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Article

Seasonal Trend Analysis of Climatic Parameters Relation to Impacts on the Crop Productivity of the Major Crops in Bangladesh

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Abstract: In Bangladesh, climate change is a major concern because of its geophysical location and climate dependent agriculture. As sessile organisms, crops plants have to face difficulties often in this environmentally vulnerable country. Therefore, this study examines the seasonal trend of two climatic parameters viz. temperature (maximum and minimum) and rainfall over a period of 1983 to 2013. Besides, this study provides insight into the relationship between climatic parameters and crop yield of two major crops viz. rice and wheat during 1997-2013. To assess the relationship of climatic parameters with time and yield using Pearson correlation analysis, time series data used at an aggregate level. SPSS software utilized for this analysis. The cropping seasons such as rice growing seasons *Aus* (summer rice), *Aman* (autumn rice) and *Boro* (winter rice) exhibited a significant increase in maximum and minimum temperature. Rainfall found to have a decreasing trend for all the seasons. This study also revealed that the climatic parameters had significant effects on rice yield, but these results varied among three rice crops. Maximum temperature had positive effects on all rice yields, especially on *Aus* and *Aman*. Minimum temperature had a negative effect on *Aman* rice yield but a positive effect on *Aus* rice yield. Wheat yield negatively associated with temperature. Rainfall exhibited negative relation with both rice and wheat yield.

Keywords: agricultural productivity; agrometeorology; climate change; crop yield

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1. Introduction

Climate change is a burning global issue though its effects do not evenly distribute throughout the world. Bangladesh will be one of the hardest hits of climate change [1]. The effects of climate change in agriculture are found more evident in Bangladesh where most of the people depend on agriculture. The geographic position and physiographic status of the country caused a variant climatic condition as well as frequent natural calamities like cyclones, floods, and drought. However, climate change exacerbates the climatic condition by causing various natural hazards. Though agriculture achieved an immense progress technologically but still agriculture is susceptible to unfavorable weather conditions. Agricultural productivity entirely depends on climatic factors such as temperature, rainfall, light intensity, radiation and sunshine duration. The agricultural sector becomes more vulnerable to climate change as the climatic factors are changing and near future they will be more erratic. Though Bangladesh faced a lot of natural, economic and social challenges from the achievement of its Independence; expansion and development in the agricultural sector are very remarkable. It will be a hard challenge for Bangladesh to keep pace with the changing climate and continue with the growth in agriculture. Increase temperature, changing rainfall patterns and sea level rise, coupled with increased flooding, frequent cyclones, rising salinity in coastal belts and recurrent drought in the North West region are likely to reduce crop yields and crop production. An IPCC estimation showed that rice and wheat production would be declined by 8 and 32%, respectively by 32% by 2050 (against the base year of 1990) in Bangladesh [2]. As a result, Bangladesh would require a long-term preparation to face the upcoming challenges. In essence, it is important to identify the existing vulnerabilities and future opportunities. However, there is some trend analysis of climatic parameters in Bangladesh but hardly any research on climatic trend concerning crop productivity. This work aims to study the probable correlation between the climatic parameters and crop productions.

2. Materials and Methods

The study was conducted based on the secondary data on climatic parameters and crop production. Maximum temperature, minimum temperature and rainfall were the three relevant climatic parameters selected for the study. Major crops selected for the analysis were rice (*Aus*, *Aman*, and *Boro*), and wheat. The chosen period for the cropping data was 1997 to 2013. The required climatic data procured from 35 meteorological stations of Bangladesh Metrological Department (BMD) present in Bangladesh for the period of 1983 to 2013. Temperatures data included daily, monthly average and mean annual maximum and minimum temperatures for the period from January 1983 to December 2013. It also included the daily rainfall data of the same period. These data were entering and processing in the computer by using MS-Excel programs. Further calculations conducted through this program. These year-wise monthly data then transformed into seasonal data according to the growing period of the crops. The rice growing seasons according to Sarker et al. [3] listed below:

- *Aus* Growing Season: March-August
- *Aman* Growing Season: June-November
- *Boro* Growing Season: December-May

The cropping season for wheat was counted from October to March, as it has the growing period in *Rabi* season.

For Agricultural data, National level yield data of the main food crops (*Aus* rice, *Aman* rice, *Boro* rice, and wheat) in the selected time span collected from various version of 'Statistical Yearbook of Bangladesh' published by Bangladesh Bureau of Statistics (BBS). Department of Agricultural Extension (DAE) was also another source of collecting information. Since yield data found as fiscal year basis, such as 1990- 1991, 1991-1992, 1992-1993, so these data were converted to yearly data as 1990-1991 considered as 1991. Then the data transformed into production per unit such as kg/ha. All the information converted into standard units (kg, ha, mm, °C). After the collection of all the information, they were processed and compiled by MS Excel 2007 and SPSS-20 software. An investigation was taken to identify the probable linkage between the climate variability and change and trend of crop production, so the impact on production can exhibit. For this part of the analysis, the production data of main crops used to identify the trend of production of these crops in response to the maximum temperature, minimum temperature, and amount of seasonal rainfall. Then, an attempt was taken to investigate any possible correlation between the trend of climate change and trend of change in the crop production, to realize any types of likely impacts of climate change on crop production during the specified period. Correlation analyses were used to test the relationship between the variables which done through SPSS-20 software.

3. Results

3.1. Trend of Temperature of Crop Growing Seasons and Their Impact on Crop Production

In this study, three rice-growing seasons namely *Aus* season, *Aman* season and *Boro* season and wheat growing season *Rabi* brought under consideration. In *Aus* season, the average annual maximum temperature had an increasing trend (Figure 1 (a)) which had the correlation coefficient value of 0.565 and this trend was significant at the 0.01 level of significance (Table 1). Minimum temperature data exhibited significant increasing trend having correlation coefficient value of 0.535

