



Relationship between precipitation and rice production in Rangpur district

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Abstract

An experiment was carried out to reveal the precipitation pattern and to find out the interrelationship between precipitation and production of rice in Rangpur district. Rangpur division is more favorable for rice production. Monthly and yearly precipitation data (1983-2013) were collected from Bangladesh Meteorological department (BMD), Agargaon, Dhaka; Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka and rice production data were collected from Bangladesh Rice research Institute (BRRI); Department of Agricultural Extension (DAE), Rangpur, Bangladesh. From the analyzed precipitation data, it was clearly found that in 1984, 1985, 1987, 1999 and 2005, there were heavy precipitations and resulting flash flood. The average precipitation of Rangpur was higher (1344 mm) in 1987 than 1984, 1985, 1999 and 2005. In Rangpur district, rice production was the highest in the year of 1983, 1986, 1988, 1989, 1990, 1991, 1992, 1993, 1995, 1996, 1997, 1998, 2001, 2002, 2003, 2004, 2007, 2008, 2009, 2010, 2011, 2012 and 2013 and lower in the year of 1984, 1985, 1987, 1994, 1999, 2000, 2005, and 2006 on the basis of total annual precipitation. Rice production reduced main two reasons such as, heavy precipitation causes flash flood and lower precipitation causes drought stress condition. Both are threat-full for higher rice production. The results show that more precipitation in the years of lowest rice production period, heavy precipitation responsible for deduction of rice production area because of flooding and drought and also shows that normal/ minimum precipitation favorable for rice production at Rangpur district. From this study, it is concluded that the irregular precipitation of period (1984, 1985, 1987, 1994, 1999, 2000, 2005, and 2006) was not satisfactory for rice production due to heavy and/or excessive lower precipitation that resulting flood and/or in part of Rangpur district of Bangladesh. The analysis exposed that precipitation was one of the most important factors for higher amount of rice production in Rangpur district.

Key words: Rainfall, Bangladesh, rice production, flash flood, Rangpur

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Introduction

The climate of Bangladesh has changed significantly in recent years (Shahid, 2009, 2010a). It has been observed that the annual rainfall and daily mean temperature of Bangladesh has increased by an amount of 5.2 mm/year and 0.9 °C/decade respectively (Shahid, 2010b). Bangladesh will experience 5% to 6% increase in rainfall and 1.9 °C increase in temperature

by 2030 (IPCC, 2007). Small changes in the mean and standard deviation values can produce relatively large changes in the probability of extreme events (Groisman *et al.*, 1999, Rodrigo, 2002, Chiew, 2006, Su *et al.*, 2006, Shahid, 2011a). In light of recent climate trends and current predictions for the 21st century, climate change is becoming a major issue for scientists and

society in general. There is an increasing interest in different parts of the world in research on the variations of precipitation.

Precipitation is one of the most important aspects of any climate change because ecosystems and societal responses are most sensitive to them. Trend analysis of rainfall for the last two decades (1983-2013) reveals a bit different trend. It shows monsoon rainfall is increasing and pre-monsoon and post-monsoon rainfall is slight decreasing in the northern west part of Bangladesh. Sen's test reveals rainfall during monsoon is increasing at the rate of 10 mm/year. This trend is significant as 70% of the annual rainfall occurs in monsoon (Ahasan *et al.*, 2010). Increases in maximum climate events, such as prolonged period of hot days and intense rainfall days, have greater negative impacts on human society and natural environments than changes in climate means. Several studies have reported how a single catastrophic precipitation event can devastate long term accomplishments of human society within a short period (Zong and Chen, 2000). As the primary impacts of climate change on society result from extreme events (Rodrigo, 2002), it might have severe negative consequences for Bangladesh. The impacts of more variable precipitation and extreme weather events are already visible in Bangladesh (Shahid, 2010b, 2011a). Bangladesh is one of the most vulnerable countries of the world to climate change as the country has low capacity to address the devastating impacts (Shahid, 2010c). Studies shows that changes climate will have severe implications on agriculture (Karim *et al.*, 1996), water resources (Shahid, 2011b) and public health (Shahid, 2010c) of Bangladesh.

