

## **FARMERS' PERCEPTIONS ON IMPACTS OF CLIMATE VARIABILITY AND ADAPTATIONS TO AGRICULTURE: A CASE STUDY OF PANCHAGARH, BANGLADESH**

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### **Abstract**

Bangladesh is considered as one of the worst vulnerable countries to climate change and its variability. However, it is not known how farmers of the northern districts of Bangladesh are affected and responded to climate vulnerability. The study was carried out for assessing farmers' perceptions on climate variability in one north district (Panchagarh) of Bangladesh. Focus Group Discussion (FGD), Key informant interviews and field observation techniques were performed to collect data. Descriptive statistics is used to analyze data. Results indicate that more than 90% farmers already realized the changes of climate variables including increased summer temperature, decreased winter duration, occurrence of early and late monsoon and decreased rainfall, which are consistent with the observed data. Ninety five percent farmers believe that pests and diseases infestations were linked to the changes of climate variables. However, they did not have long- term adaptation plan for their farm, although they are adopting some measures, such as diversified cropping systems, use of improved crop varieties, synthetic fertilizer, chemicals, etc. in agriculture. Additionally, they followed some techniques and strategies for growing seedling including use of polythene layer in the seedbed for raising Boro rice seedling to protect the seedlings from heavy fog during winter season while they grow Aman rice seedling at several intervals to cope with early or late monsoon. This study concludes that farmers' perception to climate change and its variability and their coping measures can be useful for further implementing any policies and actions for sustainable crop production.

**Key Words:** Climate change, Climate variability, Farmers perceptions, Impacts, Adaptation measures.

### **Introduction**

#### **Background**

Bangladesh is an agriculture based developing country, which is vulnerable to climate change and climate variability (Ali, 1996; Hossain *et al.*, 2012; Alam, 2017). Its socio-economic conditions and geographical location exaggerate its vulnerability. The main impacts of erratic behavior of present climate are tropical cyclone, storm surge, salinity intrusion, flood, drought, and heat stress that affect crop productivity adversely (NAPA, 2005). Both average minimum and maximum temperatures of this country have increased significantly during the last few decades at a rate of 0.15°C/decade and 0.11°C/decade, respectively (Figure 1). As a consequence, the country has experienced with frequent severe floods in 1984, 1987, 1988, 1998, 2004, and 2007 that was caused severe damages of crops field (Ministry

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of Environment and Forest (MoEF, 2008). Furthermore, drastic agricultural damages and losses are observed due to coastal flooding, salinity intrusion, cyclone, etc. in the coastal areas of Bangladesh.

Despite negative consequences of climate change, a few studies revealed that it may have positive impacts for crop production as well. For instance, Sarkar *et al.* (2012) showed both positive and negative aspects of temperature in rice production. The study showed minimum temperature has negative impact on Aman rice whereas positive impact on Boro rice production. Another study by Hossain *et al.* (2018) estimated an increase of net crop income about US\$ 4-15 per hectare due to 1 mm/month increase in rainfall and 10°C increase in temperature in Bangladesh where the farms have access to enough irrigation facilities.

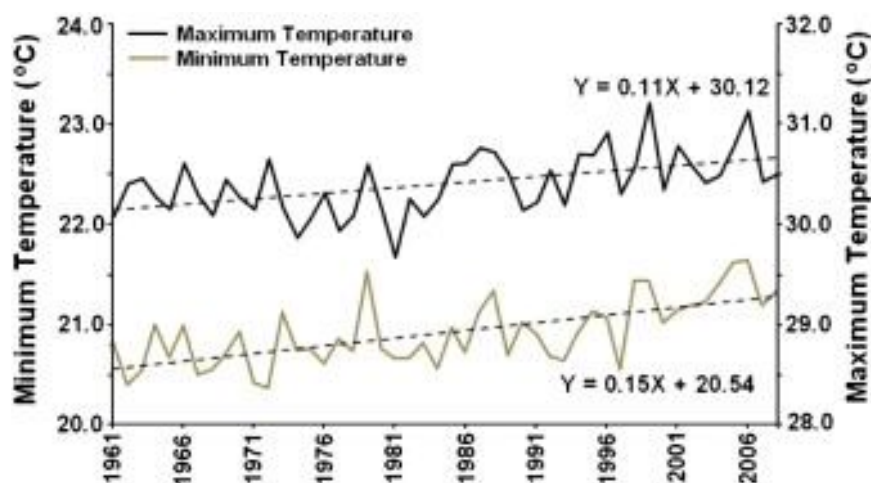


Figure 1. Observed maximum and minimum annual average temperature during 1961-2008 over Bangladesh. Slopes of the trend lines are given in °C/decade (Adopted from Shahid *et al.* 2012)

This study also estimated an increase of future net crop income from US\$25-84 per hectare. Munang *et al.* (2008) estimate a substantial yield increases for bambara groundnut, soybean, and groundnut for the future (2020, 2080) in Cameroon. Furthermore, this study found change of temperature patterns is much more important than rainfall.

