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# Climate Change and Its Effects on Crop Production and Water Tablein Rajshahi Division

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*The climatic parameters are changing constantly. These parameters may affect crop production and groundwater table. This may create a threat to food and water security. The author tried to find out the relationships of overall crop production rate, crop production per unit area and groundwater table with climatic parameters. The study concluded that the temperature increase and rainfall decrease cause groundwater table drawdown, decrease of crop production for a few major crops and few crops are weather parameter resilient. The author also concluded that few crop production increases with the increase of temperature and decrease of rainfall.*

**Keywords***:* Rajshahi Division, Climate change, groundwater table, crop production, major crops, groundwater table degradation.

**Field of Research:** Water Resource Engineering (Groundwater Hydrology) and Environmental Engineering.

## 1. Introduction

Food and water are one of the basic needs of human being. Rice is the staple food and mostly groundwater is consumed in Bangladesh. In 2014-2015 among all the cultivated areas, more than 75% land areas are used for cultivation of rice (Bangladesh, 2015). Rajshahi division is one of the major crops producing area of the country. Effects of climate change include temperature increase, rainfall decrease, severe weather events and changes in other weather parameters. These parameters directly affect the crop production and indirectly affect the groundwater table. According to United States Department of Agriculture, Due to the increase of carbon-di-oxide in the atmosphere, temperature rise and altering of precipitation timing is occurring. It will affect the agricultural productivity (Walthall, 2012). In this paper, decreasing rates the productivity of the crops and the groundwater table with the climate change was identified.

Rajshahi Division produces a very high amount of crops compared to other divisions of Bangladesh. The soil condition of this area is very favorable for crop production. Very few literatures covers about the crop production and climate change in Rajshahi Division. In fact, the literature in Bangladesh in relation to crop production, groundwater table and climate change is very less.

Different kinds of rice, potatoes, jute and wheat are the major crops in Bangladesh. On the other hand, water is one of the most essential components of the ecosystem Scarcity of any of these will seriously affect the human being as well as total ecosystem.

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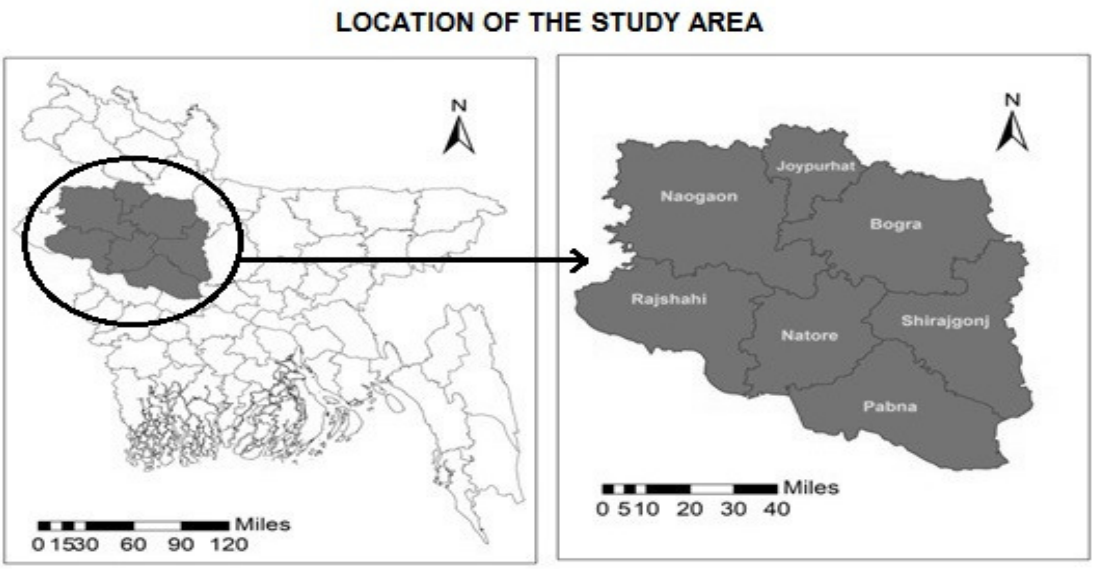
The paper is organized in five sections. These are the Introduction, literature review, Methodology, Results and discussions and conclusion. Introduction is attached to section 1 and section 2 deals with the literature review. Section 3 contains methodology of the study. Results and discussions are provided in section 4 and the conclusion is attached in section 5.

**Figure 1: The Geographic Location of the Study Area**




The figure 1 represents the study area and the study area is located in the northwestern part of Bangladesh. The seven chosen districts of Rajshahi division are Rajshahi, Naogaon, Joypurhat, Bogra, Natore, Pabna and Shirajgonj. The study area is shown in the figure 1. The study area is surrounded by two major rivers named Padma and Jamuna. The area consists of Ganges river floodplain, Barind Tract (Lower Atrai Basin). The landscape information is very much important for agricultural related study.

## 2. Literature Review

As per the fifth assessment report of the IPCC, the climate change is negatively affecting the crop production along with very less positive effects. The crop production in the recent age has declined a lot across different parts of the world(Porter, 2014). This is resulting the rise of price of different food in many locations. In most of the studies in the recent age is based on assumption and experimental results of different models. This study deals with the exact condition of climate change and the effect on crop production and water table in Rajshahi division. Many papers and articles were written on climate change across the world, but very few papers are written to quantify the effects of climate change on crop production and the groundwater table.

Groundwater table provides us the fresh and mostly pure water. But the extraction of water may cause groundwater table drawdown. The groundwater exploration since last 50 years went drastically high. The extraction rate in 1950 was 100-150 $km^3$. At present, the rate has reached to 950-1000 $km^3$ (McBean, 2011). The groundwater is

extracted by using a pump at a very high rate, but it is not refilled in the same rate by the process of infiltration. In Bangladesh most of the irrigation is dependent on groundwater. The drinking water in the rural areas is mostly groundwater too. Climate changing parameters are temperature, rainfall humidity etc. Their changes in recent age are noticeable. The groundwater table measurement is very necessary to estimate the rate of extraction and to determine the extracted volume of water. In Bangladesh, most of the literature was made on the drawdown of the water table. This study was aimed to find out the exact amount of drawdown of the water table in the study area as well as to quantify the volume of losing water from the ground.

