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Trend Analysis of Different Climatic Parameters Related to Rice Production in North Eastern Part of Bangladesh

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Abstract Rice production in north-East part of Bangladesh is highly vulnerable to climate variability. Thus the present study has been conducted in Sylhet region, in the district of Sylhet, Sunamgonj, Hobiganj & Moulvibazar, Bangladesh to analyze the trend of various climatic parameters on which the production of rice depends. The average seasonal climate change trend was found that, the tendency of temperature (mean, maximum and minimum) rainfall, sunshine hours and wind speed was increasing for the Ausseason, but the tendency of relative humidity was decreasing and for the Amon season the tendency of temperature (mean, maximum and minimum) rainfall, sunshine hours and wind speed was increasing, the tendency of relative humidity was mostly decreasing for the Boro season. The trend of Aus, Amon and Boro production for Sylhet region is increasing which indicates there is a positive linear relationship between Aus, Amon and Boro production with time. In multiple regression analysis with Rice production and climatic variables, it is revealed that, 80.2%, 81.5%, and 62.3% of the variance in Aman, Aus, and Boro respectively.

Keywords Rice Production, Climate Parameters, Aus Season, Amon Season, Boro Season

1. Introduction

Bangladesh is the sixth biggest rice-producer country in the world. In the last three to four decades, great efforts in rice research and agricultural innovations were made to increase rice production, and it has increased to about 48 million tons in 2009 from about 17 million tons in 1970. The country is also said to have among the highest per capita consumption of rice (about 170 kg annually), and its food safety and economy mainly depend on good production of rice [1].

Although the success in rice production, the country still faces many challenges in the agricultural sector due to predict climate change impacts and always growing population. Effects like temperature rise, erratic rainfall, uncertain weather as well as great climatic events like frequent cyclones, prolonged flood, sea level rise and others, are already being felt in Bangladesh [1]. Rice production is the most vulnerable to the impacts of climate variability and change. In the last few decades, significant changes in climate are observed, which affected the rice production. Therefore, a good number of studies had been conducted on this issue. However, most of those were emphasized on the global warming matter. Hence, an attempt has been made to find the close relationship between the climatic components and yield as well as among climatic components to predict and forecast the impacts of climatic change on the rice production in Sylhet region. The adoption of a farming system can be treated successful only if it is ecologically viable, as well as economically profitable. All crops have their critical and optimum climatic requirements. Analysis of climatology at regional scale is most useful for the solution of practical agricultural problems. The climatic information serves not only as guide to the selection of the proper sites for a given crop but also the most desirable period for sowing and harvesting [2]. In Bangladesh, such study has been done to analysis the pattern and trend of rainfall, temperature, solar radiation, relative humidity, heat budget and energy balance on different ecosystem, and meteorological application on rice production, response of weather on wheat yield. But past records prevailed that very few study has done to analysis the relationship between climatic parameters and rice production.

2. Climate parameters and their Phenomena in Bangladesh

Climate is one of the most important factor to have a profound impact on food availability and socio-economic conditions of the people in general and farming community in particular. The average condition of the atmosphere near the earth's surface over a long period of time, taking into account temperature, precipitation, humidity, wind, cloud, barometric pressure etc. environmental location and physical settings govern the climate of any country [4].

It was found that Bangladesh experienced drought condition having disastrous crop-failure. Drought occurs occasionally, mainly in the western part of the country when pre-monsoon and monsoon rains start late or less than normal. Islam *et al.* (1997) observed that grain yield of *T. aman* rice was affected on the amount and distribution of rainfall during lean period of October to November. Yield losses occurred due to higher percent of sterility by drought followed by less spikelet number per panicle and reduced 1000 grain weight [4].

3. Study Area

Considering the scope of obtaining required data, Sylhet region is selected to conduct the study, which is in north eastern part of Bangladesh and located between the latitudes of 20°34N- 26°38N and longitudes of 88°01E-92°41E covered an area of 12,569 km^2. It is bounded by India to the North, East and South, Mymensingh and Kishorganj to the West.

Climate is not invariant in greater or less degree, it is ever changing. In all points of the world, one-year, one decade, one country differs from another. Temperature variations from year to year and from epoch to epoch generally increase towards high latitudes. Rainfall variations are greatest in low latitudes, where the heaviest individual falls occur, rain and snowfall varies most in and near the warm and cold deserts of the Polar Regions [5].

The year to year difference of crop yield is mainly due to the fluctuations in weather. The most important component of weather is the amount of rainfall and its distribution on during the life span of plant growth. Islam (1995) also found a minor change in the physical and or climatic environment also carried a large change in plant life and plant communities [6-7].