Many studies reported that climate change and its variability have serious impacts on agriculture. Fluctuation in climate variables (e.g., temperature, drought, rainfall, etc.), brings adverse impacts on agricultural production systems (NAPA, 2005; MoEF, 2008; Iqbal and Siddique, 2015). There is an evidence of considerably increased weed, pest and disease occurrence in the agricultural field due to change of climate variables which ultimately, hampered crop production a lot (Tubiello *et al.*, 2007). Trnka *et al.* (2011) found that maize production in Europe has increased over the past six decades, but also a new pest (e.g., the European corn borer) has emerged

that was previously absent in this region. Pathak *et al.* (2003) reported that increased temperature caused reduction of rice and wheat yield. Many studies can be found regarding the negative impacts of the changes of climate variables (Ruane *et al.*, 2013). Each crop requires a certain temperature and rainfall for its different developmental stages (Kim *et al.*, 2012; Manickam *et al.*, 2012; Tao *et al.*, 2012). Therefore, climate variables are crucial for farmers who totally depend on nature for crop production.

Nevertheless, food production and GDP of Bangladesh have been increased by threefold between 1971 and recent time (MoEF, 2008). National as well as global food production has been increasing with increasing human population and economic growth. It has become possible due to continuous change of farm practices and development of new crop varieties. Farm practices have been continuously changing with the change of climate, economic and population growth as well. In order to adjust with climate variability, some strategies in agriculture are followed by farmers. Anik and Khan (2012) found 16 adaptation measures in the North-Eastern Bangladesh. Among these adaptation measures, crop diversification, floating garden, duck rearing, cage aquaculture, wave protection walls, re-digging of canal and construction of embankments were popular in this region. They also noticed that only 10% respondents had sufficient knowledge regarding climate change issue. Another study, conducted in Nepal, revealed that integration of knowledge of farmers in the process of development of climate change adaptation technology led to adopt location-specific technology in a more efficient manner (Chhetri *et al.*, 2012).

Since, Bangladesh has been experiencing a significant climate variability and agricultural production is being affected accordingly, it is relevant to explore farmers' perceptions, experiences and adaptive strategies to climate variability and climate change in agriculture. Therefore, the present study has been conducted aiming to:

- investigate farmers' perceptions and experience towards climate change and climate variability, and
- explore their coping mechanisms with climate variability in the district of Panchagarh, Bangladesh.

## Methodology

### Study area

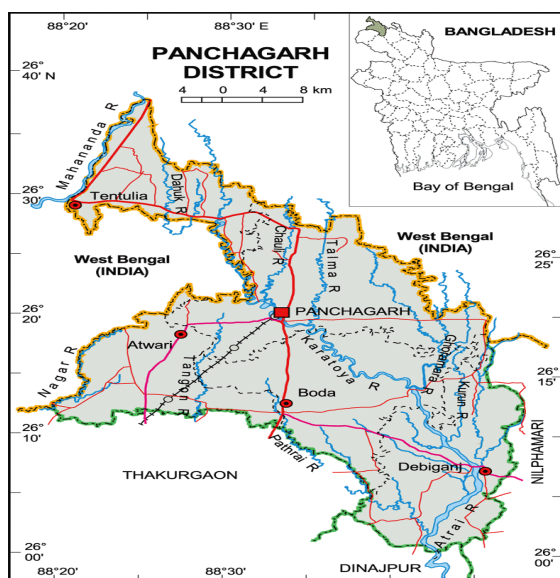
Panchagarh district is, northern district of Bangladesh under Rangpur division. It has an area of 1404.63 sq km having 288 km long three sides Indian border (e.g., Darjeeling district on the north, Jalpaiguri, and Kuchbihar districts on the northeast, West Dinajpur and Purnea district on the west) and Dinajpur and Thakurgaon districts on the south and Nilphamari district on the east (Fig. 2). It has five Upazila, namely Panchagarh Sadar, Debiganj, Boda, Atwari, and Tetulia. The soil of this study area is sandy, alluvial and shows similar characteristics with the soil of the old Himalayan basin. Paddy, jute, wheat, potato, sugarcane are the main crops in this study area. Recorded maximum and minimum temperatures are 30.2°C and 10.1°C, respectively, and annual total rainfall is 2931 mm. There are several rivers and the

main rivers are Karatoya, Atrai, Tista, Mahananda, Tangon, Dahuk, Pathraj, Bhulli, Talma, Nagar, Chawai, Kurum, Versa, Tirnoi and Chilka (Banglapedia, 2012).