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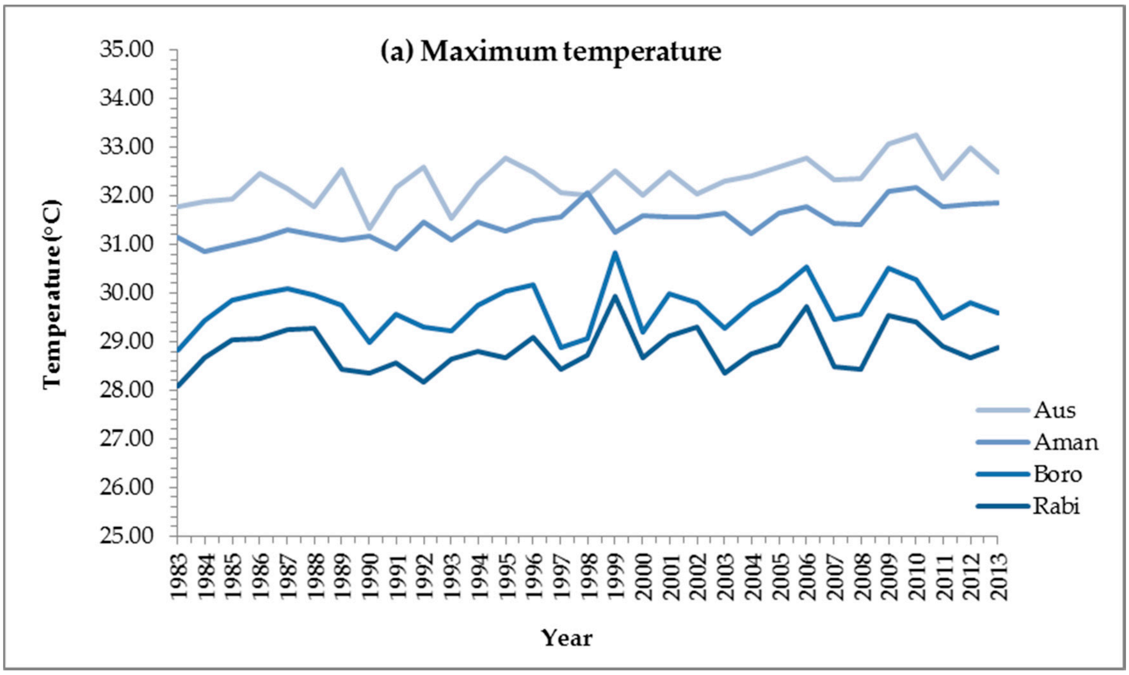
(Table 1). During *Aman* season, maximum temperature data showed a more statistically significant rising trend (Figure 1). The correlation coefficient value for this trend was 0.780 which was statistically significant (Table 1). In *Boro* season, there observed an increasing trend in both maximum and minimum temperature (Figure 1). However, the trends were not statistically significant. The correlation coefficient values were respectively 0.219 and 0.339 (Table 1). Throughout the *Rabi* season, there was also evident of statistically non-significant increasing trend in maximum and minimum temperature.



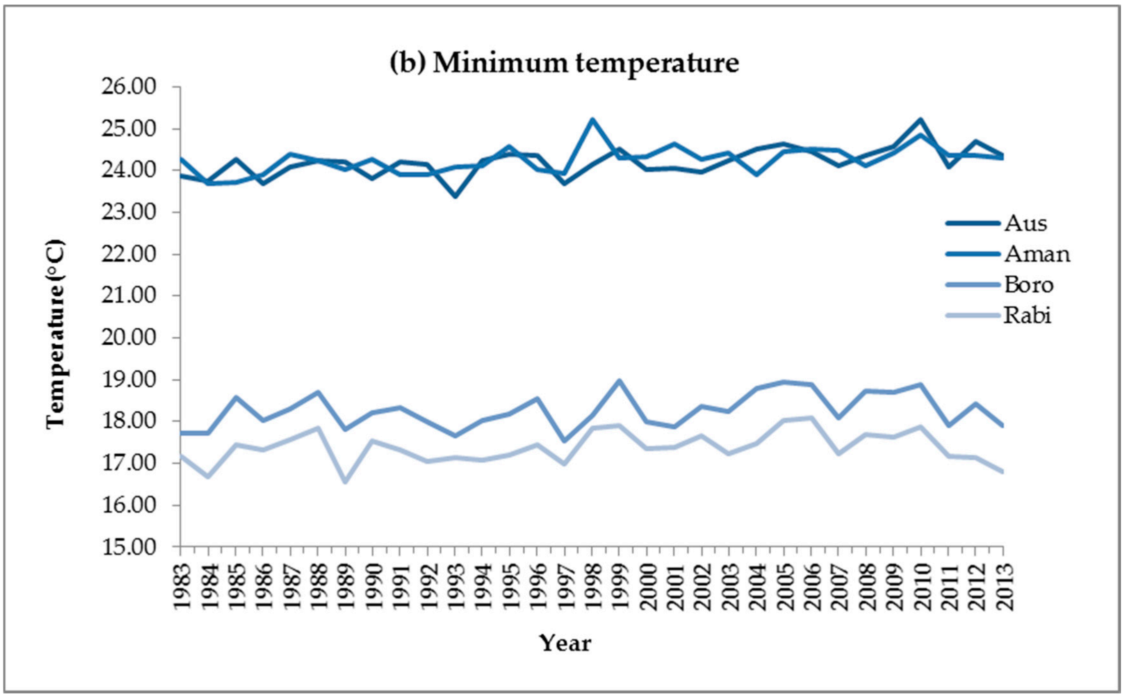


Figure 1. (a, b) Trend of average maximum and minimum temperature (°C) in different crop growing seasons (1983-2013).

Table 1. Correlation results for temperature with time for different growing seasons.

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Season	Climatic parameter	Correlation coefficient	R^2
Aus	Maximum Temperature	0.565**	0.362
	Minimum Temperature	0.535**	0.315
Aman	Maximum Temperature	0.780**	0.780
	Minimum Temperature	0.472**	0.222
Boro	Maximum Temperature	0.219	0.058
	Minimum Temperature	0.339	0.119
Rabi	Maximum Temperature	0.237	0.055
	Minimum Temperature	0.221	0.059

** and * represents 0.01% and 0.05% level of significance.

In the study, there also examined the relationship between yield and climatic parameters. The effects of the climatic parameters on crop yield examined through correlation analysis.

Table 1. Correlation results for temperature with crop yield.

Crop yield	Climatic parameter	Correlation coefficient	R^2
Aus Rice	Maximum Temperature	0.571*	0.941
	Minimum Temperature	0.499*	0.941
Aman Rice	Maximum Temperature	0.553*	0.815
	Minimum Temperature	-0.557	0.815
Boro Rice	Maximum Temperature	0.319	0.743
	Minimum Temperature	0.093	0.743
Wheat	Maximum Temperature	-0.212	0.249
	Minimum Temperature	-0.431	0.249

** and * represents 0.01% and 0.05% level of significance.

There observed a strong positive correlation between *Aus* rice yield and maximum temperature (Figure 2a) which had a correlation coefficient value of 0.571 and this correlation were significant at 0.05% level of significance (Table 2). With minimum temperature, the yield of *Aus* rice also exhibited a strong positive correlation during the discussed period (Figure 2b). The correlation coefficient value of this correlation was 0.499 which was significant at 0.05% level of significance (Table 2).