Among the climate parameters the most important one is rainfall. Rainfall varies not only with time but also with geographical area and altitude in space and is a continuous random variable [8]. This is the free source of water directly and most uniformly available to a crop and the foliage. But it can be utilized most efficiently by reducing its harmful effect and increasing beneficial outcomes, which requires planning of agricultural activities in such a way that the beneficial effect of the rainfall is maximized and dangerous effect minimized [9].

According to WMO (1999) atmosphere is energetically the most active and most rapid varying component of climate, while the ocean response rather slowly. Global temperature in 1998 was the warmest since reliable instrument records began 139 years ago. The second warmest year was 1997, with the five global averages being in the 1980's warmest year. It is evident that the global mean surface air temperature has increased by .3°C to .6°C over the last 100 years [5]. Karmakar and Shrestha (2000) reported that the present 5-year running average trends of climate elements continue, the annual mean maximum temperature was likely to rise by 0.48°C and 0.88°C by 2050 and 2100 years respectively whereas the annual mean minimum temperature was likely to decrease by 0.66°C and 0.11°C by 2050 and 2100 respectively. But the overall annual mean temperature over Bangladesh was likely to increase by 0.21°C and 0.39°C by 2050 and 2100 years respectively. The annual total rainfall over Bangladesh is likely to increase by 304.72 mm and 588.65 nun b 2050 and 2100 years respectively [10].

March and April are the least humid months over most of the western part of the country. The lowest average relative humidity (57%) has been recorded in Dinajpur in the month of March. The least humid months in the eastern areas are January to March. Here the lowest monthly average of 58.5% has been recorded at Brahmanbaria in March. The relative humidity is everywhere over 80% during June through September. The average relative humidity for the whole year ranges from 78.1% at Cox's Bazar to 70.5, at Pabna [11].

The solar radiation requirement of a rice crop differs from one growth stage to another. Shading during the vegetative stage only slight affected yield and yield components. In contrast, shading during the reproductive and ripening phases caused significant reductions in yield by reducing panicle number, final spikelet number, grain weight etc. Kumar and Tripati (1991) reported that direct sun under drought condition reduced leaf water potential and influences canopy temperature of wheat [13].

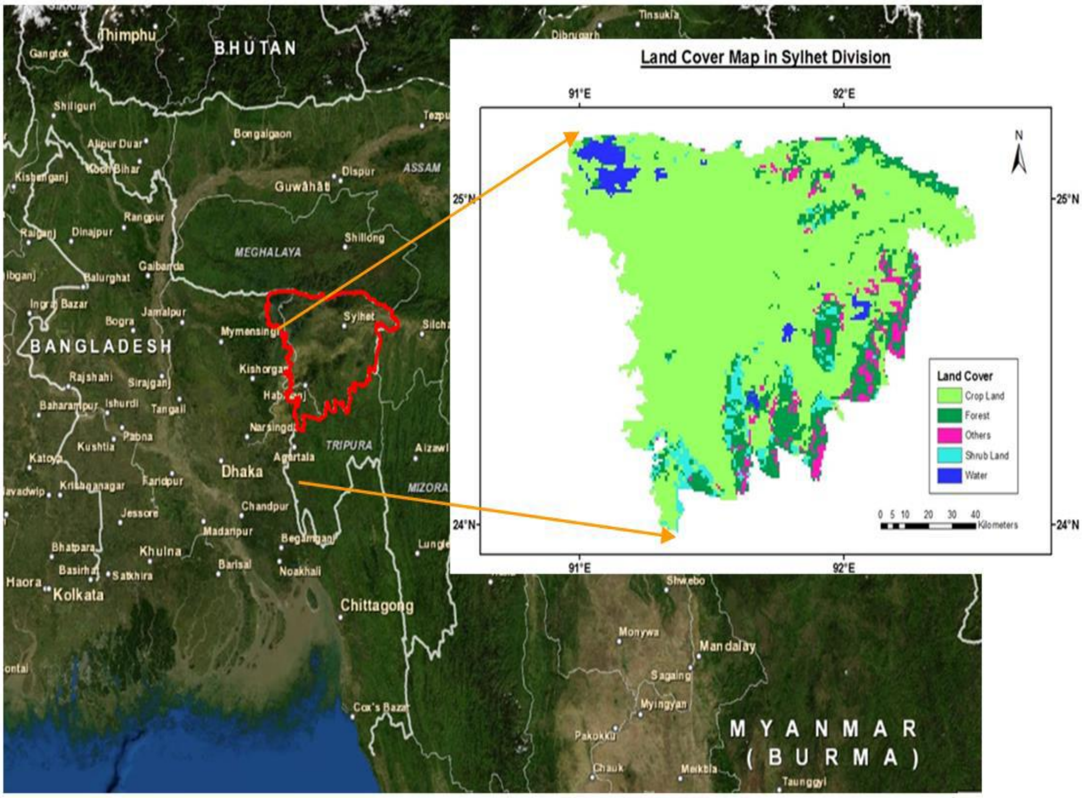

Figure 1.1: Study Area

Materials and Methods

Monthly mean data of different climatic elements such as maximum temperature (°C), minimum temperature (°C), rainfall (mm), relative humidity (%), sunshine (hr) and wind speed (m/s) of this area for the period of January 1996 to December 2013 (*i.e.* 18 years) were used in this study.