Agriculture is one of the sectors, which is most vulnerable to climate variability and change since it is inherently sensitive to local climate (Challinor *et al.*, 2007). Food productivity will be particularly sensitive to climate change, because crop yields depend directly on climatic condition. In tropical regions, even small amounts of warming will lead to decline a large amount of crops production. In cold areas, crop

harvests may increase first for moderate increase in temperature but then fall. Higher temperatures will lead to large decline in cereal (e.g. rice, wheat) production around the world (Stern, 2006). Bangladesh is a developing country; rice (*Oryza sativa* L.) is one of the most important world crops, providing the main food source for more than half of the people on earth. Since the great majority of the people of Bangladesh depend on agriculture for their livelihood, agriculture crop in this region is highly susceptible to variations in climatic system. It is anticipated that crop production would be extremely vulnerable under climate change scenarios, and as a result, food security of the country will be at risk (Karim *et al.*, 1996). The climate of Bangladesh is changing and it is becoming more unpredictable every year and resulting about 2.6 million ha of land are affected by flood (Karim, 1997). Global warming induces changes in temperature and rainfall, which is already evident in many parts of the world, as well as in our country (Ahmed and Alam, 1999). Rice production would be major concern in recent years due to changing climatic conditions, because there is a significant amount of rice yield may hamper for only fluctuations of those climatic parameters (Basak, 2010). Precipitation plays a most important function in the agro-economy of Bangladesh as well as Rangpur district, located in the tropical region in rice production. In the years of increased yield, predicted precipitation in rice season was found to have exceeded the water requirement for rice (1000-1100 mm). These in combined could be the reasons for the rice yield increases for those cases (CDMP II, 2013). Its climate is characterized by the large variations in seasonal precipitation with moderately warm temperature and high humidity. The precipitation depends on season to season and location to location.

In winter season (November-February), the precipitation record is lowest and it accounts for only less than 4% of the annual precipitation. Precipitation in this season varies from 20 mm in the west and south, to 40 mm in the northern part of Bangladesh (especially Rangpur district), which is caused by the

westerly disturbances that enter the country from the north-western part of India. In the pre-monsoon hot season (March-May) precipitation is recorded for 10-25% of the total annual precipitation. The average precipitation of this season varies from 200 mm in the north-west (Rangpur region) part of the country to 800 mm in the northern part of the country to northeast (Sylhet region) (Cottam, 1997). This research work demonstrates the temporal variation patterns of precipitation in a climate vulnerable region like Rangpur. Precipitation is an important issue, with a variety of its influences on agriculture, water health and economy. This study provides wide-ranging information on changes in climatic event like rainfall through investigations over the country. In Bangladesh, there are many research works regarding rice production, which showed relationship among rice production and different diseases, various elements of soil etc. But there is a few works to show the interrelationship between rice production and precipitation in Rangpur district. But there is an important linkup in between precipitation and rice production. This study was conducted to find out the interrelationship between precipitation and rice production in Rangpur district.

Materials and Methods

Study area

On the basis of rice production and precipitation pattern, northern region of Bangladesh is advanced than the other areas. Among the northern region Rangpur district was selected as the study area, mainly considering the individual meteorological station. This district (Figure 1) is bordered on the north by Nilphamari district, on the south by Gaibandha district, on the east by Kurigram, and on the west by Dinajpur district. In Rangpur district there have 2,641.84 km² of land. According to the census of 2014, total rice production area is 6, 81,405 acre (BBS, 2013). For, rice production needs a high amount of water which is highly dependent on rainfall and a certain temperature.

The climate of Rangpur is humid subtropical with a predominantly hot and humid summer and a relatively cool winter. The city belongs to the monsoon climatic zone, with annual average highest temperatures of 23 °C (Aug-Oct) and average lowest temperature of 7 °C (Jan-Feb). Nearly 80% of the annual average precipitation of 3334 mm occurs between May and September (Islam and Uyeda, 2007).

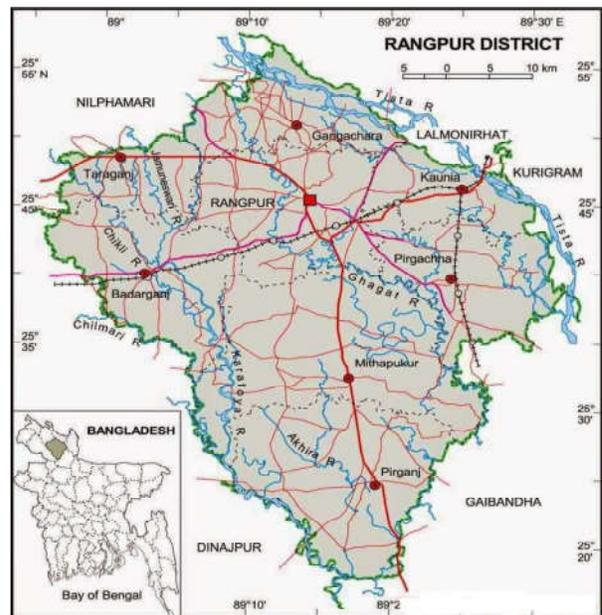


Figure 1. Map of study area with details (Source: Local Government Engineering Department's Website, Peoples Republic of Bangladesh)

Data Sampling and Analyses

In this study monthly and yearly data of precipitation were collected from Bangladesh Meteorological Department (BMD), Agargaon, Dhaka. Some missing data of precipitation were also collected from Bangladesh Agricultural Research Institute (BARI), and Bangladesh Agricultural Development Council (BARC). All rice production data was collected from Bangladesh Rice Research Institute (BRRI) and Bangladesh Agricultural Research Institute (BARI), Rangpur, Bangladesh. All data were put into MS Excel

spreadsheet for data analysis. For data analysis there were some calculations such as average, standard deviation etc. Average and standard deviation were calculated with the help of MS Excel spreadsheet.