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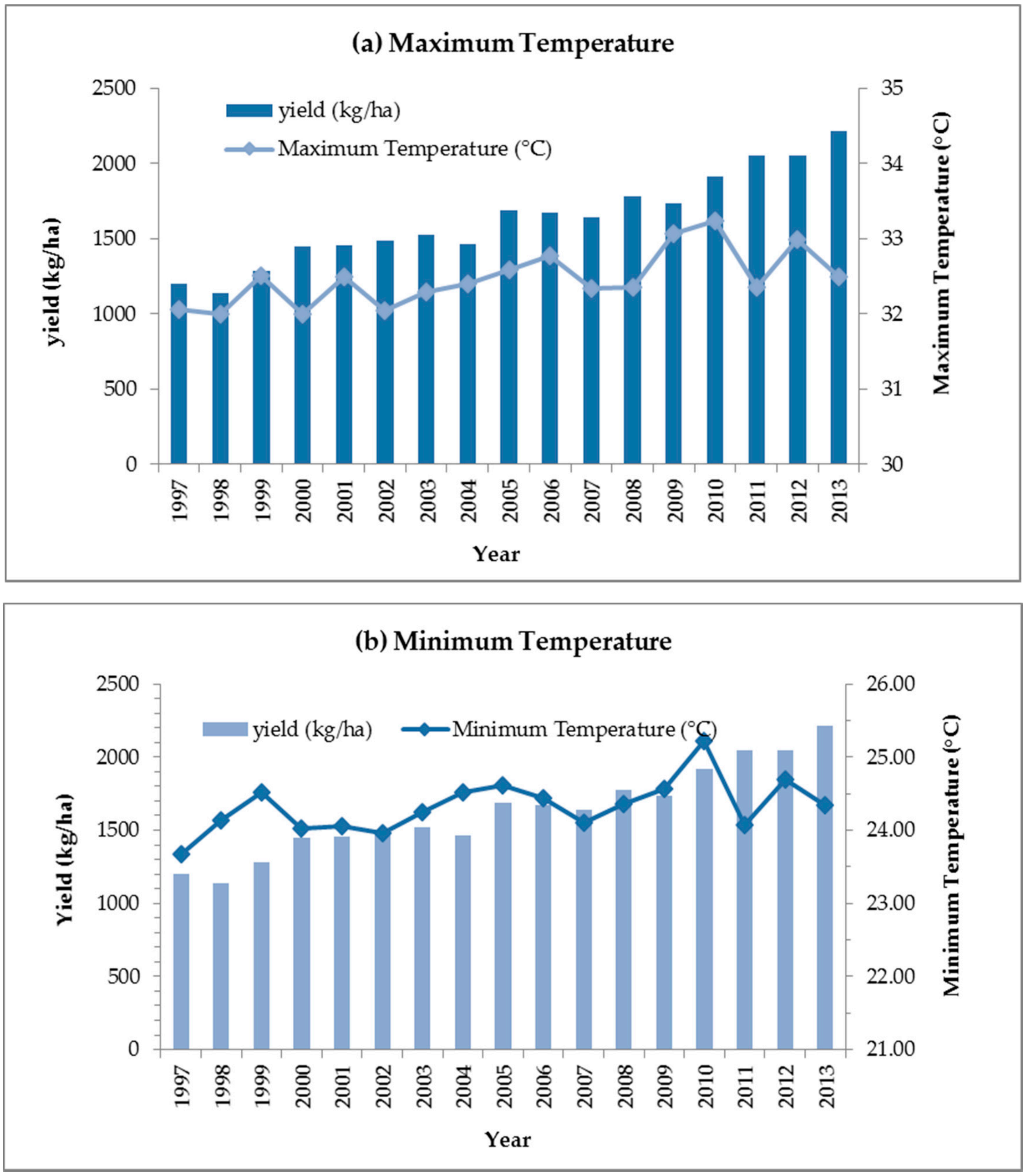
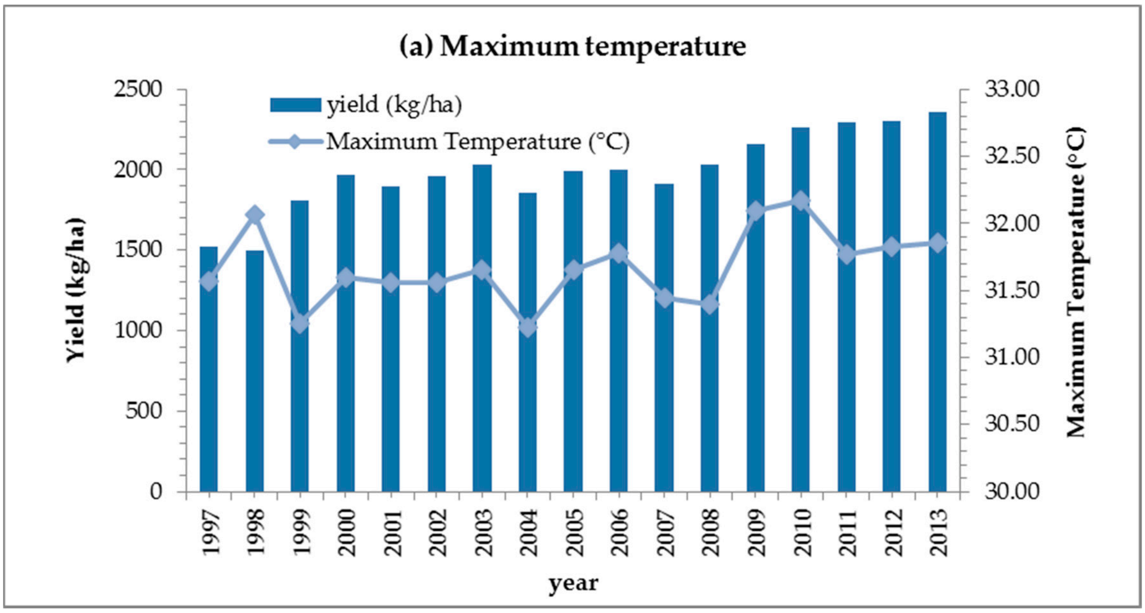


Figure 2. (a,b) Annual variation of *Aus* yield in response to maximum and minimum temperature (°C) during 1997 to 2013.