The collected data was comprised with a number of climate parameters and their monthly average values. From different parameters, only those are selected for this study which is supposed to have direct impact on rice production. The selected variables are coded as shown in Table 4.1. Data were put in MS excel and Fast Statistics software for statistical analysis. Seasonal rice production and average climatic parameters (temperature, rainfall, relative humidity, wind speed and sunshine) of Sylhet region were analyzed to see the variation and trend line of Correlation and Simple Linear Regression of climatic parameters during 1996-2013.

Table 4.1: List of Selected Variables

Name of the Parameter	Code Used	Unit
Mean Temperature	T_{mean}	ºC
Maximum Temperature	T_{max}	ºC
Minimum Temperature	T_{min}	ºC
Relative Humidity	RH	%
Rainfall	RF	mm
Wind Speed	WS	m/s
Sunshine Hour	SSH	hr

The dependent and independent variables of the study are selected carefully. Rice production rate is obtained by dividing production per year by cultivated area for 18 years period and this was selected as dependent variables and independent variables are different climatic parameters.

The change of climate are observed during three seasons in a year namely AusSeason (April to July), Amon Season (August to November) and Boro Season (December to March). To find out the impact of climate parameters of each year on the production of Aus, Amon and Boro rice, and season-wise climate data are correlated with the production. Data were put in MS Excel, Fast statistics to see the impact. The correlation coefficient i.e. coefficient of variation r, tests the strength of their relationship either positive or negative. The value of r must not be outside the range of -1 and +1. The value r = 1 occurs only when all the data points, lies perfectly on a straight line with a positive slope; r = -1 is also a perfect linear relation in which the line has a negative slope. A value of r close to either of these of extremes corresponds to a tight clustering of data points around a straight line, meaning strong linear relation. The value of r = 0 is interpreted as an absence of linear relation.

5. Results & Discussion

The maximum & mean temperature shows an increasing trend during Aus season (April to July) as shown in Fig 5.1, 5.2 & 5.3. The highest mean and maximum temperature during Aus season in 2013 was 28.875° C & 36.925 °C respectively which was 27.4 °C, and 34.75 °C in 2002.

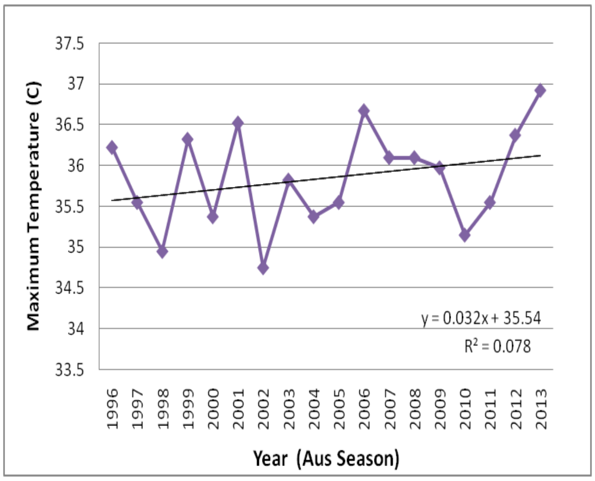

Figure 5.1: Trend of Aus Season T_{mean} (ºC).

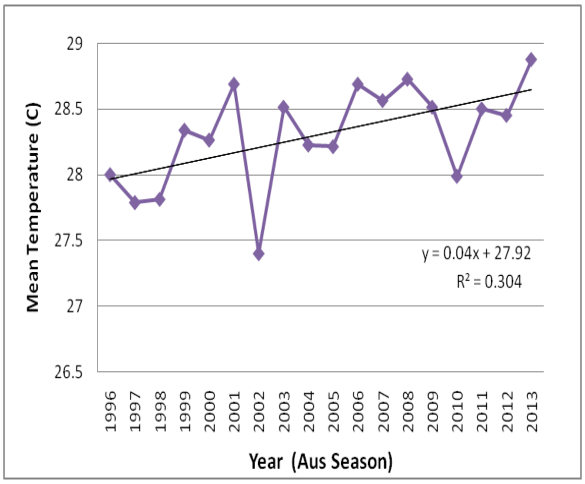

Figure 5.2: Trend of Aus Season T_{max} (ºC).

The minimum temperature also shows an increasing trend that was 19.775 °C & 21.45 °C in 2011 and 1996 respectively as in Fig 5.3. The rainfall intensity, sunshine hour, wind speed were increasing but on the other hand the relative humidity was decreasing during the period of Aus season which are indicated in Fig 5.4, 5.5, 5.6 & 5.7 respectively.