Results and Discussion

Precipitation

The most dominant element of the climate of Bangladesh is the precipitation. Because of the country's location in the tropical monsoon region, the amount of precipitation is very high. During the early part of the pre-monsoon season, a narrow zone of air mass discontinuity lies across the country that extends from the south-western part to the north-eastern part. This narrow zone of discontinuity lies between the hot-dry air coming from the Bay of Bengal. As this season progress, this discontinuity weakens and retreats toward north-west and finally disappears by the end of the season. Higher precipitation causes flooding during the month (April-September), on the other hand minimum precipitation that resulting drought (April-September) from Table 1. That's really not suitable for crop production. Karmakar and Shrestha (2000) reported that the present 5-year running average trends of climate elements continue, the annual-total rainfall over Bangladesh is likely to increase by 304.72 mm and 588.65 mm by 2050 and 2100 years, respectively. Recently, in 2010, low rainfall (30% below average levels) during the monsoon Climate and excessive rainfall in the post-monsoon caused extensive damage in the agricultural sector. The lack of rainfall created agricultural drought in the country while excessive rainfall at the beginning of the post-monsoon period provoked flash floods. In 2007, more than 9 million people were affected by severe flooding caused by heavy rainfall (Prothom-alo, 2011).

The rainy season, which coincides with the summer monsoon, is characterized by southerly or south-westerly winds, very high humidity, heavy precipitation and long consecutive days of precipitation which are separated by short spells of dry seasons.

Precipitation in this season is caused by the tropical depressions that enter the country from the Bay of Bengal.

Yearly precipitation at Rangpur district

The total precipitation recorded at Rangpur district for the year 1983-2013 was presented bellow in tabular form in Table 1. The total values of precipitation were highest in the year of 1984, 1985, 1987, 1995, 1999 and 2005 and the lowest values were observed in the year of 1994, 2000 and 2006 but acceptable precipitation (1800-2500 mm) was found in the year of 1983, 1986, 1988, 1990, 1991, 1992, 1993, 1996, 1997, 1998, 2001, 2002, 2003, 2004, 2007, 2008, 2009, 2010, 2011, 2012 and 2013.

Table 1. Yearly total precipitation in Rangpur district (1983-2013).

Year	Precipitation (mm)	Year	Precipitation (mm)
1983	2238	1999	2931
1984	3748	2000	1745
1985	2882	2001	2492
1986	2312	2002	2588
1987	3194	2003	2402
1988	2524	2004	2680
1989	1878	2005	2853
1990	2487	2006	1682
1991	2463	2007	2037
1992	2006	2008	1907
1993	2520	2009	2217
1994	1301	2010	2102
1995	2706	2011	1932
1996	2004	2012	1877
1997	1971	2013	1916
1998	2365		

Gao *et al.* (2013) explained that extreme precipitation often results from the interaction of large-scale (~100 Km) atmospheric features (i.e. terrain and other surface features). Flooding associated with heavy precipitation

is among the most disruptive weather related hazards for the environment and economy (Kunkel *et al.*, 1999). Lee (2013) studied that the scales and values of several regional meteorological parameters over Bangladesh for a year of reduced precipitation (drought) year (1994) and compared to detect any difference. The flood/drought index as calculated from the mean precipitation of June-July showed 1994 to be a drought year. Talukder *et al.* (1988) also studied that highest rainfall in July (317.8 mm) and lowest in January (3.6 mm) for various locations in Bangladesh. In these year, there held little or large amount flood for the reason of heavy precipitation.

Monthly precipitation at Rangpur district

Some areas of Rangpur district is flood affected due to heavy precipitation during monsoon season and some areas are affected by water deficit condition due to lack of precipitation. The climate of Bangladesh as well as Rangpur district is changing and becoming more unpredictable every year as for example-about 2.6 million ha are affected by flood (Karim, 1997). In every year precipitation is not equal; it is changing due to climatic change. From the Figure 2, in which year precipitation maximum, minimum and acceptable that found. Here in Figure 2 shows the monthly (April-September) rainfall pattern in Rangpur district. In the year of 1984 the highest precipitation was in June (989 mm) and lowest was in April (116mm). In May, July and August the precipitation was not in so much excess level (212,202 and 376 mm, respectively). In 1985, at pre-monsoon (March-May) and in monsoon the precipitation were heavy. In 1987, at July (1344 mm) month, the precipitation was maximum but at April that was lowest (57 mm).

