangladesh economy.

Crop agriculture in coastal Bangladesh is one of the most vulnerable sectors to climate change and climate related events (MOEF, 2005) and a wide array of adaptation options have already been practiced by the farmers to reduce the impact. But the strategies are not enough to cope with the changing climate. So, additional large-scale adaptation than currently occurring is needed. Factors that affect farmers' adaptation choices include different socio-economic, institutional and farm factors. The knowledge of these factors or determinants assists policymaker to strengthen adaptation through investing on it.

The study investigated the impact of major climate variables on crop agriculture using regional time series data and local adaptation strategies and its determinants using questionnaire survey and FGD with various statistical methods.

1.1 Background and Purpose of the Study

Few empirical studies were conducted regarding the effect of climate change on crop agriculture (Rashid & Islam, 2007), most of which focused mainly rice crops at the national level of Bangladesh. This is the first study of its kind considering other major crops like pulse and groundnut beside rice at regional level. In literature, there is only one study available about the determinants of rice farmers' adaptation strategies in Northern Bangladesh (Sarker, 2013). The study, however, considered rice farmers only and conducted in a drought prone area. Coastal region is different from drought prone region in context of climate and adaptation choices.

Greater Noakhali, located in the south-east coastal region, a typical agricultural region, represents an agroecological zone called LMREF (Lower Meghna River and Estuarine Floodplain), as most of the people mainly depends on agriculture for their livelihood. Therefore, the overall objective of the study is to assess the impact of change in climate variables on crop yield and identify the significant determinants of adaptation choices in the south-eastern coastal region of Bangladesh. To achieve the above two main objectives, the following specific objectives must be fulfilled: (1) to analyze the trend in climate variables; (2) to assess the impact of major climate variables (maximum & minimum temperature, rainfall, humidity and sunshine duration) on the yield of five major crops using OLS regression model; (3) to find out the causes of cropping pattern change in the region; (4) to find out the feasible adaptation measures and the barriers in adopting them; (5) to identify the prime determinants that affect local adaptation choices by using Multinomial Logit (MNL) Model;

2. Materials and Methods

2.1 Study Area

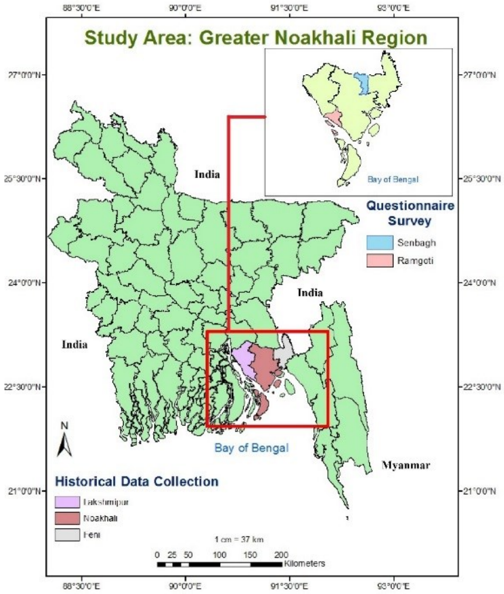


Figure 1. Location Map of Greater Noakhali Region situated at the south-eastern part of Bangladesh and locations of questionnaire survey area.

Greater Noakhali region is located between $22^{0}0'$ N to $23^{0}17'$N latitude and $90^{0}38'$ E to $91^{0}35'$ E longitude and consists of 3 districts namely Noakhali, Lakshmipur and Feni with an area of 6586 sq. km and 67,88,780 population (Population census, 2011). Aus, Aman and Boro rice, pulse, groundnut, vegetables, green chilli, sweet potato, mustard, wheat, etc. are major food crops in the region which grown in 3 distinct growing seasons namely Kharif-1 (Mid-March to Mid-July), Kharif-2 (Mid-July to Mid-October) and Rabi (Mid-October to Mid-March).

2.2 Data Collection:

Data collection framework is shown in Figure 2. Thirty years' historical time series data (1985-2014) about cropping area, production & five major climate variables were collected in March 2015 and 400 farmers' household survey data (using semi-structured questionnaire survey) with 2 FGD were collected during Mid-August to Mid-October, 2015.