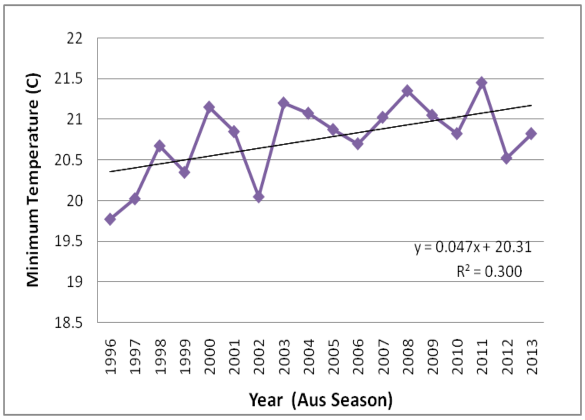

Figure 5.3: Trend of Aus Season Tm_{in} (ºC).

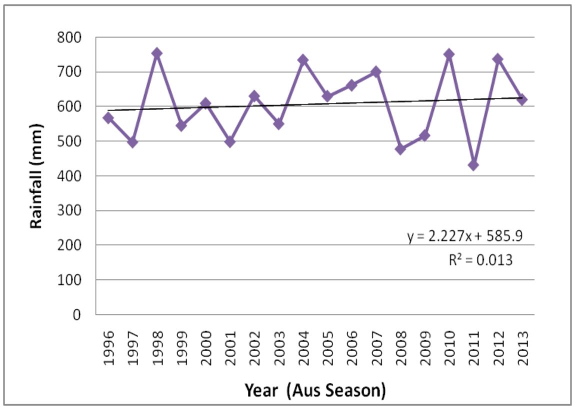

Figure 5.4: Trend of Aus Season Rainfall (mm).

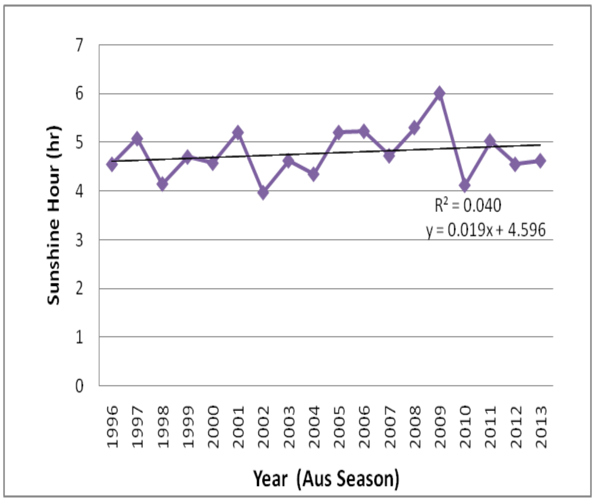

Figure 5.5: Trend of Aus Season RH (%).

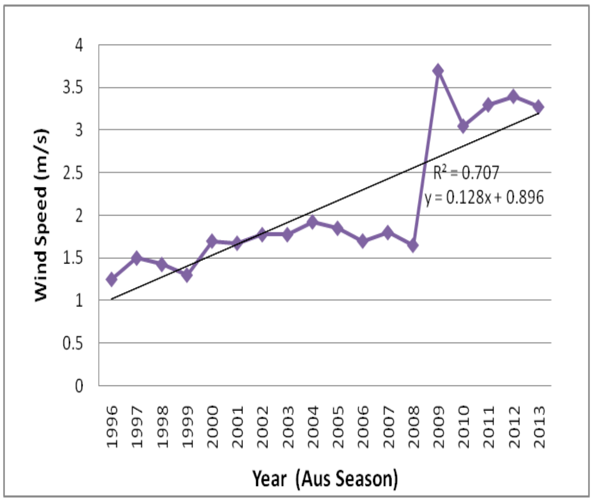

Figure 5.6: Trend of Aus Season SSH (hr).

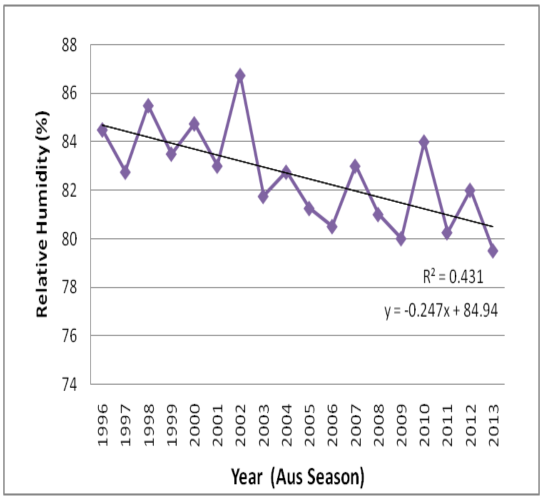

Figure 5.7: Trend of Aus Season WS (m/s)

During Amon season (August to November) the mean temperature had an increasing trend but maximum and minimum temperature were decreasing. The rainfall intensity and relative humidity had a decreasing trend whereas the sunshine hour and wind speed had increasing trend which are clearly shown in Fig 5.8 to 5.14.