There are three trends of temperature in Bangladesh. These are: annual average temperature, the highest temperature in August and lowest temperature in January (McBean, 2011). Other regions lie within them. From 1950, these trends went up at a high rate. The temperature of Bangladesh is increasing at the rate of 0.018℃ per year (J. K., 2013). It was seen from the research that due to the increase of carbon-di-oxide in air, the temperature is increasing drastically. Increased temperature increases microbial activities. These bacteria and viruses collect their food from the crops produced. Thus the production decreases with the increase of temperature. High temperature also causes biotic stress among the plants and crops. These cause reductions of productivity (Walthall, 2012). The temperature change also causes extreme events like drought, cyclone, storm and so on. These also reduce the productivity of the lands. The temperature change trends before and after the year 2000 was aimed to discuss in this study.

The rainfall provides sufficient water for the growth of the crops because the water retention rate increases in the soil due to rainfall. The annual rainfall in Bangladeshis highest during the month of June, July and August. The rainfall mostly occurs during the monsoon season in Bangladesh. Rainfall helps in increasing productivity of the crops. But in recent times the rate of yearly rainfall has decreased a lot. The trends before and after the year 2000 was aimed to discuss in this study.

## 3. Methodology

The study was conducted in 7 districts of Rajshahi division. These are: Rajshahi, Naogaon, Joypurhat, Bogra, Natore, Pabna and Shirajgonj. The total crop production, crop production per unit area was found out from 2007 to 2016 from the Yearbook of Agricultural Statistics published by Bangladesh Bureau of Statistics (BBS). These values were plotted and analyzed in Matlab software for graphical and analyticalapproach. The major crops, namely Local Aman rice, Local Aush rice, Local BORO rice, High Yielding Variety (HYV) Aman rice, HYV Aush, HYV BORO rice, jute, potato and wheat were only analyzed in this paper. Minor crops were not included in the analysis. The efforts on research, the seed qualities, fertilizer application, availability of irrigation facility, availability of governmental support etc. can be included for further improvement of the study. These efforts on the production of major crops was no considered due to the simplicity of the paper.

The data of temperature and rainfall from 1975 to 2016 of Bogra, Ishwardi, Rajshahi were taken from the Bangladesh Meteorological Department (BMD) and plotted in Matlab software for graphical analysis. Since all the districts of the study area do not have coverage of the BMD, the data were interpolated from nearby stations and

assumed to vary in the same fluctuation rate. For this aspect, the districts around same latitudes were assumed to be similar in nature. The data from 1948 to 1974 was ignored due to the unrest condition of the country and possibility of manipulation of data. The changes in climate parameters of Bogra were assumed to vary in similar fashionin Bogra, Joypurhat and Naogaon and the climate parameters of Iswardi was assumed to vary in similar fashion in Natore and Pabna and climate parameters of Rajshahi are assumed to vary similarly in Rajshahi and Shirajgonj. Few differences might be experienced while interpolating the data due to geographical differences of the location of the districts.

For the analysis of groundwater table, the static water level from 2003 to 2016 of the service wells of Department of Public Health Engineering (DPHE) were taken from DPHE office and plotted in Matlab software for graphical and analytical approach. The data of groundwater table from 1995 to 2002 was not considered due to many missing data of the static water level of wells. Out of 607 service wells in the study area, 167 service wells were analyzed which is 27.5% of the total number of wells. The rest was ignored due to the lack of continuity of data in this time period. The missing data were interpolated or extrapolated for analyzing 167 service wells. The overall water extracted was measured by assuming the average porosity of the soil equal to 0.4.Previous research showed that the climate change affected the crop productions and the water table. But these methodologies quantified their exact amounts in the study area.

## 4. Results and Discussion

The present study was concerned about the climatic parameter change in the seven districts of Rajshahi Division and its impacts on crop production and the groundwater table. For this study, the temperature and rainfall parameters were taken as vital climatic factors. The crop production variable was analyzed on the basis of total crop production and crop production per unit area. The groundwater table was analyzed since 2000 to get drawdown comparisons. The findings and results are shown as per the following heads:

### 4.1 Climatic Parameter Changes

**Figure 2: Graph of Average of Monthly Maximum Temperature from 1975 to 2016**

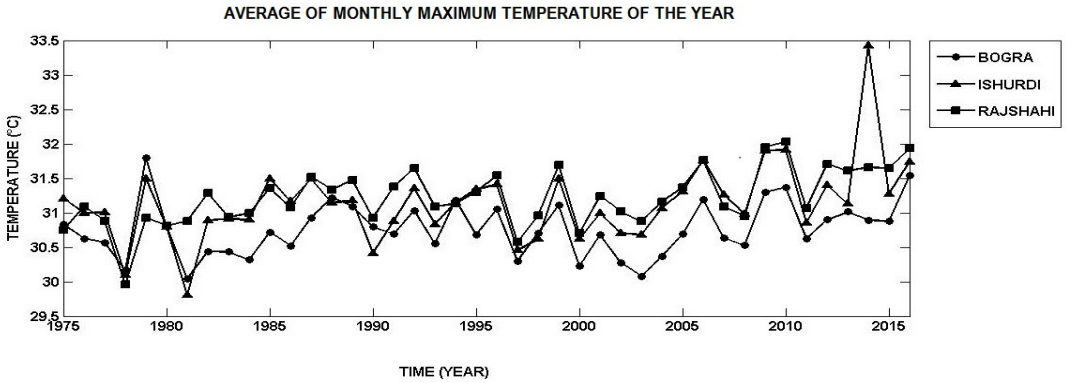
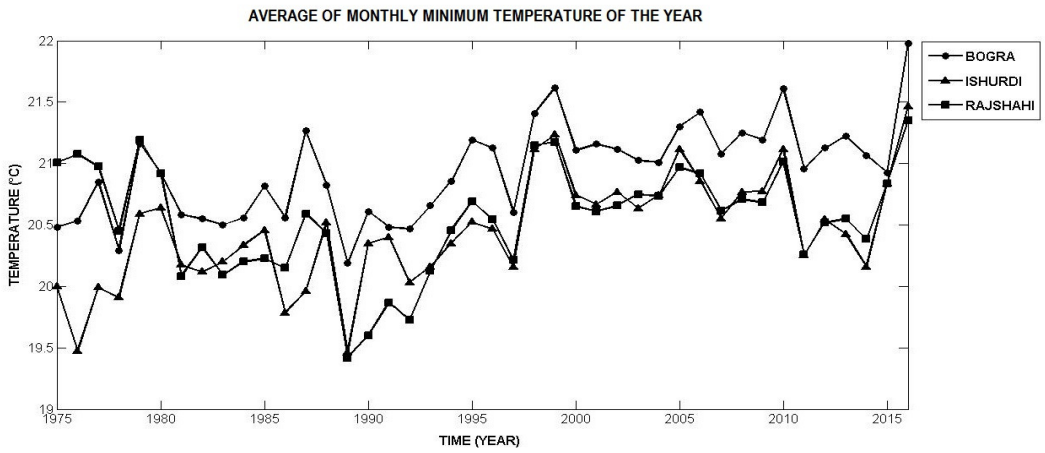