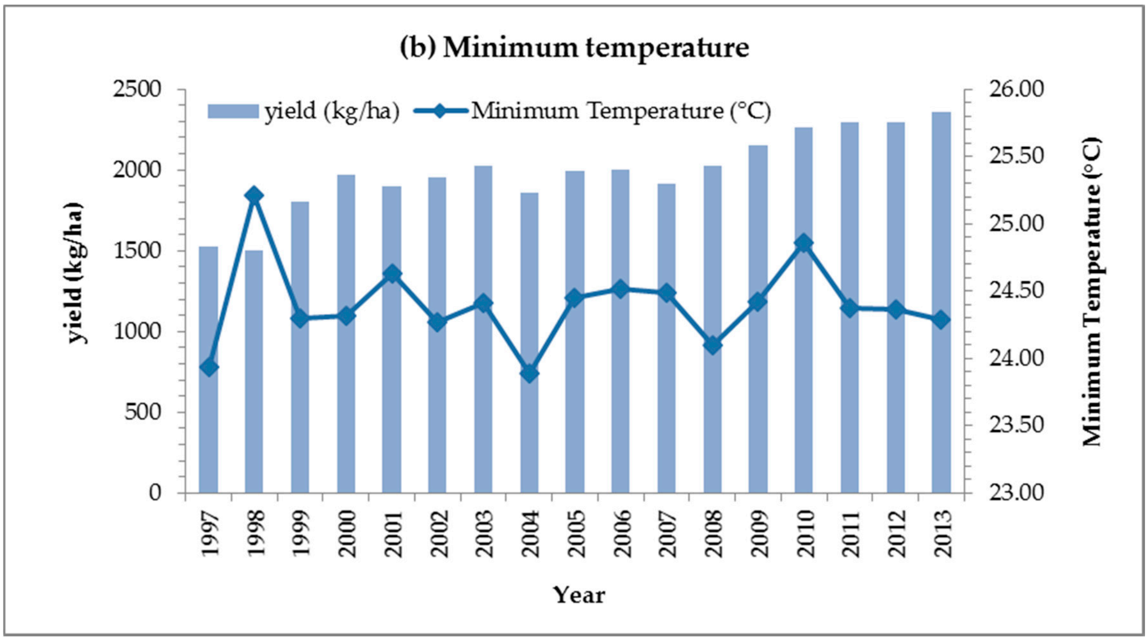


Figure 3. (a,b) Annual variation of *Aman* yield in response to maximum and minimum temperature (°C) during 1997 to 2013.

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The contributions of the climatic variables to the *Aman* rice were varied. The relationship between *Aman* yields and maximum temperature showed a strong positive correlation (Figure 3a). The correlation coefficient value of this relationship was 0.553 which was significant at the 0.05% level of significance (Table 2). On the other hand, minimum temperature observed a negative correlation with *Aman* yield (Figure 3b) which had correlation coefficient value of −0.557 but this relationship was not statistically significant (Table 2).

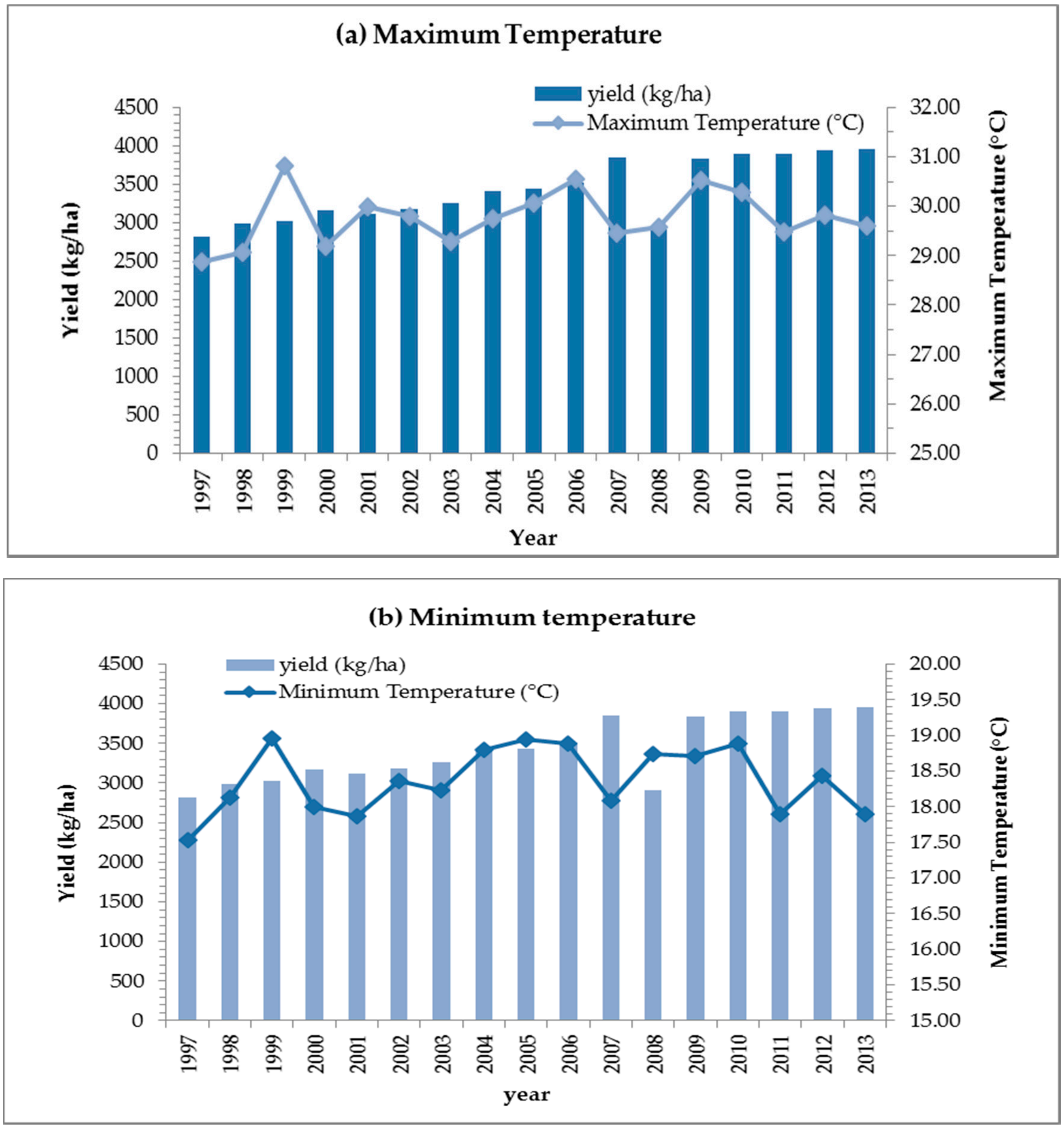

Figure 4. (a, b) Annual variation of *Boro* yield in response to maximum and minimum temperature during (1997-2013).