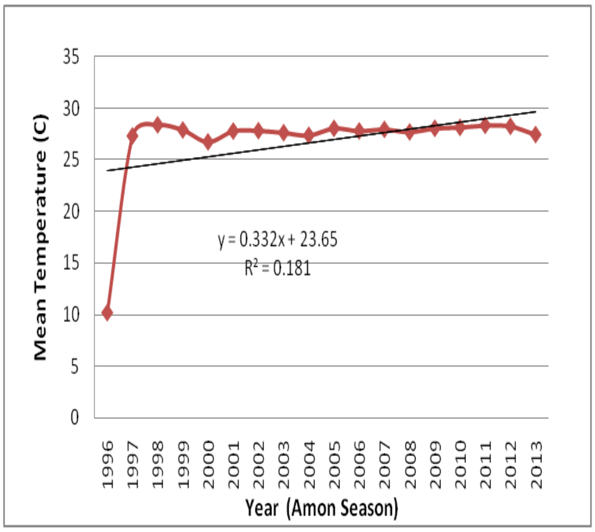

Figure 5.8: Trend of Amon Season T_{mean} (ºC).

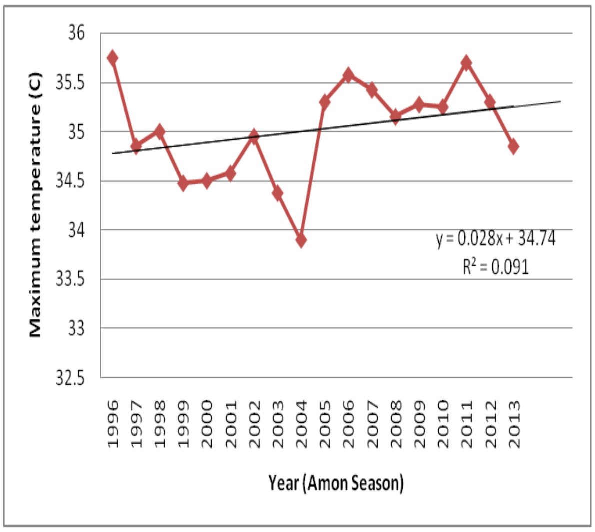

Figure 5.9: Trend of Amon Season T_{max} (ºC).

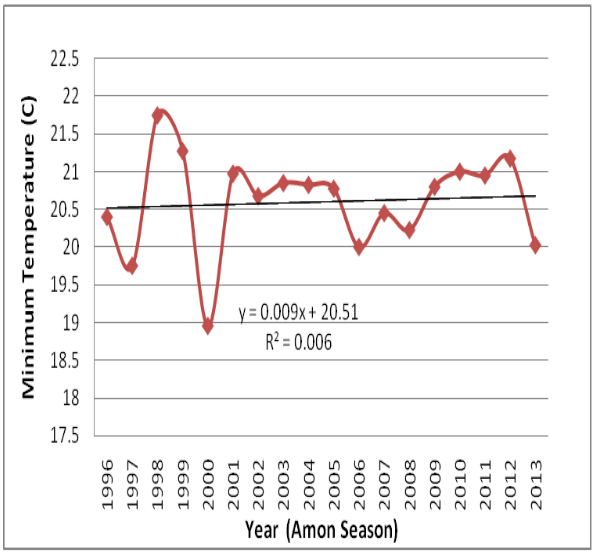

Figure 5.10: Trend of Amon Season T_{min} (ºC).

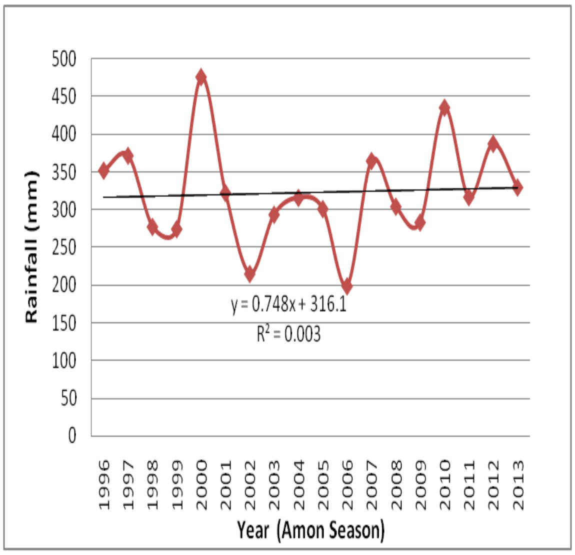

Figure 5.11: Trend of Amon Season RF (mm).