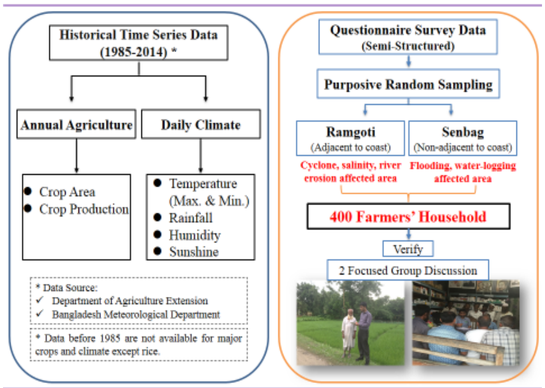


Figure 2: Structural framework of data collection

2.3 Methods:

Major methods applied in the study are shown in Table-1

Table 1: Methods used in the study

Subjects	Methods	Software
Annual and seasonal climate variation	Descriptive statistics, trend graph & linear trend model	MS Excel 2013
Crop yield & climate relationship	OLS method with basic regression assumptions and non-climatic trend removal technique	SPSS 22
Cropping pattern change and causes	Tables and Graph (historical & survey data)	MS Excel 2013, SPSS 22
Adaptation options	Pie & Bar chart (survey data)	SPSS 22
Determinants of farmers' adapt. options	Multinomial Logit (MNL) Model	Stata 13

2.3.1 Crop Yield-Climate Relationship:

To determine a true crop yield-climate relationship, daily climate data were converted into growing season climate data. Then, ordinary least square regression with basic regression assumptions (stationarity of the time series, no heteroskedasticity, no or little multicollinearity, no autocorrelation, normality assumption of the regression residuals) and non-climatic trend removal techniques (first difference the time series and log transformation) was applied. Consequently, the following format of regression modeling was used for the selected five major food crops:

$$Y_{it} = \alpha + \beta_1 MaxT_{it} + \beta_2 MinT_{it} + \beta_3 Rain_{it} + \beta_4 RHumid_{it} + \beta_5 Sunshine_{it} + \epsilon_{it}$$

2.3.2 Determinants of Farmers' Adaptation Choices: Evidence from MNL model:

To describe the MNL model, let y represents a random variable having the values {1, 2, ……, J} for J, a positive integer, and x represents a set of control or explanatory variables. In this case, y indicates adaptation choices or categories and x incorporates different socio-economic, institutional and farm attributes. The MNL model has response probabilities:

$$P(y = j/x) = \frac{\exp(x\beta_j)}{[1 + \sum_{h=1}^{J} \exp(x\beta_h), \ \ j = 1, \ldots, J]}$$

where B_j is K×1; j =1, . . . , J.

3. Results and Discussion

The linear trend model disclosed a clear evidence of changing climate in the region (Table-2).

Table-2:Results of linear trend model of annual climate.

Climate Variables	Coef. for time (trend)	P value	R Square	Sig
Mean Temperature (^{0}C)	0.0194	0.0004	0.362	***
Maximum Temperature (^{0}C)	0.0218	0.0006	0.3435	***
Minimum Temperature (^{0}C)	0.0168	0.0039	0.2604	***
Annual Rainfall (mm)	-12.7611	0.1847	0.0620	NS
Relative Humidity (%)	0.0131	0.4308	0.0223	NS
Sunshine Duration (hrs)	-0.0172	0.0254	0.1661	**

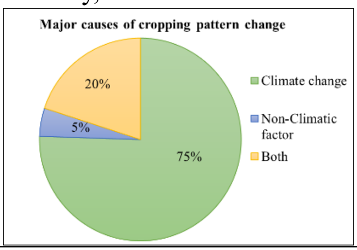
Table-3: Regression Results of five major crops' yield

Independent Variables	Boro Rice	Aman Rice	Aus Rice	Pulse	Groundnut
Maximum temperature	-0.030	0.853	0.152***	-	-
Minimum Temperature	0.042*	-1.525	0.021	-	0.048
Rainfall	0.00028**	-0.013	2.780e-5	-0.114	-0.00027
Relative Humidity	-0.014*	1.115	0.030*	13.607**	-
Sunshine Duration	0.026	0.291**	-0.031	49.254***	-0.071**
Intercept	0.013	0.007	-1.248	5.622	-0.003
Model R^2	0.522	0.421	0.538	0.258	0.231
Adjusted R^2	0.418	0.295	0.442	0.169	0.139
Model Significance (P value)	0.003	0.02	0.001	0.05	0.08

***,**,*Significant at 1%, 5%, and 10% probability level, respectively.

The multiple regression models revealed that all five crop models were significant at 5% level except groundnut which was significant at 8% level and climate variables have significant effects on crop yields but the effects vary among different crops (Table-3). More definitely, maximum temperature and minimum temperature negatively influenced the yield of Boro and Aman rice, respectively. Rainfall significantly favored the yield of Boro rice while affected the yield of Aman rice, pulse and groundnut though insignificantly. Moreover, relative humidity and sunshine exhibited significant negative effect on Boro rice and groundnut consecutively. The R^2 values indicated that three rice crops, such as Aman (42.1%), Boro (52.2%) and Aus (53.8%), were greatly influenced by climate variability and change in compared to other major crops in the study area.