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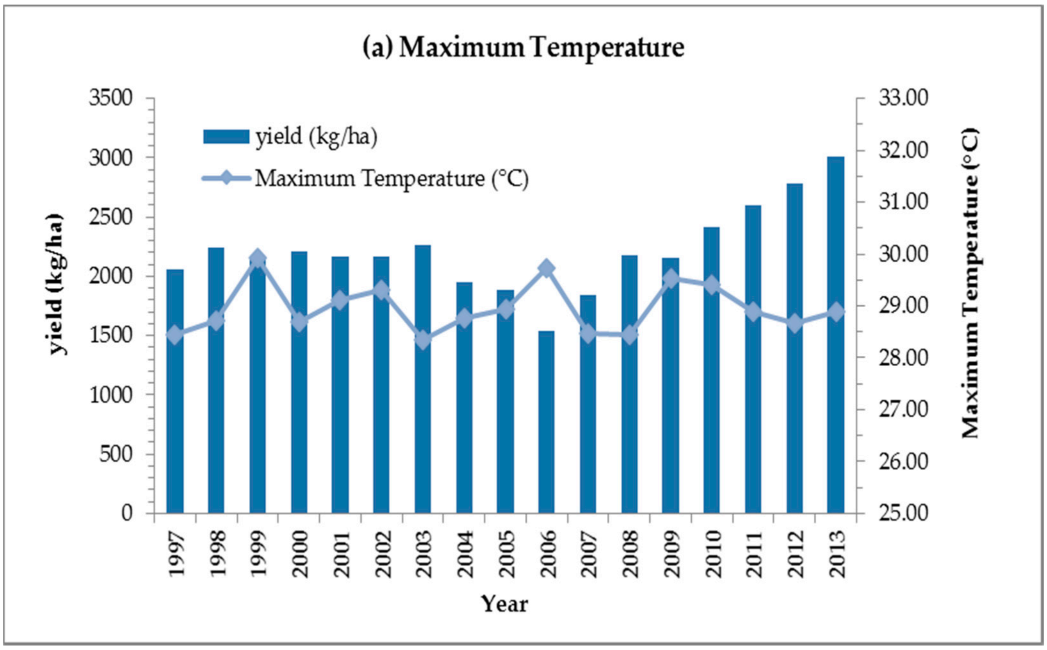
The yield of *Boro* with response to maximum temperature exhibited a nearly strong positive correlation (Figure 4a) which had the correlation coefficient value of 0.319, but this relationship is not statistically significant. In the case of minimum temperature, (Figure 4b) correlation coefficient value indicates a non-significant relation with *Boro* yield (Table 2).



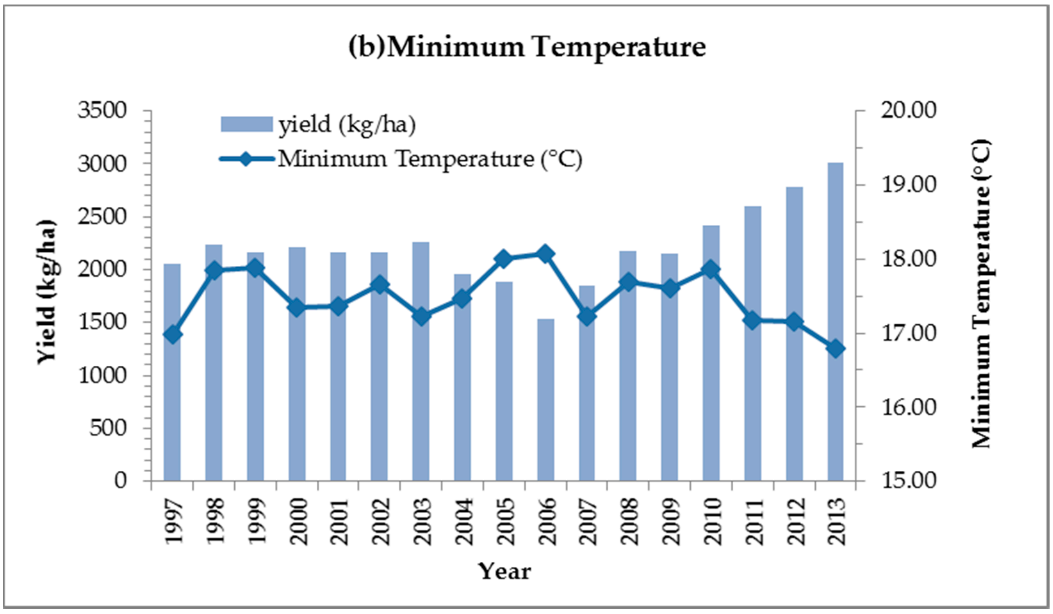


Figure 5. (a,b) Annual variation of Wheat yield in response to maximum and minimum temperature during (1997-2013).

The contributions of the climatic variables to the wheat yield were not very significant (Table 2). Though the effects of all the climatic parameters exhibited a negative correlation with yield, the relationship was not statistically significant (Figure 5).

3.2. Trend of Rainfall of Crop Growing Seasons and Their Impact on Crop Production:

The rainfall for all season showed a decreasing trend with fluctuations. In *Aus* season the rainfall trend showed a negative correlation with the time that represents that the average annual rainfall had a downward trend (Figure 6). The correlation coefficient value for this trend was −0.242 which was not statistically significant (Table 3). In the case of *Aman* season, the study had an evident of negative correlation of rainfall with time which indicated the decreasing trend of rainfall (Figure 6), but the trend was not statistically significant which had correlation coefficient value of −0.133 (Table 3). Likewise, the other season *Boro* and *Rabi* the annual seasonal rainfall exhibited a decreasing trend which was not statistically significant (Table 3).