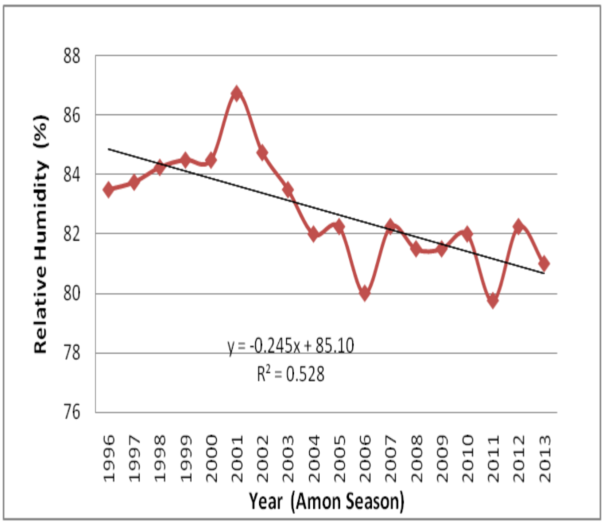

Figure 5.12: Trend of Amon Season RH (%)

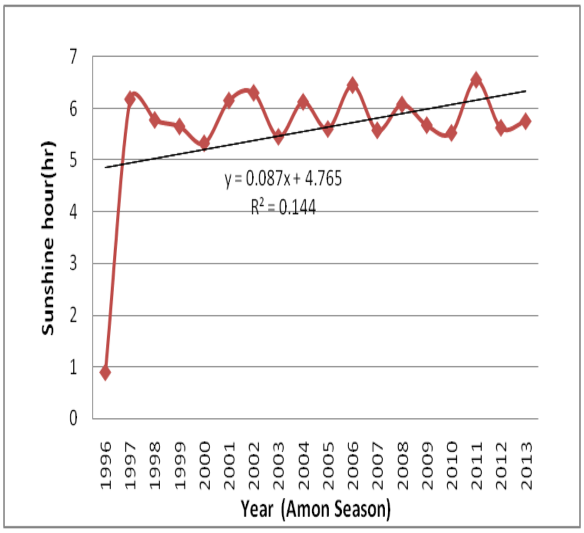

Figure 5.13: Trend of Amon Season SSH (hr)

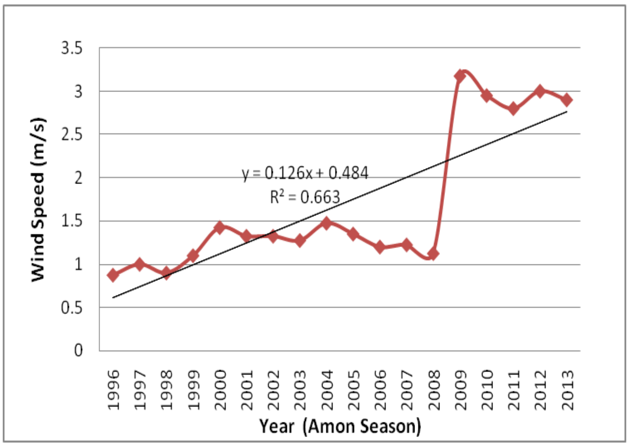

Figure 5.14: Trend of Amon Season WS (m/s)

In Boro season, the mean and maximum temperature had in increasing trend and inversely the minimum temperature had a decreasing trend. The rainfall had marked decreasing trend where in the year 2005 the intensity was 109 mm and in 2013 it reached 5.75 mm. The relative humidity and sun shine hour were decreasing and wind speed was increasing.

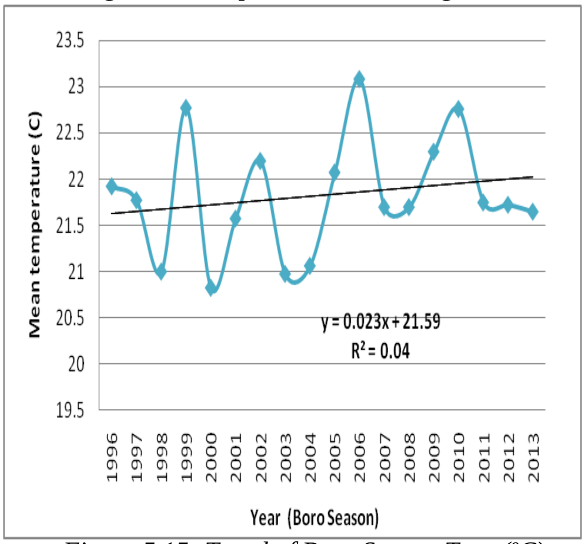

Figure 5.15: Trend of Boro Season T_{mean} (ºC).