In this study, a five specific villages, one from each Upazila are chosen purposefully and investigated. These five study sites are (a) KharijaKartonHari, Debiganj, Panchagarh; (b) Baghdogra, Bamon Kumar, Atwari, Panchagarh; (c) Vojonpur, Tetulia, Panchagarh; (d) Tunir Hat, PanchagarhSadar, Panchagarh; and (e) Prasad Khawa, Boda, Panchagarh..

## Methods

Focus Group Discussion (FGD) technique, key informant interview (KII), observation and expert judgment techniques were employed to achieve the research objectives of the study. A semi-structured questionnaire was formulated prior to field work. Thereafter, five contact farmers, one from each study site (Upazila) were selected purposively (Kumar, 2011). And contact farmers communicate other farmers in order to make the sample more representative and reliable. Based on the objective of the study, five FGDs, one from each Upazila were carried out during August 2012. Ten farmers were invited for each of the FGD. Points discussed in the meeting are recorded in both written and audio format. In addition, some extend of literature review is carried out in order to relate farmers' opinions about climate change and following adaptation in agriculture with its reality. Furthermore, 50 farmers' houses were visited to observe the agricultural activities in the study areas. More importantly, long term experiences (>20 years) in farming achieved through living in this area were integrated with the collected data.

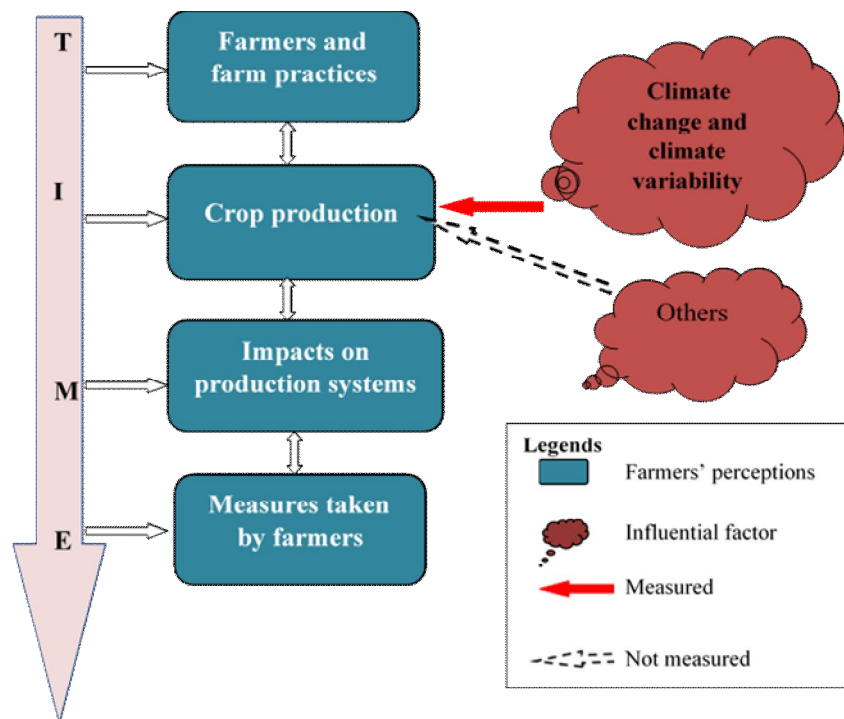


**Figure 2. Showing geographical location of the district of Panchagarh with its Upazila (5) of Bangladesh (source: Banglapedia, 2012).**

## Conceptual framework

In this study, it was expected that farm and practices can be changed over time. Farmers' livelihood depends on crop production and profit from their farm. They struggle with

crop production in order to sustain. However, some factors, for instance, change of climate variables, population and economic growth, etc. are significantly influencing farm practices. Farmers have been experiencing with changes of these factors and their negative impacts on agriculture. In response to these changes, they have been adopting some measures continuously to cope with these changes (Anik and Khan, 2012). The impacts of climate change and climate variability in agriculture are the main focus of this study (Fig. 3). This study assumed that all changes in the agricultural farms and livelihoods due to climatic factors, though some other factors may influence these changes. And, it is one of the limitations of this study.