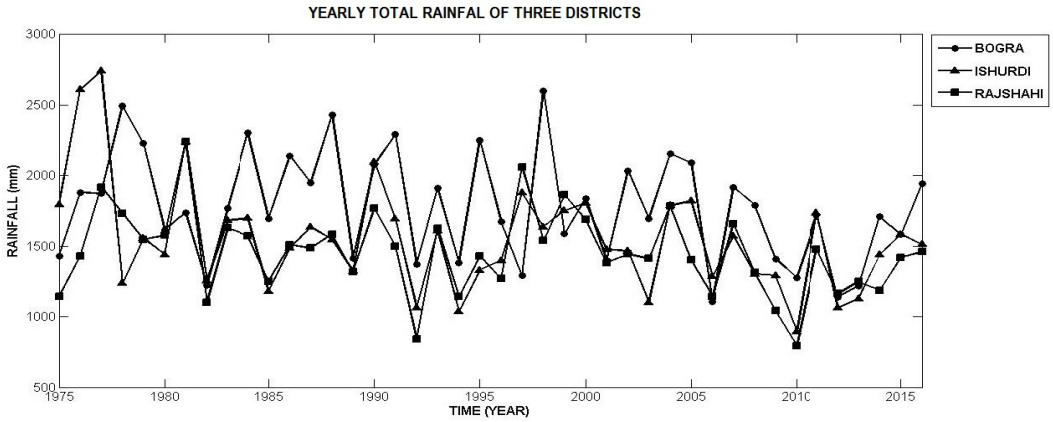
**Figure 3: Graph of Average of Monthly Minimum Temperature from 1975 to 2016**




The figure-2 and figure-3 represent the trends of both average of monthly maximum and minimum temperature since 1975. It indicates this variable started increasing in three stations located in the study area after the year 2000. The figure-2 shows monthly average maximum temperature was almost steady from 1975 to 2000.The slope of monthly maximum temperature from 1975 to 2000 and from 2000 to 2016 will give comparative increasing rate of the temperature variable for both time periods. The gross amount of increase in average of monthly maximum temperature in Rajshahi, Bogra and Ishurdi from 1975 to 2016 is 1.1833℃, 0.7084℃ and 0.5334℃ respectively and their slopes are 0.0281738,0.0168667 and 0.0127 respectively. The gross increase of average of monthly maximum temperature in Rajshahi, Bogra and Ishurdi from 2000 to 2016 is 1.2333℃, 1.3167℃ and 1.1247℃ and their slopes are 0.0771, 0.0823 and 0.0703 respectively. Thus, it can be said that the slopes of average of monthly maximum temperature in Rajshahi, Bogra and Ishurdi from 2000 to 2016 is 2.73, 4.88 and 5.54 times higher than the slope of average of monthly maximum temperature in 1975 to 2016 respectively.

The gross amount of increase in average monthly minimum temperature in Rajshahi, Bogra and Ishurdi from 1975 to 2016 is 0.267℃, 1.4917℃ and 1.4667℃ respectively and their slopes are 0.00651,0.03638 and0.0358 respectively. The gross increase of average of monthly minimum temperature in Rajshahi, Bogra and Ishurdi from 2000 to 2016 is 0.7℃, 0.8667℃ and 0.725℃ and their slopesare0.044, 0.0542 and 0.0453 respectively. Thus, it can be said that the slopes of average of monthly minimum temperature in Rajshahi, Bogra and Ishurdi from 2000 to 2016 is 6.75, 1.49 and 1.27 times higher than the slope of average of monthly minimum temperature in 1975 to 2016 respectively.

**Figure 4: Graph of Yearly Total Rainfall from 1975 to 2016**




The figure 4 represents the total rainfall amount in each year from the year 1975 to 2016.

It was observed from the graphs that the gross decrease of the total amount of rainfall since 1975 to 2016 in Rajshahi, Bogra and Ishurdi stations were -316 mm, -511 mm and +283mm respectively. But the decrease of the total amount of rainfall from 2000 to 2016 is+230 mm, -103 mm and +296 mm respectively. The rainfall variable changing slope of the 2000 to 2016 is 1.87, 0.52 and 2.68 times higher than the rainfall variable changing slope of 1975 to 2016 in Rajshahi, Bogra and Ishurdi stations respectively.