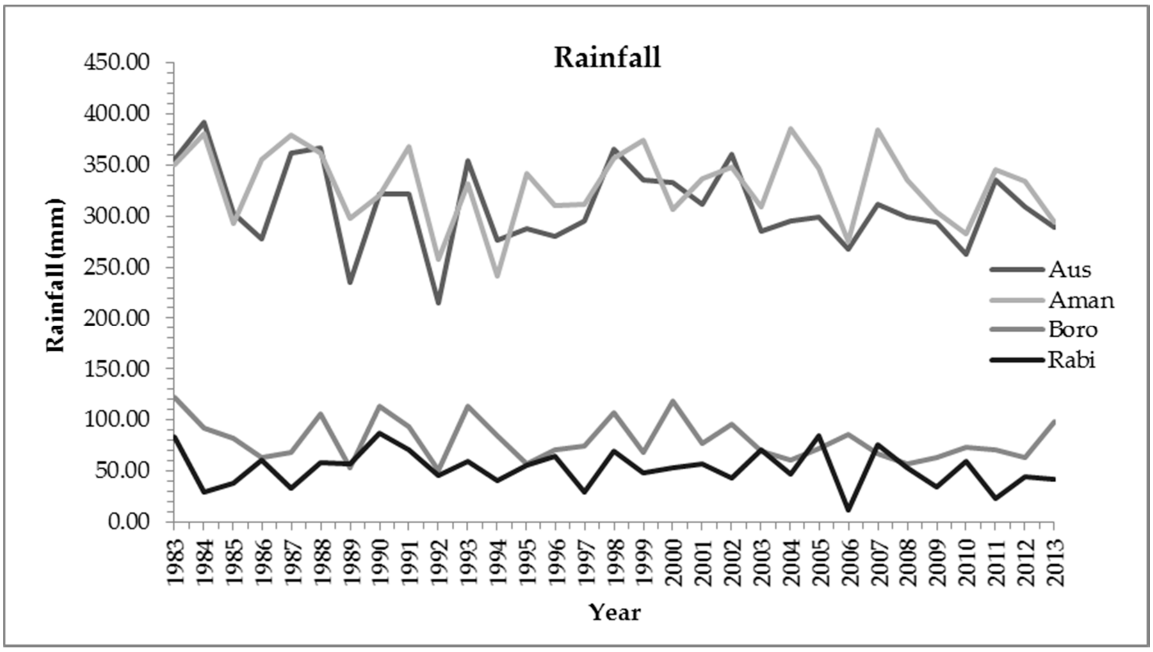


Figure 6. The trend of average rainfall (mm) in different crop growing seasons (1983-2013).

In the study, there observed a significant decrease in rainfall which could affect the *Aus* and *Aman* production which depends on rain. The yield of *Aus* rice with response to rainfall was found to show a negative correlation (Figure 7).

Table 2. Correlation results for rainfall with time for different growing seasons.

Season	Climatic parameter	Correlation coefficient	R^2
Aus	Rainfall	−0.242	0.054
Aman	Rainfall	−0.133	0.017
Boro	Rainfall	−0.231	0.075
Rabi	Rainfall	−0.168	0.034

** and * represents 0.01% and 0.05% level of significance.

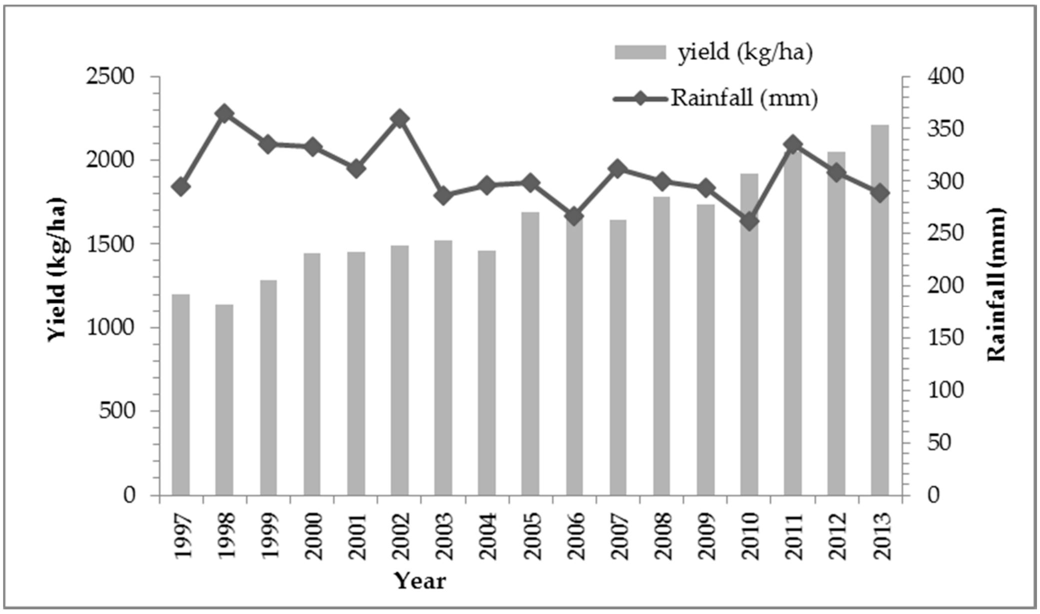


Figure 7. Annual variation of *Aus* yield in response to rainfall (mm) during 1997 to 2013.

In this case, the correlation coefficient value was −0.412 which was not statistically significant (Table 4). Although the rainfall does not appear to be statistically significant, it negatively associated with the *Aus* rice yield. There observed a strong negative correlation between *Aman* rice yield and rainfall (Figure 8) which had a correlation coefficient value of -0.603 and this correlation was significant at 0.05% level of significance (Table 4).

Table 3. Correlation results for temperature with crop yield.

Crop yield	Climatic parameter	Correlation coefficient	R^2
Aus Rice	Rainfall	-0.412	0.941
Aman Rice	Rainfall	-0.603*	0.815
Boro Rice	Rainfall	-0.115	0.743
Wheat	Rainfall	-0.042	0.249

** and * represents 0.01% and 0.05% level of significance.

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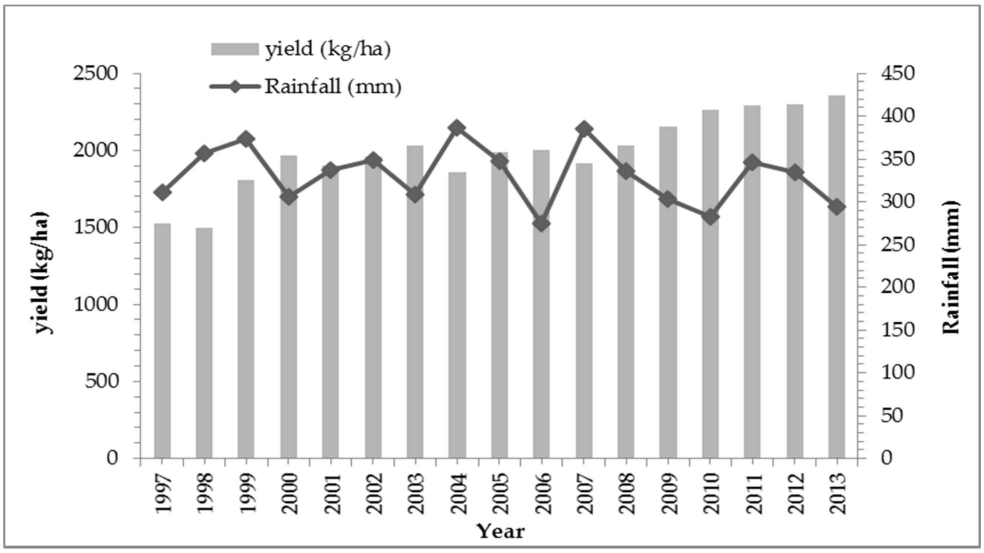

Figure 8. Annual variation of *Aman* yield with response to rainfall (mm) during 1997 to 2013.