**Figure 3. Conceptual frameworks of farmers' perceptions with climate variability.**

### Data analysis

Qualitative data were collected and analyzed in descriptive statistics. Since, focus of this study was to look at farmers' perceptions and their coping mechanisms towards climate change and climate variability, collected information was synthesized and presented in term of frequencies and narrative texts. Due to small sample size, no further statistical test was performed.

### Results and Discussion

After collecting data from FGD, observation and KII, both the interview notes, and recording were analyzed and synthesized the outcomes in a descriptive format which are described in this chapter.

### **Past and present diversity in crops**

This study revealed that most of the farmers in this study area have been involving in agricultural activities for a long time (>20 years). They did farming in order to meet up their family's food demand in the past. Thirty years ago, they cultivated a few crops, such as Aus rice and Aman rice. In addition, they grew jute, sesame and different kinds of millets (e.g., pear millet, foxtail millet). But, all crop varieties were local and low yielding. They used to cultivate these crops totally depending on nature. They never applied artificial irrigation, synthetic fertilizer, pesticides, and insecticides for crop production, rather they grew crops in traditional method. They used cow dung as a fertilizer in the land. They ploughed their land with the help of animal (FGD 1-5). Figure 4 shows pictures of FGD.

However, due to rapid population growth and economic growth, agriculture has been becoming more intensified and diversified. Now, farmers grow crops not only to fulfill their food demand but also to earn money. But, Oaliur (FGD 4, #3) expressed his feelings as "*we are now applying some improved methods in agriculture, but, there is no profit from this sector at present*". On the contrary, they are still growing crops as they have to lead their life with this. In the past, cropping patterns were same in the five study locations. But, now it varies slightly. According to the participants, at present, rice, tomato, sugarcane, and eggplant are commonly growing crops at the region of Tunir Hat in the Panchagarh Sadar Upazila while rice, wheat, jute, maize, chili, sesame, and potato at Vojonpur in the Tetulia Upazila; rice, wheat, jute and groundnut at Prasad Khawa in the BodaUpazila; rice, wheat, cabbage, cauliflower, groundnut, eggplant, maize and lady's finger at Kharija Karthon Hari in the Debiganj Upazila, and rice, potato, cabbage, cauliflower, chili, water melon, and maize at Baghdokra in the Atwari Upazila. Recently, farmers of Boda and Debiganj Upazila consider groundnut as a profitable cash crop compared to other crops. In these regions, farmers grow leafy vegetables (e.g., red amaranth) and other vegetables as well. It is clear that cropping patterns have been changing enormously that led to agriculture more diversified.

### **Past and present farm practices**

Farmers have been adopting new crops as well as improved varieties with time passages. Then, a question comes; how and why do they adopt new crops? Most of participants from five FGD mentioned that they adopted new crops or new technologies by following others. They get information about new and improved crop varieties and new farming practices mostly from their neighbor farmers and the agro-shops. When a new crop variety comes to the market, at the beginning, it is difficult to take decision to grow this crop for a farmer. But, as soon as one farmer grows it and gets high yield and then this information diffuses rapidly among other farmers. In this study area, tea stall in the local market is the common gathering place where farmers can exchange their views and opinions about agricultural activities to each other. Almost all participants from five study sites complained about service of Sub Assistant Agriculture Officer (SAAO). Farmers are not

receiving proper guidelines from government sides. They do apply their own experiences. On the contrary, Upazila Agriculture Officer (UAO) of Boda told that Government provides several services to farmers. For example, informing farmers about new crop varieties and new technologies, giving training farmers how to manage pest and diseases as an integrative way, etc. Nonetheless, very few farmers contacted to SAAO and Agriculture Extension Officer (AEO). Therefore, it is highly recommended the awareness rising program among the farmers so that they can get appropriate information from SAAO and AEO.

It is obvious that Bangladesh Government took several initiatives in the agriculture sector in order to attain self-sufficiency in food. Government is continually investing money in this sector for the improvement of food security of this country. Bangladesh Government gives subsidies in agricultural sector, especially in synthetic fertilizer. As a result, crop yield in particular rice yield has been increased several times than in the past thirty years (MoA, 2007). In addition, private seed companies are importing seeds from other countries that also contribute to increase crop yield. However, all participants from five FGD agree that rice yield has increased several times. But, their net income has decreased, because of higher inputs (e.g., seeds, fertilizers, pesticides, irrigation, labor, etc.) cost. According to Aziz (FGD 3, #3), “*due to weather changes, yield of a crop declines gradually*”. Apart from this, they also complained that they are depriving of a reasonable price of their farm products.