In 1995 and 2005, at pre-monsoon (March-May) started the lowest precipitation but in monsoon the precipitation increases. In 1999, the rainfall was the highest both in pre-monsoon and monsoon period for that reason rice production was not satisfactory. In 2000 and 2006, pre-monsoonal rainfall was heavier but little in the monsoon period. Precipitation may not be

always helpful for rice cultivation but the early precipitation helps in rice production in a good scale, which we observed in 2000 and 2006. In 1994, the average rainfall both in pre- monsoon and monsoon was not at good level that's why production was not satisfactory. Lee (2013) studied that the scales and values of several regional meteorological parameters over Bangladesh for a year of normal precipitation (1993) and those for a year of reduced precipitation (drought) year (1992) and compared to detect any difference. Daily precipitation and rainfall data and meteorological charts from Bangladesh Meteorological Department were used in their work. The flood/drought index as calculated from the mean precipitation of June-July showed 1994 to be a drought year. Karmakar (2004) studied the monthly country averaged rainfall had inter annual variation and it had increasing linear trends during the pre-monsoon season. The rates of increase of country-averaged rainfall were 1.3359 mm/year, 1.0909 mm/year and 1.1189 mm/year in March, April and May respectively. The variation of monthly country averaged rainfall over Bangladesh maintained a similar pattern of variation with 11-13 year cycle. A study over Satkhira by Rimi *et al.* (2009) revealed an insignificant negative correlation between boro rice production and rainfall. Moreover, the study of Quadir *et al.* (2003) showed that the crop yield is low for rainfall. The yield increase with increase of rainfall up to a certain optimum level and further increase of rainfall causes decrease of crop yield. Figure 2 also shows summation of average. These values followed the fluctuation of average monthly precipitation.

Figure 2 Shows the monthly total precipitation. In Figure 2a. 1984 the highest rainfall was in June (989 mm) and the lowest was observed in April. In Figure 2b. 1985; c. 1987; d. 1995 and f. 2005 the total highest rainfall was observed in July (770 mm, 1344 mm, 804 mm and 671 mm), respectively. Figure 2e. 1999 the total rainfall was lowest in April and highest total in August (829 mm). Figure 2g. 1994 and i. 2006 also

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shows that the total highest rainfall was in June (427 mm and 472 mm), respectively and lowest in April. In Figure 2h. 2000 the total precipitation was lowest in September and highest total precipitation was in June (438 mm). There was enriched total precipitation from the starting of pre-monsoon. Figure 2a.1984 also shows the highest total precipitation at June where in Figure

2b. 1985 shows the highest precipitation in July. The precipitation was higher in 1984, 1985, 1987, 1995, 1999 and 2005 than the year of 1994, 2000 and 2006. The precipitation during monsoon and pre-monsoon seasons has increased whereas it decreased in winter and post-monsoon seasons at northern region in Bangladesh.