Major cropping pattern change in the area involves the dominance of Boro rice and soybean which shifted its postion currently to the 2nd and 4th respectively in terms of cropping area. According to questionnaire survey result, climate change (75%) is mainly responsible for cropping pattern change besides some non-climatic factors such as introduction of high yielding varieties, high profitability, reduced water availability, etc.



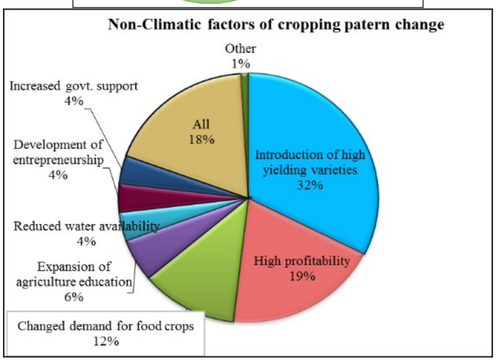


Figure-3: Causes of cropping pattern change.

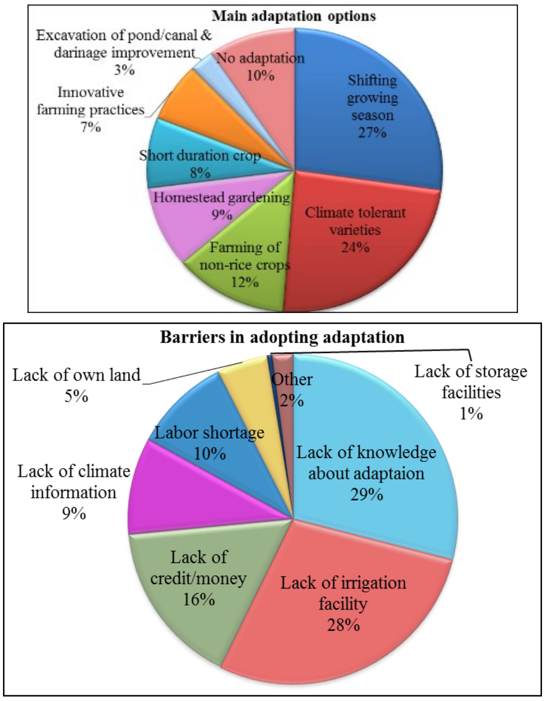


Figure-4: Farmers' main adaptation options and barriers to adaptation in the area.

Result from the MNL model:

The MNL model with eight categories of adaptation choices was run and tested for the IIA assumption by employing Hausman, SUEST based Hausman and Small Hsiao test which supported the proof of non-violation of the assumption. The most important finding comes from the MNL model that specifies household size, livestock ownership, tenure status, farm size, access to information on climate, access to credit, distance to market, education and nonfarm income are statistically significant determinants of different adaptation choices. Therefore, these significant variables are likely to enhance farmers' adaptive capacity.

4. Conclusion

The study was carried out with a 30-year data set of agro-climatic parameters from 1985 to 2014 in the south-eastern coastal region of Bangladesh to investigate the impact of climate change on crop agriculture with particular attention to the determinants of adaptation choices in a regional scale. The results disclosed the evidence of changing climate over the last three decades in the south-eastern coastal region of the country. The multiple regression models unveiled that climate variables have considerable effects on crop yields but the effects vary among different crops. Pronounced negative impacts of climate variables on major crops' yield were observed besides positive effects.

The questionnaire survey unveiled that climatic factors were mainly responsible for cropping pattern change with some non-climatic influences. Farmers' perceptions on climate change was consistent with the trend of regional climate data. The most significant determinants of adaptation choices were tenure status, information on climate, access to credit and livestock ownership.

By taking into account the effect of climate variables on major food crops, the development and implementation of drought tolerant varieties, particularly for Boro and Aman rice, expansion of flood tolerant varieties for Aman rice and extension of irrigation facilities more intensively particularly for Boro rice have been recommended as some policy implications for the region. Moreover, Government should also target improving the significant determinants to strengthen farmers' adaptation by taking necessary policy measures and thereby, reducing vulnerability to climate change.

5. References

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