A significant difference can be found about farm practices between recent and past 20 or 30 year. In case of land preparation, now farmers use tractor and power tiller while only animal power was used in the past. Nevertheless, Nur Islam (FGD 4, #7) thinks that due to plowing of land by using tractor, weed infestation in crop field has been increased. Furthermore, crop diversification, irrigation facilities for Boro rice cultivation, use of chemicals, etc., are the remarkable changes in agriculture.





**Figure 4.** Showing picture of five focus group discussion (FGD). A, B, C, D, and E present FGD in the study sites 1, 2, 3, 4, and 5, respectively.

According to the participants from these study areas, there are two main reasons behind changing crop and crop varieties, namely (i) low yield and less profit of crop, and (ii) adaptability of local varieties reduces with time passages. Some of them consider the socio-economic factor for changing crop. For instance, recently, people do not eat foxtail millet due to economic growth while in the past 10-15 years; people used it as a substitute of rice. However, new crop varieties are more susceptible to disease and pest. All participants of the FGD 1 and FGD 4 clearly observed the drastic yield reduction of fruits, especially mango. Romesh Chandra (FGD 1, #3) told, “*The yields of mango, jackfruit and black berry have decreased compared to last thirty years and one mango tree could supply sufficient fruit to family members*”. In the past, farmers would get enough fruit to eat, but now it is another way around. Nevertheless, they believed that this reduction of local fruit production and lower crop yield were due to climate change.

#### **Perceived past and future trends in climate variables**

The trends in climate variables from last 20- 30 years are discussed with the participants of the all FGD in the five-specific locations of Panchagarh district. Results have been shown in Figure 5. Results clearly indicate that 70% respondents

observed increasing trends in temperature, whereas only 5% of them think that temperature is decreasing. In case of rainfall, 60% participants observed decreasing trends in rainfall, while 20% of them believe that rainfall is increasing day by day. These results have reasonable agreement with the observed data (Figure 1).

Apart from the above mention two climate variables, more than 90% participants strongly believe that weather has been changed a lot, and it is changing day by day. And they agreed with the following events as they are observed in this area:

- Drought is becoming more severe day by day;
- Variation (early to late) in the starting time of monsoon;
- Duration of winter period has been declining over time;
- Sometimes, in the winter, cold wave is observed than in the past.

However, there are some mixed opinions found about the trend of some climatic events. For example, some of them think that severity of coldness has been increased, whereas some of them think it another way around. For instance, Tohidul Islam (FGD 4, #6) expresses as “*we would wear only one warm cloth in the past, but, now, we wear many warm clothes and shoes, cap, etc. in order to protect ourselves from cold*”. Nonetheless, most of the participants mean that severity of coldness during winter decreases over time.