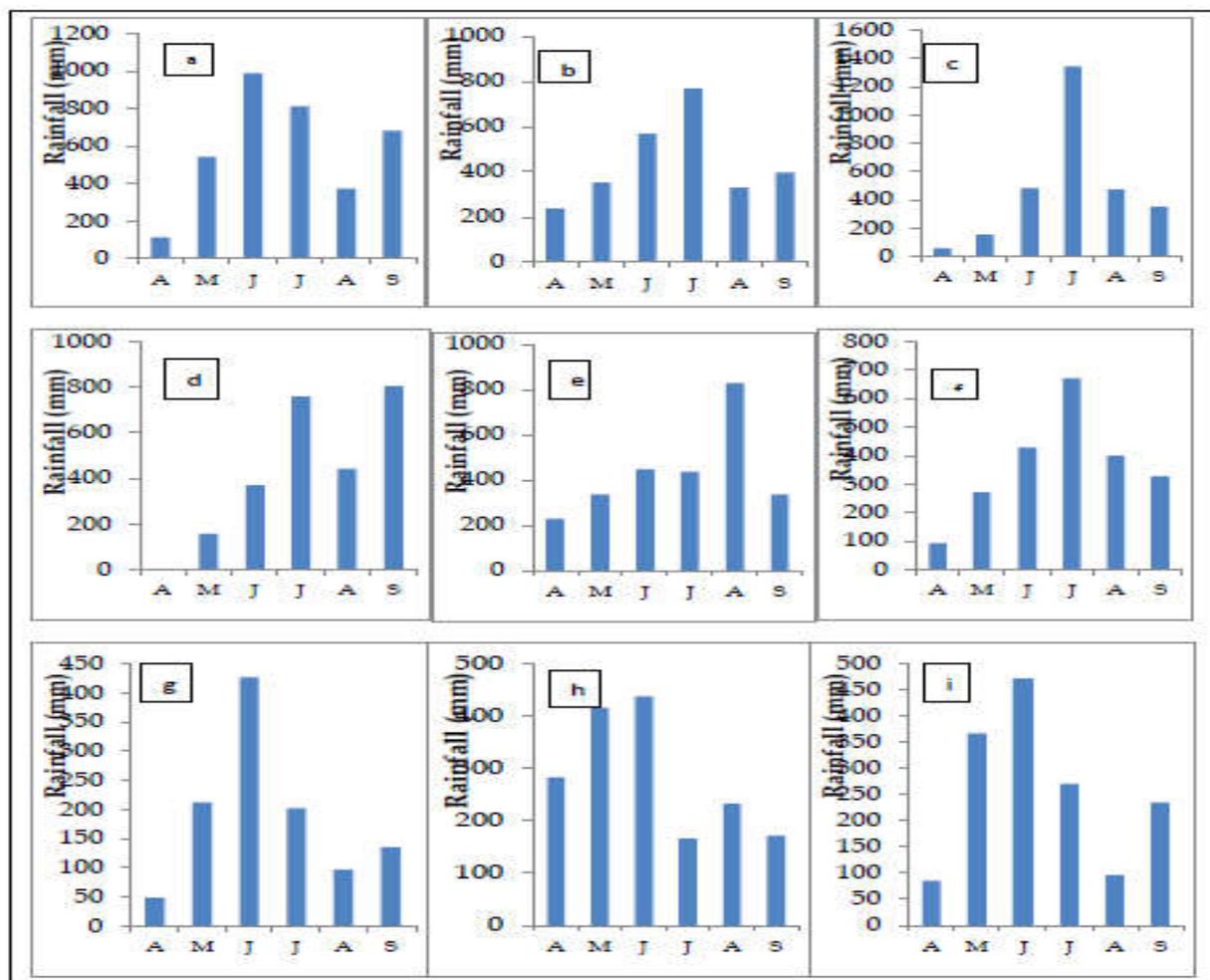


Figure 2. Monthly (April-September) rainfall pattern of Rangpur district of selected years [a. 1984; b. 1985; c. 1987; d. 1995; e. 1999; f. 2005; g. 1994; h. 2000 and i.2006] denotes rainfall, respectively.

The changing pattern of precipitation in each year is found to increase by 5.47 mm and 2.90 mm in monsoon and post-monsoon season respectively. In winter and pre-monsoon periods, it has decreased at

rate of 0.4 mm and 1.75 mm per year. Changing precipitation pattern and water requirement of crops show that variability of precipitation affects crops at different times. If variability is associated with an

untimely cessation at the reproductive or ripening stage of the rice, yield reduction is severe (Moomaw and Vergara, 1965). In 1994 pre-monsoon (March-May), the precipitation was lower than the precipitation in 2000 and 2006. These types of early extreme precipitation such in 1994 greatly influence the rice production of Rangpur region. Total monthly precipitation was higher in 1984 considering all the year. From the consideration of precipitation rice production was preferable in the year of 1983, 1988, 1989, 1990, 1991, 1992, 1993, 1996, 1997, 1998, 2001, 2002, 2003, 2004, 2007, 2008, 2009, 2010, 2011, 2013 because maximum and minimum precipitation were found in the year of 1984, 1985, 1987, 1994, 1995, 1999, 2000, 2005 and 2006.

Rice production in Rangpur district

In Rangpur area, rice plays a vital role in food security northern people as well as whole country economics. Success and failure of these crops have significant impact on food security. In that case precipitation is most dominant factor for rice production. For rice production needs a high amount of water (1800-2500 mm) which is highly dependent on rainfall and at a certain level of temperature. In Figure 3 shows normal relationship between production area (ha) and total rice production (m ton) of Rangpur district at different years (1983-2013) that has significant importance especially for this region (Rangpur district).

From the analysis of data, there clearly showed that in 1983 to 2013 there were so much variation in total rice production and area (Figure 3). From Figure 2, in which year precipitation was higher and in which year precipitation was lower. Another important thing is to be found several years there were rice production was highest due to suitable precipitation (Figure 2). In the year of 1984, 1985, 1987, 1995, 1999 and 2005, there were total area for rice production reduces and finally production of rice reduced (Figure 2). Figure 3 also showed the rice production was satisfactory within the comparison to cultivation area than the other years, where the amount of precipitation was minimum.