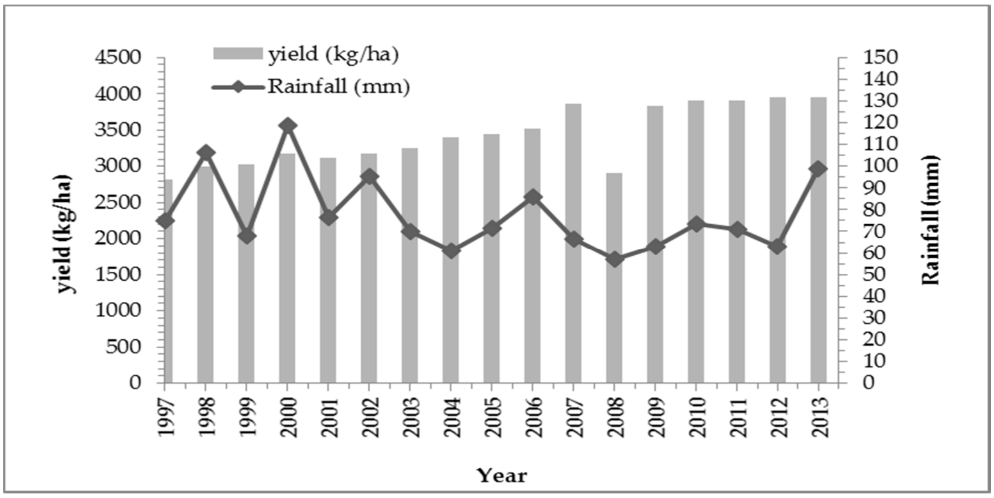

Figure 9. Annual variation of *Boro* yield in response to rainfall (mm) during 1997 to 2013.

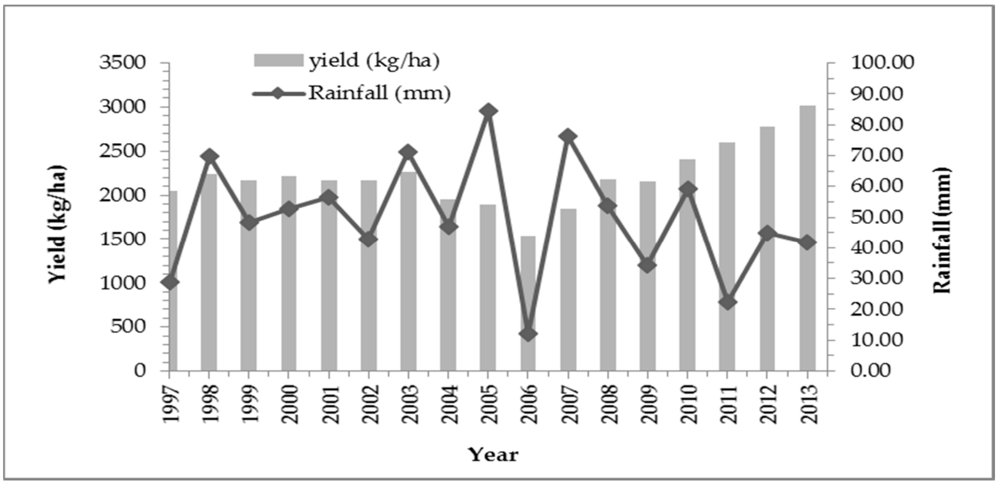

Figure 10. Annual variation of Wheat yield in response to rainfall (mm) during 1997 to 2013.

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The yield of *Boro* rice showed a weak negative correlation with rainfall (Figure 9). The correlation coefficient value was −0.115 which was not statistically significant (Table 4). *Boro* rice is grown using irrigation during dry season along with increasing scientific cultivation techniques. So the effect of rainfall on *Boro* production is less. There observed a negative correlation between wheat yield and rainfall (Figure 10) which had a correlation coefficient value of −0.042 and this correlation was not statistically significant (Table 4).

4. Discussion

Every crop requires an environmental condition under which its life cycle can complete, known as critical temperatures, are very necessary for crop production [4]. Though critical temperatures play a primary role in the vegetative and reproductive growth of a plant, it differs among different growth stages of the plant. There is a defined range of maximum and minimum temperatures for each species, considering the observable growth. Rising temperatures up to the optimum level of the plant help to increase the vegetative growth but the high temperatures hinder the pollination, fertilization or grain formation at the reproductive stage [4]. However, in the study, the rising temperatures are observed in the different crop growing season, *Aus* and *Aman* season had a significant increase in both maximum and minimum temperature. In some years it was above 33° C. Generally rice plant is sensitive to temperature stress, range from 20° to 30° C is considered optimum for the rice growth. As rice has an origin in tropical and subtropical climate, so the development of rice plant is hindered below 15°C as well as the higher temperature have an adverse impact on crop growth [5]. Nowadays, rice-cultivating regions of the world already existed the optimal limit for rice growth which considered about 28/22° C. In this situation, the increase in temperature will affect the rice growth and yield. In a study, it showed that 1°C increase in daytime maximum/nighttime minimum temperature from 28/21° to 34/27° C, rice yield was decreased about 7-8% [5].