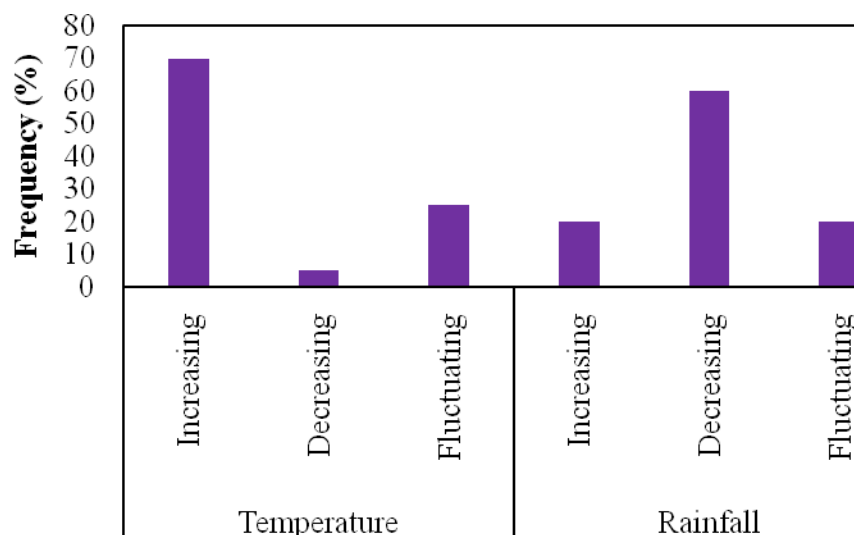


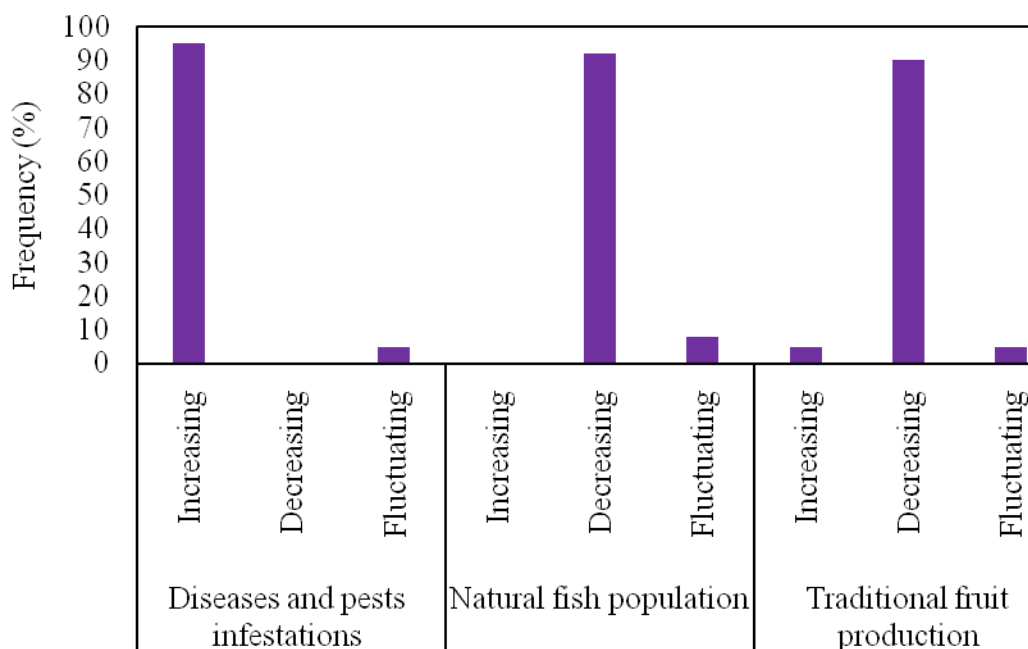
Figure 5. Farmers' perceptions on temperature and rainfall.

### Impacts on agriculture due to climate variability and others

Negative consequences of the changes of the above discussed climate variables are discussed with the participants as well. Since they are involved in agriculture for a long time (>20 years) and they had practical experiences with the changes of climate

variables. Based on farmers' experiences, major impacts of climate change and its variability on agriculture have been presented in Fig. 6. More than 90% farmers believed that diseases and pests infestations have been increasing in the crop field, while natural fish population and traditional fruits (e.g., mango, jackfruit, etc.) production have been decreasing over time. Natural fish population has been decreased drastically due to application and run out mechanism of chemicals in the crop field. They believe that there is a very close link between agricultural production and weather (FGD 1-5). Good weather brings good crop yield and vice-versa. Furthermore, majority of the participants of five FGD agreed the following impacts of the weather change as they experienced-

- Sometimes, failure of seed germination occurs in particular Boro rice due to heavy fog;
- Sometimes, transplanting rice seedlings fail due to scarcity of water during Monsoon;
- High temperature reduces working efficiency of farmers in the field;
- Higher inputs (e.g. synthetic fertilizer, seed, chemicals, etc.) require for crop production.



**Figure 6. Farmers' perceptions on impacts of climate change on agriculture.**

Moreover, some participants (FGD 5, #10, FGD 4, #8) believe that recently, fog caused harm to crop production while in the past, it did not cause such severe effect. But, this may not be the cause of climate change.

Apart from climatic events, some other factors are identified by farmers for the causes of diseases and pests infestation in the crop and drought. For example, farmers could not transplant some of their Aman rice seedlings due to lack of sufficient monsoon water in 2012 (Fig.7). Some farmers think that some crop seeds are imported from foreign countries. Consequently, new pathogens and insects are imported along with crop seeds (FGD 1, #3, 6; FGD3, #8 and FGD4, #2). In addition, a few of them think that they are also responsible for the climate change. Shotendra Nath (FGD 1, #6) thinks that due to extracting ground water during Rabi seasons and cutting trees, the weather events may change. Furthermore, due to considerable variation of crop morphology, weed infestation may be higher now than in the past. Height of all HYVs plant and crop are smaller than old one, and therefore, these dwarf crop varieties may be favorable for weed growth and development.