## 4.2 Changes in Total Crop Production

**Figure 5: Graph of Total Production of Local Aman as Per Districts per Year**

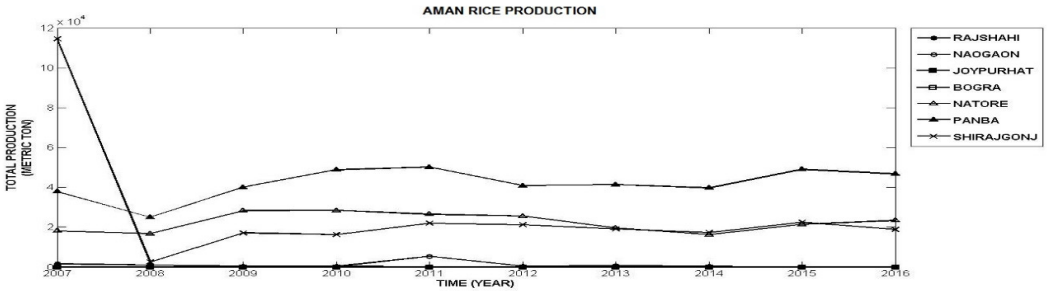



**Figure 6: Graph of Total Production of Local Aush as Per Districts per Year**

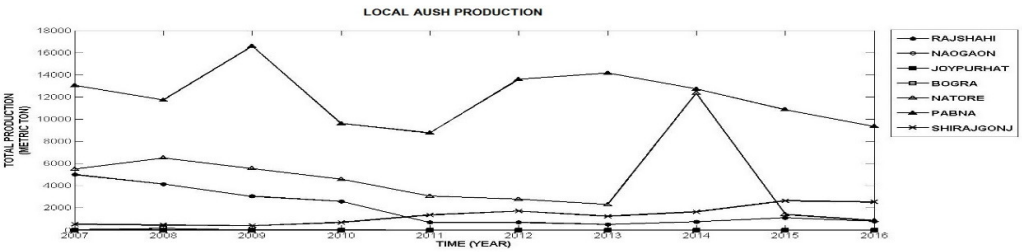


**Figure 7: Graph of Total Production of Local BORO as Per Districts**

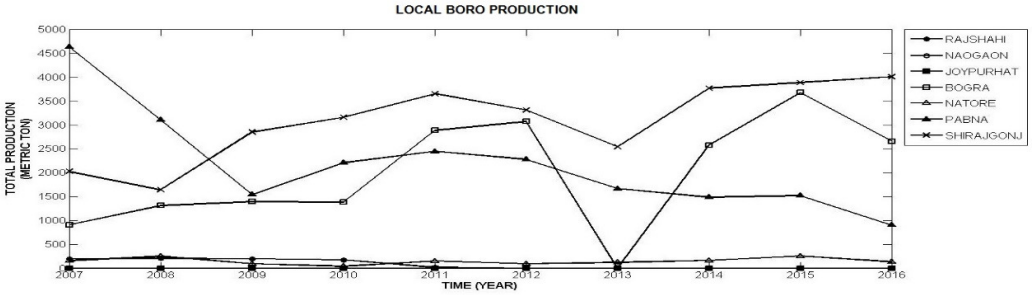



**Figure 8: Graph of Total Production of HYV Aman as Per Districts**

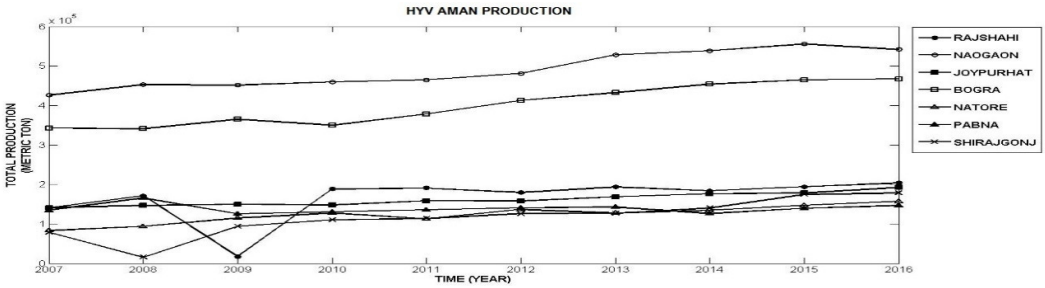



**Figure 9: Graph of Total Production of HYV Aush as Per Districts**

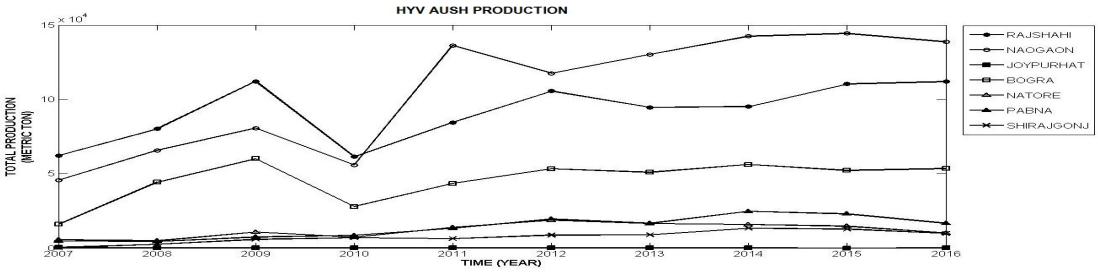



**Figure 10: Graph of Total Production of HYV BORO as Per Districts**

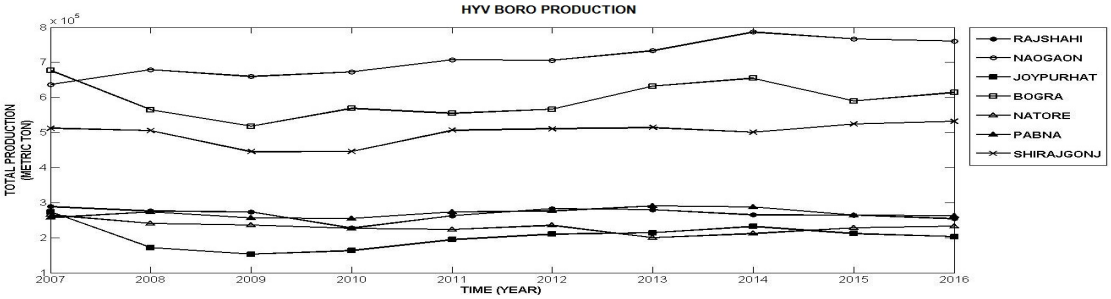


**Figure 11: Graph of Total Production of Jute as Per Districts per Year**

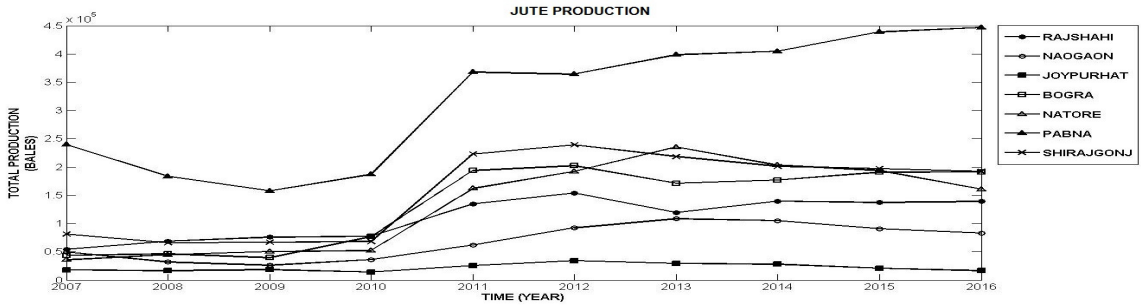



**Figure 12: Graph of Total Production of Potato as Per Districts per Year**

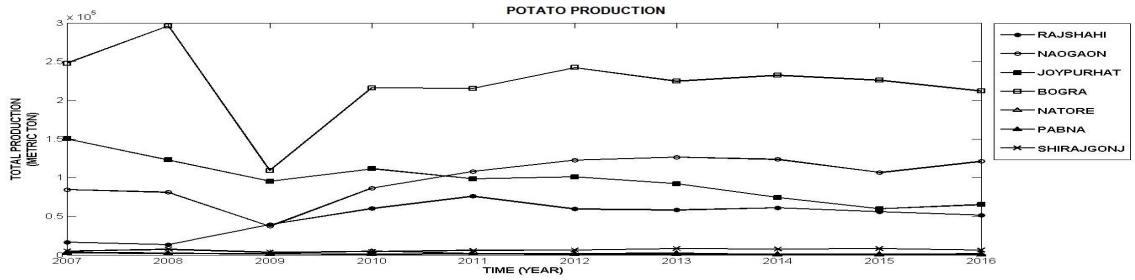
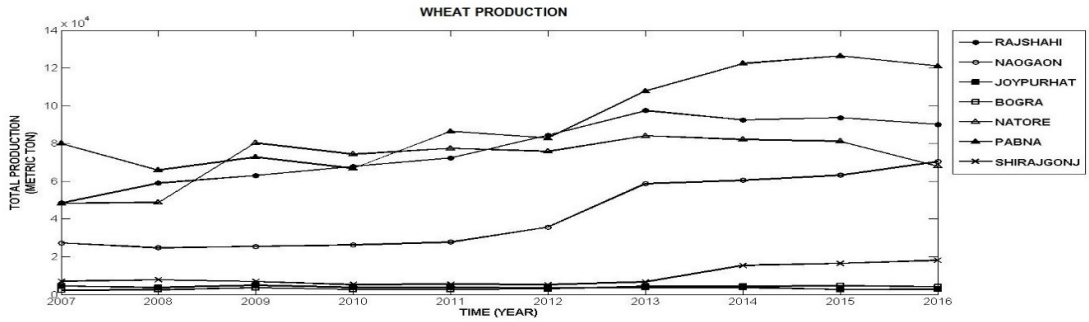



**Figure 13: Graph of Total Production of Wheat as Per Districts per Year**




The figure 5 to figure 13 show the trends of total productions of different major crops as per districts of Rajshahi Division.It was observed that the gross total cumulative increase in production of Local Aman rice was 22717 metric tons, decrease of Local Aush rice was 6362 metric tons, decrease of Local BORO rice was 25 metric tons, increase of HYV Aman rice was 477608 metric tons, increase of production of HYV Aush rice was 205824 metric tons, decrease of total production of HYV BORO rice was 50818 metric tons, increase of jute production was 707872 metric tons, decrease of potato production was 52462 metric tons and increase of wheat production by 156716 metric tons. It was seen from figure 9 and 11 that the production of HYV Aman and jute started increasing since the year 2010. Again, from the figure 13 it was seen that after 2012 the production of the wheat started increasing. If it is correlated with the climate parameters, it was observed from figure 2 and figure 4 that the maximum temperature variable of the year 2010 was having a declining trend in 2010 and the rainfall variable was showing a downward trend. From the figure 3 and 4 it was observed that the minimum temperature variable had an upward trend from the year 2013 and the rainfall had a trend of upward direction.