Choudhury (2005) reported that aus rice production showed increasing trend over Sylhet, aus rice production was gradually increased with increasing cultivated area. Sarker *et al.* (2012) performed time series analysis to assess this question for three major rice crops (Aus, Aman and Boro) in Bangladesh at the aggregate level using both Ordinary Least Squares and median quintile regression.

The authors use maximum and minimum temperature and rainfall as climate variables and found a significant relationship between climate change and agricultural productivity in Rangpur. In the year of 1984, 1985, 1987, 1995, 1999 and 2005 the monthly total precipitations were higher that caused flood during rice growing season and that's why the production of rice in Rangpur district drastically reduced because of reduction of cultivation area. As a result in 1984, 1985, 1987, 1995, 1999 and 2005, the total rice production of Rangpur region is declined than the other years. In the year of 1983, 1986, 1988, 1989, 1990, 1991, 1992, 1993, 1996, 1997, 1998, 2001, 2002, 2003, 2004, 2007, 2008, 2009, 2010, 2011, 2012 and 2013 production of rice was more or less same due to suitable (1800-2500 mm) precipitation.

Rashid and Islam (2007) identified droughts, floods, soil salinity and cyclones as the major extreme climatic events that have affected agricultural production adversely. Changes in behavioral patterns, human practices and international actions are suggested as anticipatory adaptive measures in the study.

The research discussion focused on the precipitation which is the most dominant factor for rice production. Rice is cultivated in Rangpur district throughout the year as Aus, Amanor Boro constitute about 100% of total rice production and grow in three different seasons. Aman is generally sown in June-July and harvested in November- December (Zakaria *et al.*, 2009, Islam, 1988). Flood and drought are such type of natural disaster which caused by heavy precipitation and scarcity of water that finally affects the growing crop.

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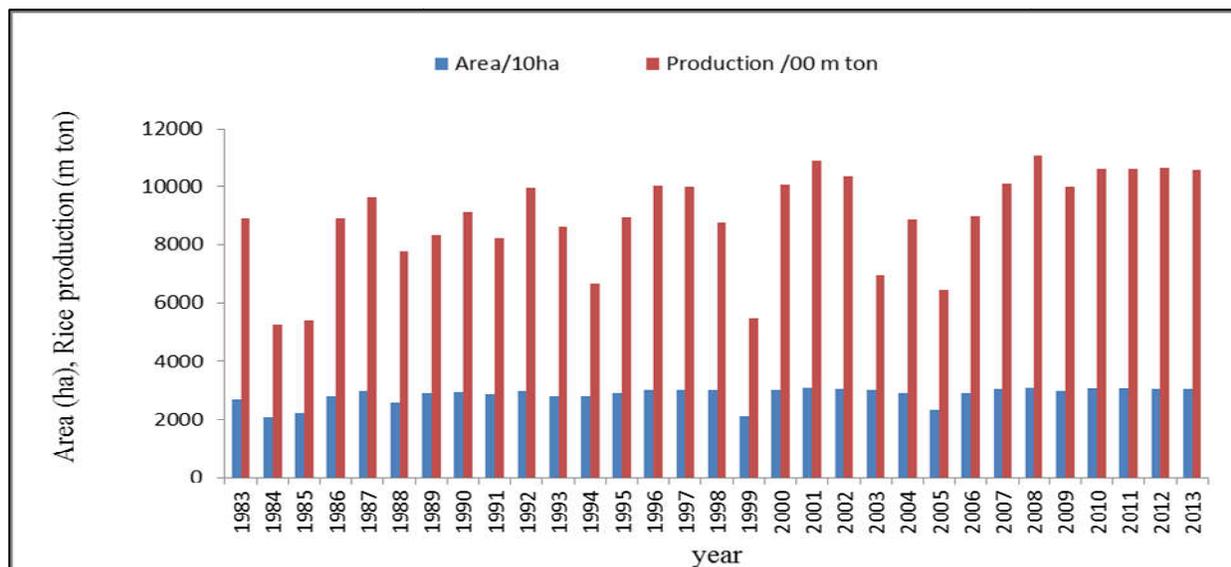


Figure 3. Area and rice production of Rangpur district at different years (1983-2013).

Interrelationship between rice production and precipitation with area in Rangpur district

Figure 4 shows that in the year of 1983, 1986, 1988, 1989, 1990, 1991, 1992, 1993, 1996, 1997, 1998, 2001, 2002, 2003, 2004, 2007, 2008, 2009, 2010, 2011, 2012

and 2013 had upper curve of rice production where the total yearly precipitation shows normal curve at Rangpur district and upper curve means that the total precipitation was suitable from previous year and the production of rice also increase.