**Figure 7. Failure of transplanting some of Aman rice in 2012 in the location of Kharija Karton Hari, Debiganj (FGD 1) due to scarcity of water. No rice plant in the land with cow behind of farmer (left) and unused rice seedling (right).**

### **Past and present adaptation measures**

Results from all FGDs reveal that although climate variables are changing over time, crop yield has increased. They mostly depend on nature. Nonetheless, net income has reduced due to high inputs cost. After discussing weather change and its negative impacts in agriculture, then, how farmers have been continuing their farm practices despite of the weather changes are investigated. From all FGDs, the following measures are identified by farmers:

- Adoption of new high yielding crop varieties;
- Application of irrigation during Rabi season;

- Application of chemicals in order to protect crops from fog and pest and disease;
- Covering seed bed with polythene sheet in order to protect new seedling in particular Boro rice from fog (Fig. 8);
- Growing Aman rice seedling at several intervals to cope with variation of monsoon occurrence time;
- Growing diversified crops;
- Following crop rotation.



**Figure 8. Using polythene sheet in the Boro rice seedling to protect new seedling from heavy fog.**

However, farmers learn from nature and they try to follow accordingly. For instance, according to Jabbarul Hoque (FGD 4, #1), farmers can predict severity of winter by observing amount of monsoon or post-monsoon rainfall. They traditionally believe that less rainfall during monsoon brings severe winter. Few farmers have the ability to provide supplementary irrigation for Aman rice cultivation. Lower profit from Aman rice prevents poor farmers to apply irrigation during this season as they need to pay for irrigation. All participants of five FGDs mention that they would grow crops without synthetic fertilizer, chemicals and weeding thirty years ago. Nevertheless, now it is not possible to grow crops without these. And present agriculture is more intensified and improved. It became now a business, no invest- no profit.

### **Future adaptation plan**

In general, farmers do not have long- term future climate change adaptation plans for agriculture rather they are used to response according to nature. In future, they will perform accordingly. However, they are worried about their future crop production because of climate changes and less profit from crop production in particular rice crop. They also expect proper guidance from governmental side to cope with climate changes. They are ready to adopt any new HYVs crop varieties as well as improved and reliable technologies.

**Limitations of the study**

The number of FGD is also less for giving an overall picture of the country. Due to time constraints and lack of available scientific literature for this study area, farmers' perceptions on climate variability are not compared with scientific literature. Therefore, this study recommends for further in depth research in these fields to get a comprehensive idea about the farmers perceptions toward climate variability and their responses to cope with the changing agro-climatic conditions.

**Conclusion**

Farmers' perceptions and experience towards climate change and climate variability and their coping mechanisms are investigated in the district of Panchagarh, Bangladesh by employing FGD (Focus Group Discussion), field observation, KII techniques. Farmers' perceptions regarding climate change issue are in practical to some extent. To cope with climate change, farm and farm practices have been changed a lot over a few decades. Current agriculture became more intensified and diversified compared to that of the past 20 or 30 years. Farmers change farm practices with time automatically. They learn from nature and perform accordingly.

More than 90% farmers believe that climate has been changing over time. There is an enormous difference between present weather and the weather of last 20 or 30 years. Based on their opinions, it can be concluded that summer temperature has been increasing over time that led to a warmer weather. On the contrary, rainfall and duration of winter have been decreasing day by day.

Farmers are also experienced with the negative impacts of weather change. In response to climate change, they continually change farm practices to cope with this. They mentioned several impacts of weather change. The most important one is increasing pests and diseases in the crop field that cause higher production cost and low yield. In addition, they observed drastic yield reduction of traditional fruits. And, reduction of natural fish population also experienced by farmers in this study area. As a result, they adopted some measures, for example, improved crop varieties, synthetic fertilizer, chemicals, etc. in agriculture. Furthermore, they follow some techniques during growing seedling, especially Boro rice seedling.

Finally, this study concludes that climate change and climate variability have negative impacts on agriculture, which are perceived by the farmers and they adopt some adaptation measures to cope with these changes over time.