The rise in temperature and change in rainfall pattern are two important indicators of the changing climate. Variation caused by these climatic elements imposed a wide range of ramification in the agricultural sector. It showed in the recent time's research that the intensified storm, floods, drought and other severe weather event are the result of rising temperature [5]. The recurrent drought and devastating floods are the consequences of the changing climatic condition [6]. Bangladesh is vulnerable to drought due to its geophysical location but varying rainfall pattern enhance the effect of drought. These droughts are agricultural drought, defined as the deficit water availability to crops [6]. From November to May, when rainfall is low, Bangladesh experienced a dry season about seven months. Therefore, droughts occur in pre- monsoon (October to May) and post-monsoon Season [7]. In this extended dry period *Rabi* and *pre-Kharif* drought affected the agricultural sector most [6]. It needs to mention that in Bangladesh, there is three crop growing seasons which are locally known as *pre-Kharif* (16 march-30 June), *Kharif* (1 July – 15 October) and *Rabi* (16 October -15 March) [8]. The effects of dry days accompanied with higher temperature and low moisture availability affect the *Boro*, Wheat, and *Aus* yield. However, the effects are more drastic on rice production [6]. The critical reproductive stages of transplanted *Aman* rice severely affected by the shortage of rainfall during December. Consequently, the germination and vegetative stage of *Boro* and wheat are also drastically impacted by drought during *Rabi* season. *Aus* production is also affected by moisture stress [9]. It reported that in Bangladesh, about 0.45 million ha of land are distressed severely by *Rabi* season drought and during pre-Kharif and Kharif season about 0.40 and

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0.34 ha of land, respectively [8]. During the study period, Bangladesh faced some severe drought in the year 2000, 2006 and 2009. It reported that during the drought of 2006, the crop reduction in the northwestern part of Bangladesh was about 25-30 % [8]. In the study, it observed that the yield of *Boro* and wheat was less compared to other years considered in the survey with a high maximum and minimum temperature (Figure 4). Rainfall during *Rabi* season tended to zero in that year. However, in the recent years, *Boro* is cultivated in entirely irrigated condition [10]. So, the effect of climatic parameters was found insignificant during the investigation period. To mitigate the adverse effect of drought use of irrigation both surface and ground water became ubiquitous in last few years. In 1985, the contribution of groundwater was 21% whereas in 2008; it reached 79% [11]. Governmental statistics showed that for the cultivation of *Boro* rice crop (which are irrigation-dependent) about 3 million ha (out of 8.02 million) of net cropped area are taken under irrigation during the dry season. However, the extensive use of groundwater accelerates the severity of drought. Typically, the rainfall during monsoon season helped to the restoration of ground water level but when the rainfall is low in it was difficult to replenishment of ground water level. Irrigation is done using deeper pump operated tube wells which could cause the depletion of ground water level and would turn the irrigated land harder. Though irrigation minimized the drought effect instantly, the consequences of groundwater depletion would impose a significant threat to the agricultural system. The ground water depletion in the dry season in northwestern part of the country is alarming as the Ministry of Environment and Forests of Bangladesh (MoEF) (2002) reported that the ground aquifer level had gone lower by 8.95 to 18.56m in that area [7].

In the study, it revealed that seasonal rainfall had a decreasing trend (Figure 6). The distribution of rainfall pattern is erratic which had an adverse impact on the crop productivity. Along with changing rainfall pattern, natural calamities like floods, cyclones which are very much related to rainfall had worsened the effect. Bangladesh has a long history of natural catastrophes. Among them, the effect of floods in 1998, 2004 and 2007 are important during the study period. It is evident from the study that in the year 1998 rainfall was higher than the other years of the selected time and the yield of *Aus* (Figure 7) and *Aman* (Figure 8) rice were comparatively less. It was due to the devastating flood in 1998. The Ministry of Agriculture reports that about 1 million hectares of the harvestable crop lost as a direct effect of the flood. As a consequence of this longest flood, the harvesting of *Aus* rice hampered, plantation of *Aman* rice delayed. In the flood-affected areas due to the loss in *Aus* and *Aman* yield, the food supply situation was extremely dangerous [12]. In the Study, there also observed a decrease in the *Aus* and *Aman* rice production during 2004 along with increasing rainfall. The cause of this decline is merely the flood commenced in 2004. Annual harvestable rice crop in the northwest districts of Bangladesh destroyed due to early flooding. Standing crops along with seedbed faced a massive damage as a consequence of this prompt and quick flood which submerged approximately 1.1 million ha of crops. 400,000 Metric Tons of *Aus* rice 600,000 Metric Tons of *Aman* rice lost due to the flood which had a significant impact on the total production of the country [13]. It observed from the study that there was a decrease in production of *Aus* and *Aman* in 2007 and also a reduction in *Boro* production during 2008. In 2007, Bangladesh experienced a devastating cyclone named Sidr along with a flash flood. The combined effects of Sidr and flood reduced the overall yield. As a consequence of Sidr about 1.51 million ha of agricultural land was damaged which was officially reported by the Ministry of Agriculture; out of which 1.12 million ha was fully and 1.39 million ha was partially destroyed. The report also confirmed that total

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1.08 million ha of cropping land was destroyed, which was 71% of total damaged cropped area. Cropland was also affected by the saline water inundated by storm surge. So, saline tolerant varieties survived only. Tidal waves completely washed away about 15–20% of the *Aman* rice. The report also showed that *Aman* rice destroyed about 1.3 million tons and *Boro* seedlings were also damaged [14]. Destruction of *Boro* seedlings was one of the main reasons for the reduction in the *Boro* production in 2008.

5. Conclusions

The objective of the study was to estimate the seasonal changes in the climatic variables and to investigate if there were any possible impacts on crop productivity. The study revealed that the trend of climatic parameters of different crop growing season had altered. Temperature found to have an increasing trend whereas rainfall had a negative trend. In the case of impacts on crop productivity, this study showed that temperature had a positive impact on crop production especially on *Aus* rice but a negative impact in response to rainfall. However, these effects became more drastic when accompanied with different natural disasters like flood, cyclone, and drought. Bangladesh has an agro-based economy and agricultural productivity highly depend on climate. So the temperature and rainfall patterns are of great importance in the country. Over the past few decades, these patterns are changing, and a very high temperature has been predicted, especially for years 2050 and 2070 due to climate change. These predictions now start to pose into reality. The alteration of climate will threaten the crop productivity remarkably. It is important to monitor the variations in the climate and their effect on crop productivity to cope up with these changes. This study based on secondary data sources which might not be able to render a practical implementation which could be helpful for the farmers. It is hard to produce any regional variation of climatic parameters in response to crop yield in the country like Bangladesh which has a different agro-ecological zone. Therefore, it is essential to conduct region-specific research to depict the actual scenario of climate change. Crop modeling, field level research, stress management should be carried out as the secondary data showed a clear indication of an alteration of climate and their stressful impacts on crop productivity.

Author Contributions: N.J.R. conceived and designed the experiment. M.H. and M.F.H. planned the experiments and helped in analyzing data. N.J.R. and M.H. wrote the paper. M. H. edited the paper. All authors read the paper and approved the final version.

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Conflicts of Interest: The authors declare no conflict of interest.

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