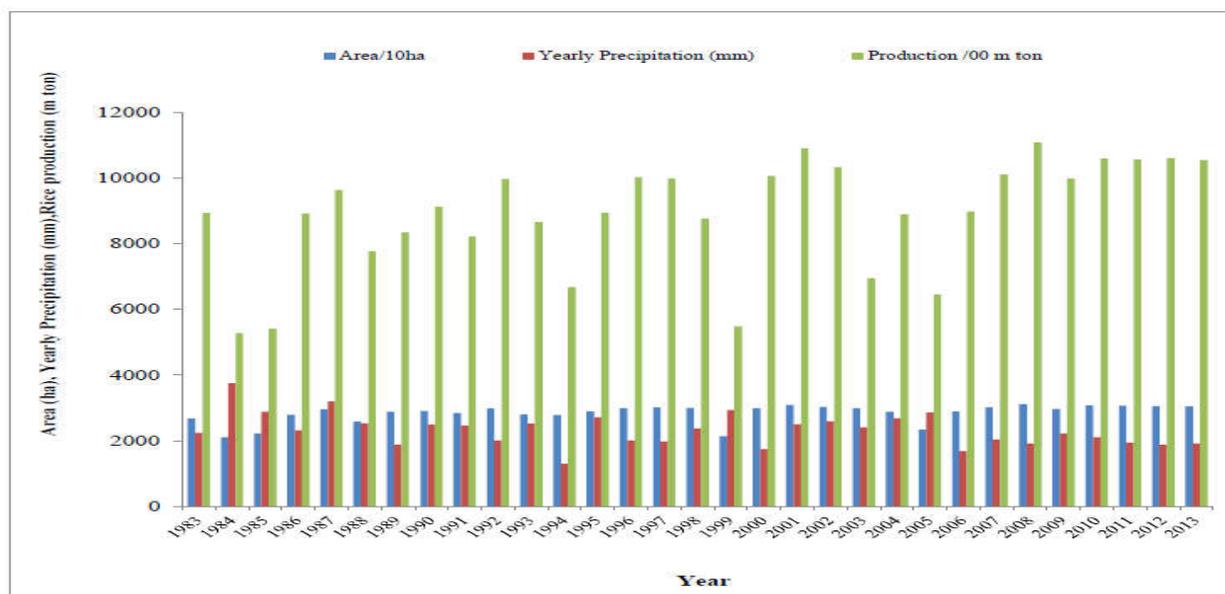


Figure 4. Interrelation between rice production and total yearly precipitation along with area (1983-2013) of Rangpur district.

Iqbal and Siddique (2014) discussed that there are many impacts of climate changes in temperature, rainfall, humidity and sunshine on agricultural productivity. We use agricultural output per acre (only rice), and agricultural output per acre (only boro rice), as measures of agricultural productivity. We consider boro rice separately because it constitutes about two-thirds of total rice production in Rangpur district. On the other hand in 1984, 1985, 1987, 1995, 1999 and 2005, there the Figure 5 shows higher curve of precipitation that causes flooding and ultimately reduces rice production with production area. In the year of 1994 (Figure 4) shows the lower curve of precipitation that resulting

drought stress and finally rice production declined but here the total rice production area was higher than the flood affected years (1984, 1985, 1987, 1995, 1999 and 2005).

Quadir *et al.* (2003) also found that the crop yield is low for low rainfall. The yield increase with increase of rainfall up to a certain optimum level and further increase of rainfall causes decrease of crop yield. This means when the precipitation decrease from before year there also decreases the production of rice. Lobell and Burke (2008) report that a change in growing season precipitation by one standard deviation can be associated with as much as a 10 per cent change in production (e.g. millet in South Asia). Drought is not a new hazard event for Bangladesh, the intensification of drought is now a cause of high concern. The north-western (NW) region of Bangladesh is more prone to drought than others. The persistent drought condition in NW Bangladesh in recent decades had led to a shortfall of rice production of 3.5 million t in the 1990s (Chowdhury, 2009).

Precipitation and rice production are strongly interrelated. Figure 4 shows clearly that when precipitation was suitable (1800-2500 mm) then the rice production was highest but when less than normal precipitation (<1800 mm) that ultimately resulting

drought stress that also reduces the rice production. On the other hand, when the precipitation was in highest level (2500<) the total rice production was reduced with cultivated areas due to heavy precipitation resulting flood. The impacts of more extreme precipitation and extreme weather events are already felt in Bangladesh. Floods in 1988, 1998, 2004, and 2007; and cyclones and tidal surges in 1991, 1998, 2000, 2004 and 2007 record the increase of extreme events both in frequency and severity. Changing rainfall patterns with increasing temperatures, flooding, droughts and salinity causes decline in rice production in Bangladesh by 8% and wheat by 32%, against 1990 as the base year (MoEF, 2008). Super cyclone Sidr in 2007 exceeded previous records of its coverage and wind velocity which killed over 10,000 people and destructed houses of 30 million. Flood in Bangladesh in 2007 was two times prolonged causing 40% crop loss, outbreak of diarrheal diseases and severe food insecurity (Mallick, 2008).