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### References

- Alam, G. (2017)/. Livelihood Cycle and Vulnerability of Rural Households to Climate Change and Hazards in Bangladesh. *Environmental Management*, **59**: 777-791.
- Ali, A. (1996). Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. *Water, Air, and Soil Pollution*, (92), Pp. 171-179.
- Anik, S. and Khan, M. (2012). Climate change adaptation through local knowledge in the north eastern region of Bangladesh. *Mitigation and Adaptation Strategies for Global Change*, **17**: 879-896.
- Banglapedia. [http://www.banglapedia.org/HT/P\\_0057.HTM](http://www.banglapedia.org/HT/P_0057.HTM) (accessed on 13 December 2012).
- Chhetri, N., Chaudhary, P., Tiwari, P. R. and Yadaw, R. B. (2012). Institutional and technological innovation: Understanding agricultural adaptation to climate change in Nepal. *Applied Geography*, **33**: 142-150.
- Hossain, M. A., Reza, M. I., Rahman, S. and Kayes, I. (2012). Climate Change and its Impacts on the Livelihoods of the Vulnerable People in the Southwestern Coastal Zone in Bangladesh Climate Change and the Sustainable Use of Water Resources. *In: LEAL FILHO, W. (ed.). Springer Berlin Heidelberg.*
- Hossain, M. S., Qian, L., Arshad, M., Shahid, S., Fahad, S. and Akhter, J. (2018). Climate change and crop farming in Bangladesh: an analysis of economic impacts. *International Journal of Climate Change Strategies and Management*, **11**: 424-440.
- Iqbal, K. and Siddique, M. A. B.(2015(. The impact of climate change on agricultural productivity: Evidence from panel data of Bangladesh. *The Journal of Developing Areas*, 49: 89-101.
- Kim, H. Y., Ko, J., Kang, S. and Tenhunen, J. (2012). Impacts of climate change on paddy rice yield in a temperate climate. *Global Change Biology*, (19): 548-562.

- Kumar, R. (2011). *Research Methodology*, London, SAGE Publications Ltd.
- Manickam, V., Radhika, R. and Murali Krishna, I. V. 2012. Geospatial analysis of the impacts of climate variables on crop productivity in Warangal district of Andhra Pradesh, India. *International Journal of Applied Environmental Sciences*, 7, 435-445.
- MoEF (Ministry of Environment and Forests) (2008). *Bangladesh Climate Change Strategy and Action Plan 2008*. Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh. xvi+68pp.
- MoA (Ministry of Agriculture) (2007). *Agriculture at a Glance*. Last accessed on 28 December 2012 through <https://moa.gov.bd/site/page/4fb627c0-d806-4a7e-a1cd-b67d4bc85159/Bangladesh-Agriculture-at-a-Glance>.
- Munang, R., Rivington, M., Bellocchi, G., Azam-Ali, S. and Colls, J. (2008). Effects of climate change on crop production in Cameroon. *Climate Research*, **36**:, 65-77.
- NAPA (2005). *National Adaptation Programme of Action*. Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.
- Pathak, H., Ladha, J. K., Aggarwal, P. K., Peng, S., Das, S., Singh, Y., Singh, B., Kamra, S. K., Mishra, B., Sastri, A. S. R. A. S., Aggarwal, H. P., Das, D. K. and Gupta, R. K. (2003). Trends of climatic potential and on-farm yields of rice and wheat in the Indo-Gangetic Plains. *Field Crops Research*, **80**: 223-234.
- Ruane, A. C., Major, D. C., Yu, W. H., Alam, M., Hussain, S. G., Khan, A. S., Hassan, A., Hossain, B. M. T. A., Goldberg, R., Horton, R. M. and Rosenzweig, C. (2013). Multi-factor impact analysis of agricultural production in Bangladesh with climate change. *Global Environmental Change*, **23**: 338-350.
- Sarker, M. A. R., Alam, K. and Gow, J. (2012). Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data. *Agricultural Systems*, **112**: 11-16.
- Shahid, S., Harun, S. B. and Katimon, A. (2012). Changes in diurnal temperature range in Bangladesh during the time period 1961-2008. *Atmospheric Research*, **118**, pp.260-270.
- Tao, F., Zhang, S. and Zhang, Z. (2012). Spatiotemporal changes of wheat phenology in China under the effects of temperature, day length and cultivar thermal characteristics. *European Journal of Agronomy*, **43**, Pp.201-212.

- Trnka, M., Brázdil, R., Dubrovský, M., Semerádová, D., Štěpánek, P., Dobrovolný, P., Možný, M., Eitzinger, J., Málek, J., Formayer, H., Balek, J. and Žalud, Z. (2011). A 200-year climate record in Central Europe: Implications for agriculture. *Agronomy for Sustainable Development*, **31**: 631-641.
- Tubiello, F. N., Soussana, J. F. and Howden, S. M. (2007). Crop and pasture response to climate change. *Proceedings of the National Academy of Sciences of the United States of America*, **104**: 19686-19690.