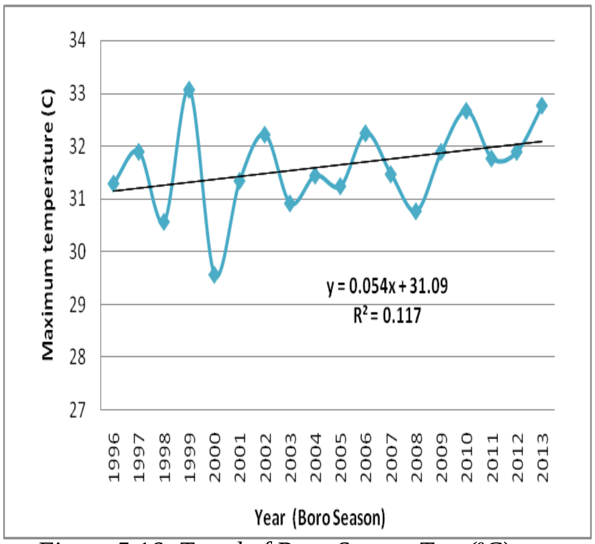

Figure 5.16: Trend of Boro Season T_{max} (ºC).

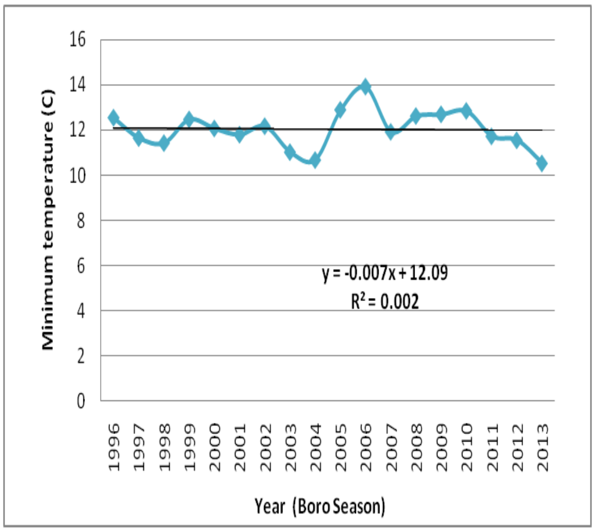

Figure 5.17: Trend of Boro Season T_{min} (ºC).

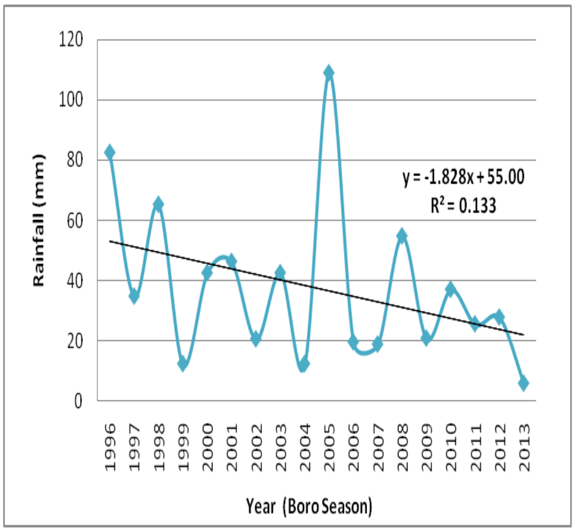

Figure 5.18: Trend of Boro Season RF (mm).

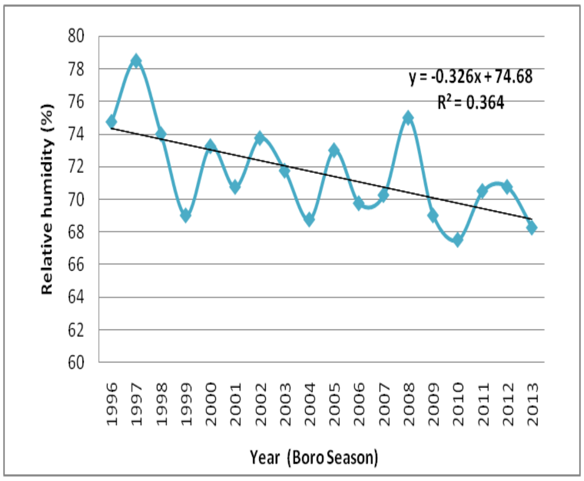

Figure 5.19: Trend of Boro Season RH (%).