Correlation regression analysis between rice production and precipitation

Figure 5 represents the $R^2 = 0.1945$ which shows that 98.1% of the variation in production of rice in Rangpur for 33 years can be explained by the independent factors like area used and precipitation. It shows the one variable like precipitation is statistically significant for the regression model as P-value is less than 0.05 but other variable like area used is statistically insignificant for the regression model as P-value is more than 0.05.

The above analysis clearly reveals that the regression model fits well to this concern case. This R^2 indicates that the rice production and precipitation are strongly interrelated. When precipitation was normal then the rice production was highest but when the precipitation was in higher level than the total rice production was reduced with cultivated areas due to flood.

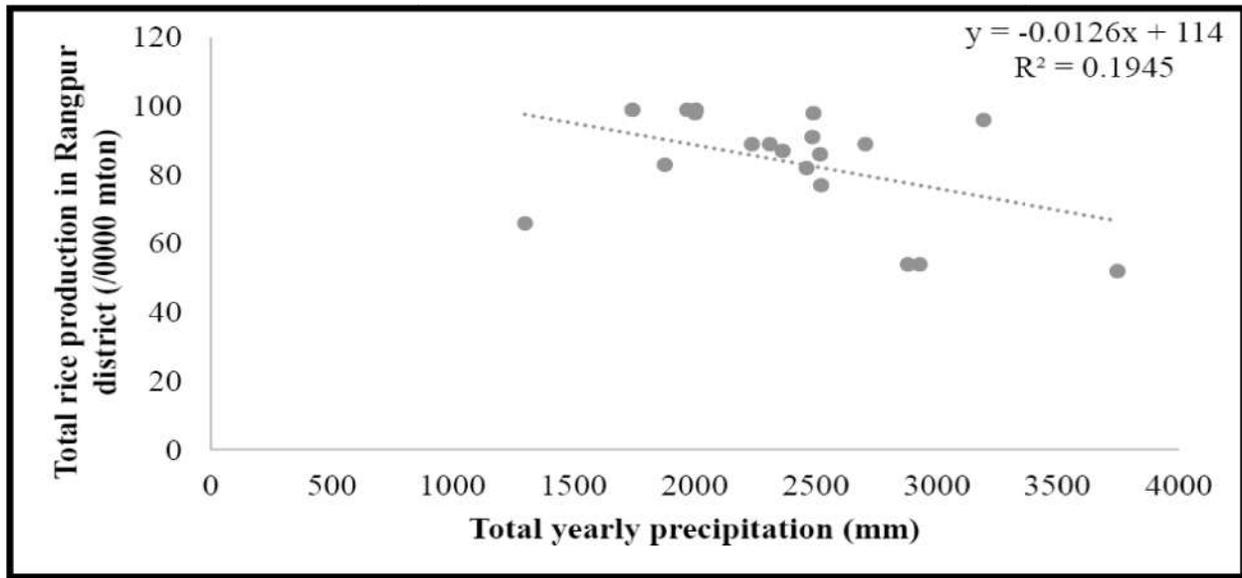


Figure 5. Correlation regression between rice production and precipitation.

Conclusion

In Bangladesh, different climate change induced events such as recurring floods riverbank erosion, drought in dry season have been augmenting vulnerability in this region and leaving impacts on the yields of crops. Contextual analysis suggests that unless urgent actions are taken, climate change will undermine efforts to ensure food security. From this study, there has been changing pattern of precipitation in 31years (1983-2013) in Rangpur meteorological station surrounding the selected location and the changes of those climatic parameters are significant during this period. Food productivity will be particularly sensitive to climate change, because crop yields depend directly on climatic conditions (precipitation patterns). In tropical regions like Bangladesh (Rangpur), even small amounts of warming will lead to decline a large amount of crop (rice) production. In cold areas, crop harvests may increase first for moderate increase in temperature but then fall. Higher temperatures will lead to large decline in cereal (e.g. rice, wheat) production around the world. The research noticed that the changing pattern of precipitation for the selected

regions are significantly higher compared to IPCC prediction over the world in last 100 years, which have considerable negative impacts on crop production like as rice production. In Rangpur district, different climate change induced events such as recurring floods and drought, have been augmenting vulnerability in many regions and leaving impacts on the rice production. Agriculture of Rangpur district is highly vulnerable to variation in weather patterns and is therefore extremely at risk from climate change, which will affect food security, particularly in the southern coastal and northern drought-prone areas of Bangladesh.

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