## 4.3 Crop production Per Unit Area

**Figure 14: Graph of Production of Local Aman per Unit Area as Per Districts**

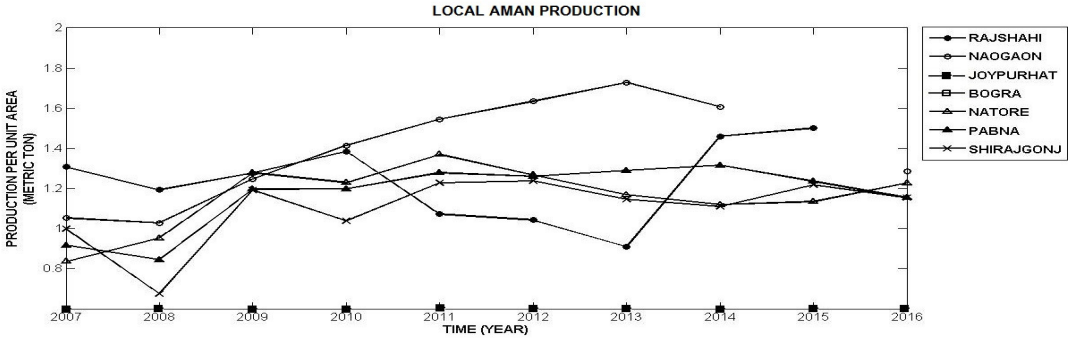



**Figure 15: Graph of Production of Local Aush per Unit Area as Per Districts**

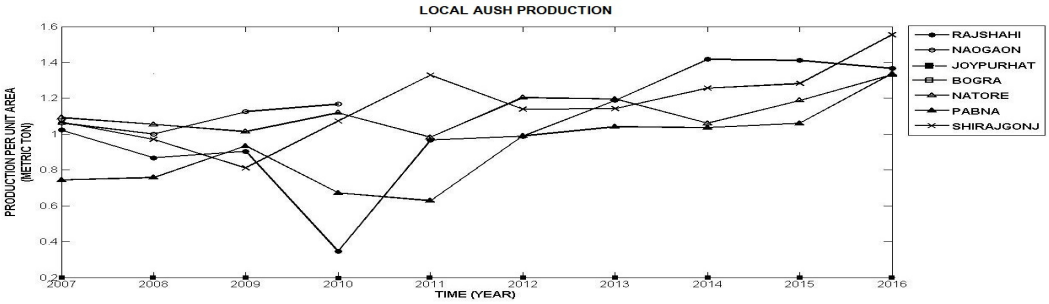



**Figure 16: Graph of Production of Local BORO per Unit Area as Per Districts**

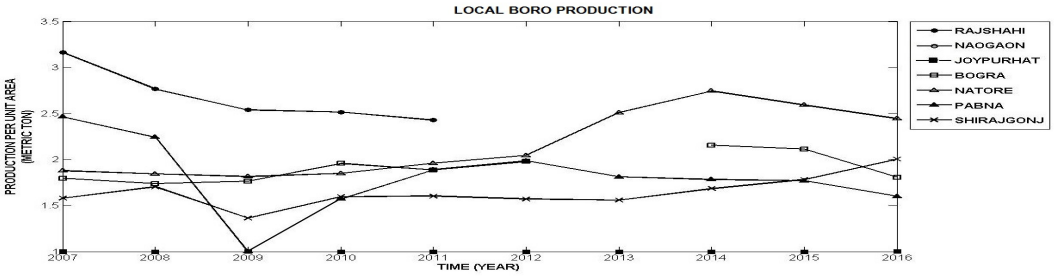



**Figure 17: Graph of Production of HYV Aman per Unit Area as Per Districts**

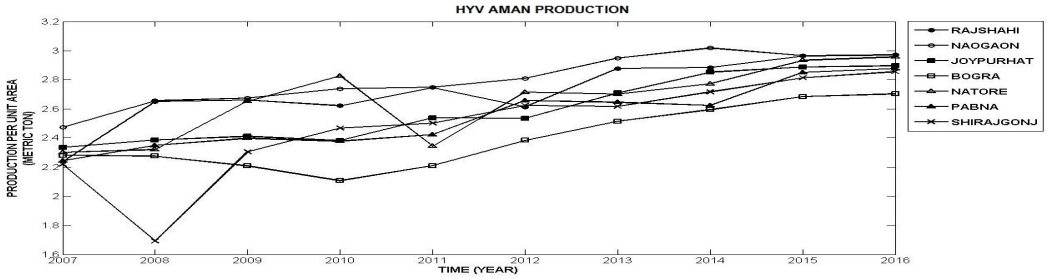


**Figure 18: Graph of Production of HYV Aush Per Unit Area as Per Districts**

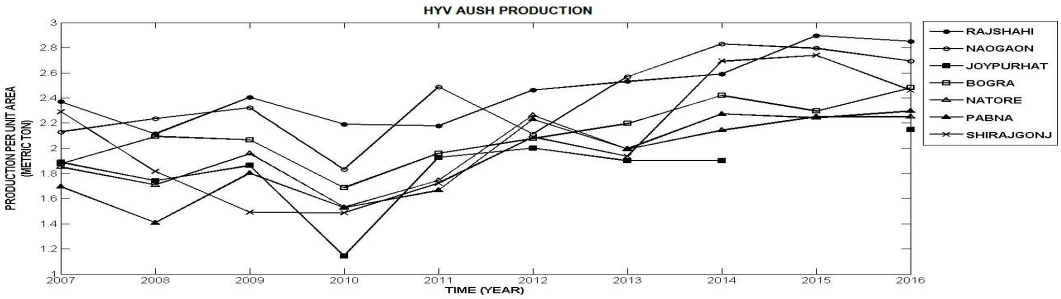



**Figure 19: Graph of Production of HYV BORO Per Unit Area as Per Districts**

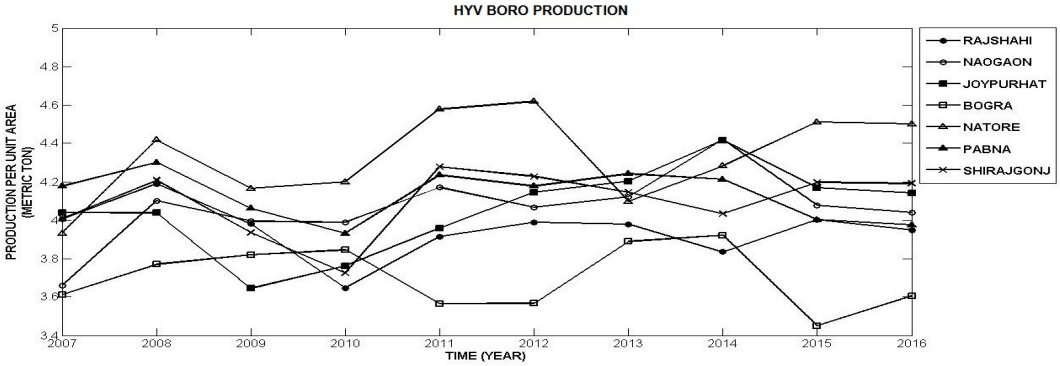



**Figure 20: Graph of Production of Jute Per Unit Area as Per Districts**

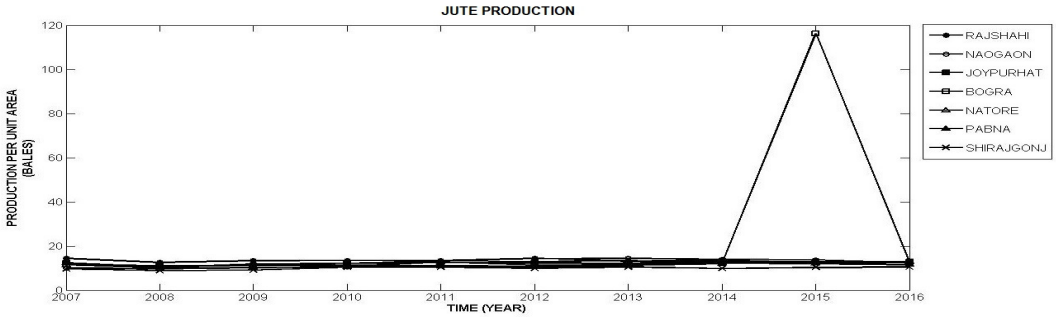



**Figure 21: Graph of Production of Potato Per Unit Area as Per Districts**

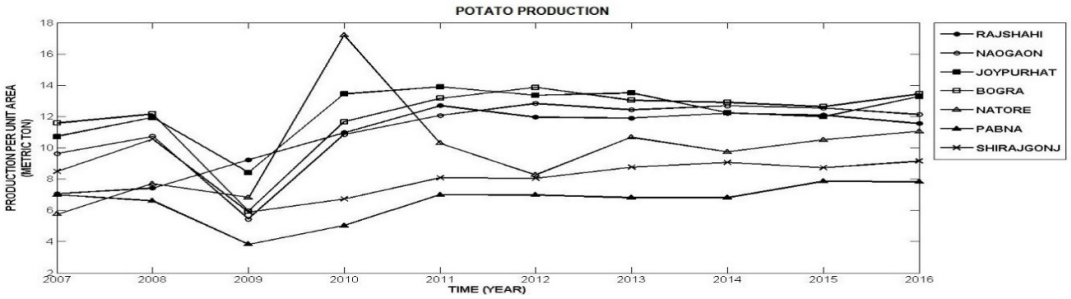
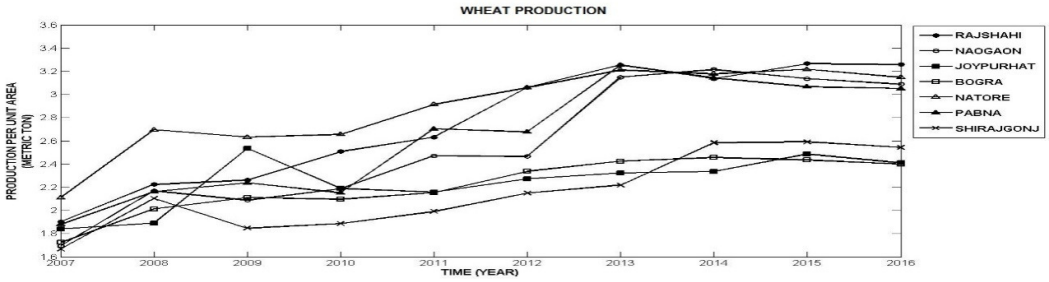


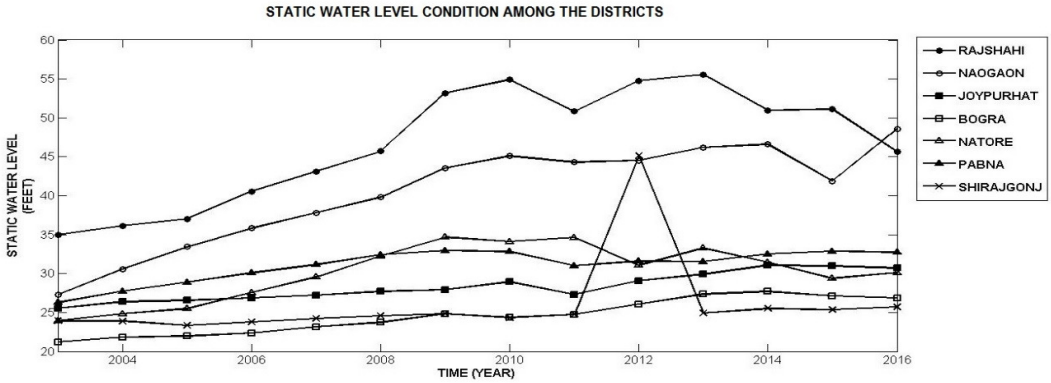
**Figure 22: Graph of Production of Wheat Per Unit Area as Per Districts**




The figures 14 to 22shows the graphs of crop production per unit area as per districts of Rajshahi Division. It was observed from the graphs that the gross crop production per unit area of Local Aman rice was increased by 0.073 metric ton per hectare , Local Aush rice was increased by 0.4 metric ton per hectare, Local BORO rice was decreased by 0.2126 metric ton per hectare, HYV Aman rice was increased by 0.592 metric ton per hectare, HYV Aush rice was increased by 0.44 metric ton per hectare, HYV BORO was increased by 0.138 metric ton per hectare, jute production was increased by 0.49 metric ton per hectare, potato production was increased by 2.6 metric tons per hectare and wheat production was increased by 1.02 metric tons per hectare during the total study period. From figure 19 it was observed that the production of HYV Aush rice, Local Aush rice, HYV BORO rice had a recession in the year 2010. From the climate parameters, it was also observed that there was a drop of monthly maximum temperature and rise of monthly minimum temperature in the same year. The study also reveals that the rainfall parameter also shows a recession in the year 2010.Thus, it can be said that HYV Aman rice, Local Aush rice, HYV BORO rice production per unit area is negatively affected by the climate parameters. At the same time the unit production of wheat, potato and HYV Aman rice had a sharp increase in their production per unit area. Thus, it can be said that they had shown a positive change with the change of climate parameters.

## 4.4 Groundwater Level

**Figure 23: Graph of Static Groundwater Level as per Districts vs Year**




The figure 23 shows the static groundwater level from the ground surface of service wells of DPHE in the study area. It was observed from the graph that the gross average drawdown of groundwater from 2003 to 2016 is 8.16 feet or 2.5 meters in each of the districts of the study area. The deduction can be made that the total amount of water that is lost from the groundwater is:

Volume $=(\text{Area})\times(\text{Drawdown})\times(\text{Porosity})$
$=(2407+3436+965+2920+1896+2372+2498)\times(2.5\times10^{-3})\times(0.4)$
$=16.5\ km^3$

This indicates that instead of having rainfall, total16.5 $km^3$ of water was lost in 7 districts of Bangladesh in last 13 years. This means the total amount of lost water can be more if we consider the other districts of Bangladesh. This also indicates that the rate of the water loosing tendency of these 7 districts per year is 1.27 $km^3$ of water. It was observed from the graph that the groundwater level in Rajshahi and Naogaon district is higher than other districts in the study area. The study regarding the water table is completely new and it quantifies the exact amount of water loss from the study area for the first time.

**Table 1: Summary of Findings and Comments on Findings**

| Serial | Findings | Comments on Findings |
|---|---|---|
| 01 | The average of monthly maximum temperature started to deviate from the normal trend from the 2000 | The flood of 1998 may leave a high amount of hydraulic energy in Bangladesh. The impact of it may initiate the increase of maximum temperature |
| 02 | The slopes of both maximum and minimum average of temperature shown increasing trend since 2000 than since 1975. | The increasing temperature might affect the biotic environment more at present than the previous time. |
| 03 | Except Bogra region, the rainfall show decreasing trends since 2000. | Groundwater recharge might be affected by rainfall. The rainfall may also affect the temperature. |
| 04. | Both maximum and minimum average monthly temperature shows a sharp rise in the year 2010. The rainfall also shows a sharp depression in the same year. | The decrease in the rainfall causes an increase of temperature. |
| 05 | The water table drawdown showed a sharp increase over the year 2010. | A decreasing trend in the rainfall in 2010 was sharp. This may hinder groundwater recharge and causes drawdown. |
| 06 | The total production of the crops Local Aush rice, Local BORO rice and potato decreased from 2007 to 2016 though the production of the production per unit area of Local Aush rice and Potato increased. | Local breeds of the crops are less resilient to weather changes than the high yielding varieties. |
| 07 | The total production of the jute and production per unit area was nearly constant during the study period. | Jute is resilient to weather effects. |
| 08 | The crop production per unit area of the wheat increased with the change of the rainfall and temperature | Wheat grows well in high temperature and dry weather. |
| 09 | Gross amount of water lost in 7 districts in the last 13 years is 16.5 $km^3$ | The water loss may cause drawdown and increase the stresses inside the ground |
| 10 | There is a significant amount of loss of groundwater from 7 districts in each year and the amount is 1.27 $km^3$ of water per year. | The lost water may be threat to increase the land submergence problem if the cumulative withdrawn amount of water is more. |

From the study the different responses of different crops had been found out. These results established the relationship of the crop production, unit crop production and the water loss from the water table with the change of climate parameters in the study area. These results will further help the researcher to study the nature of the crops and the water table. Thus the study on their improvement in particular parameter becomes easy due to these results.

## 5. Conclusion

It was observed from the study that the climate change directly or indirectly affects the crop production and groundwater table. The previous study also showed there are different responses of the crops due to the change of climatic parameters. Thus the study supports the fact that both positive and negative responses of the crops are possible due to climate change. The study also proposes that there are some weather resilient crops which are not affected by the climate change. The consequence of negative change to climate change may be threatening to food and water security of the country like Bangladesh. This study shows only 7 districts of Bangladesh. If the same statistics prevail for all the regions of the country, then the climate change issue needs to be addressed seriously. The necessary steps should be taken by all to decrease the changes in the climatic parameters. The climatic parameters cause changes in the total biomass in a food chain, natural processes, water cycle and ecosystem. These changes, in turn, affect human beings. If steps are not taken to reduce the climate change, severe food and water crisis will develop in near future. Along with these, efforts should be made to create weather resilient crops and technologies to reduce the use of groundwater for irrigation purpose. The alternative measure can be there to march forward to the sustainable future from the end of the government. Investment should be made on the research and projects to reduce the climate change. At the same time, mass people should come forward to raise awareness among the common people to stand against climate change.

The research is very much important for the environmental engineers. The analysis of the meteorological study compared to different time lapse may be a new dimension of study to find out the reasons of drastic change in few areas of study area. The loss of ground water due to over extraction of water is alarming. The reduction of crop production will lead towards the food deficiency. Thus, this study is very much important for the quantification of the losses. The study reveals the quantity of underground water loss rate, change of production of crops and climatic change in the study area. The main application of the study is in the field of water resources and environmental engineering. The quantification was necessary to enhance economic efforts towards greater development. The amount of recharge required to balance the drawdown of the groundwater level, the necessity of increasing production with respect to future population can be determined from this study.

The main limitation of the study is variety of parameters like seed quality, soil quality, effort for the production, political condition, continuous research and development, pest condition, climatic hazards and subsidy in respective field. These are very hard to quantify to determine the exact amount of production with respect to a particular year. The efforts in all these fields can be further considered for further study of the relations of discussing parameters in the study area.

The study can be useful to the researchers of the agricultural field and water resource management of an area. The researchers might find a way to create weather resilience among the crops to meet the future crop demands. The water resource managers might find an alternative of groundwater to reduce the groundwater depletion. The study indicates that the effects of temperature and rainfall in crop production and groundwater table. There might be some other parameters like relative humidity, agricultural efforts, sunlight availability, duration of bright sunlight per day, cloud cover, wind speed which might affect the crop production.

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