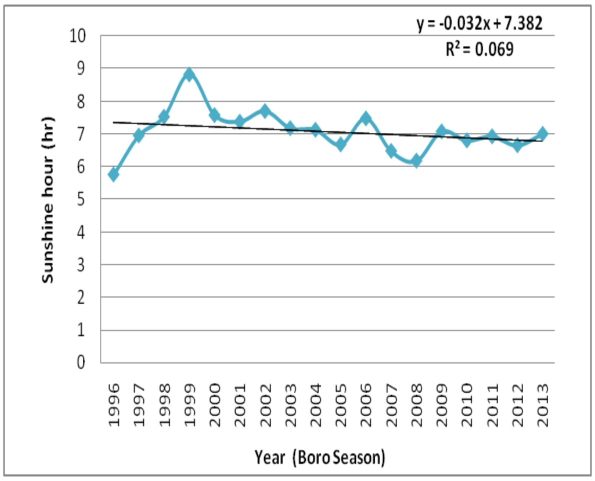

Figure 5.20: Trend of Boro Season SSH (hr).

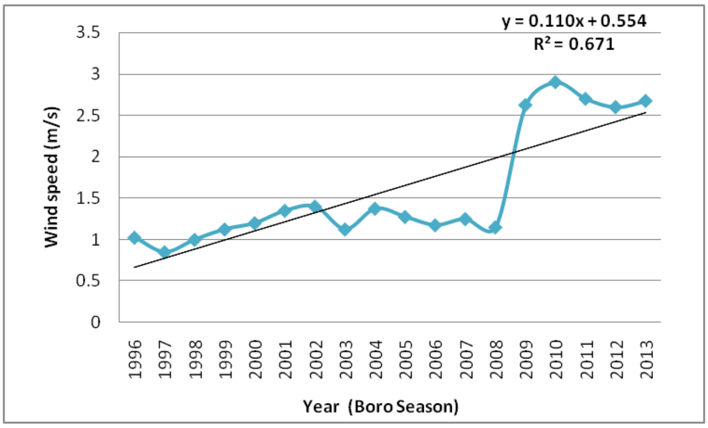

Figure 5.21: Trend of Boro Season WS (m/s)

Table 5.1: Summary of Seasonal Climate Change

Climate parameter	Aus season (April to July)	Amon season (August to Nov.)	Boro Season (Dec. to March)
T_{mean}	Increasing trend	Increasing trend	Increasing trend
T_{max}	Increasing trend	Increasing trend	Increasing trend
T_{min}	Increasing trend	Increasing trend	Decreasing trend
RF	Increasing trend	Increasing trend	Decreasing trend
RH	Decreasing trend	Decreasing trend	Decreasing trend
SSH	Increasing trend	Increasing trend	Decreasing trend
WS	Increasing trend	Increasing trend	Increasing trend

6. Variability of Production

Rice production changes due to change in weather parameters year to year. Production also varies from season to season. Seasonal production change trend was observed for the last eighteen years in each season. From the collected data, it was found that Aus, Amon and Boro rice production was swelling. Seasonal production change is presented the figure below.

Figure 6.1 shows that the trend of Aus production for Sylhet region is increasing which indicates there is a positive linear relationship between Aus production and time. The R^2 value 0.805 means that only 80.5 percent variation in Aus production is explained by time. The strength of the linear relationship between the variable and time was then calculated to determine the trend of Aus production. These relationships are measured by the correlation coefficient.

Aus Production Variability

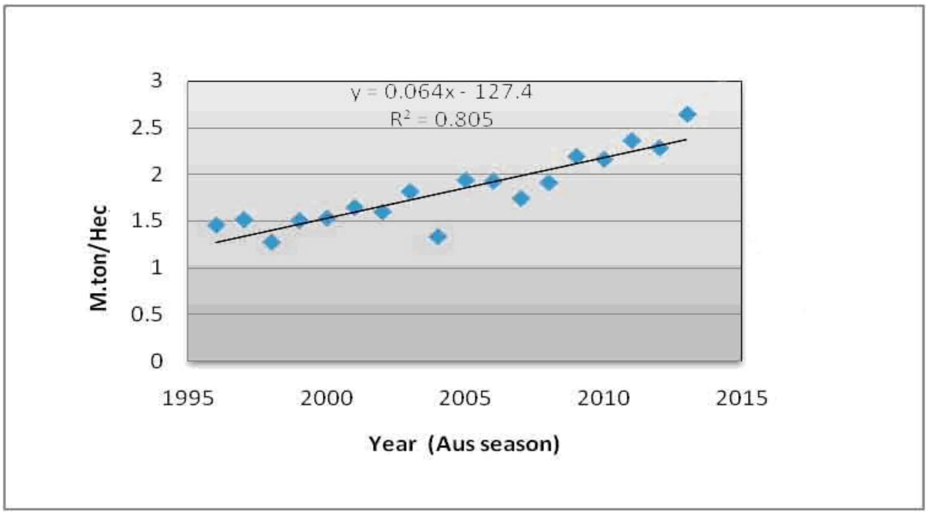

*Figure 6.1: Production trend of Aus season for the last eighteen years***.**

Amon Production Variability

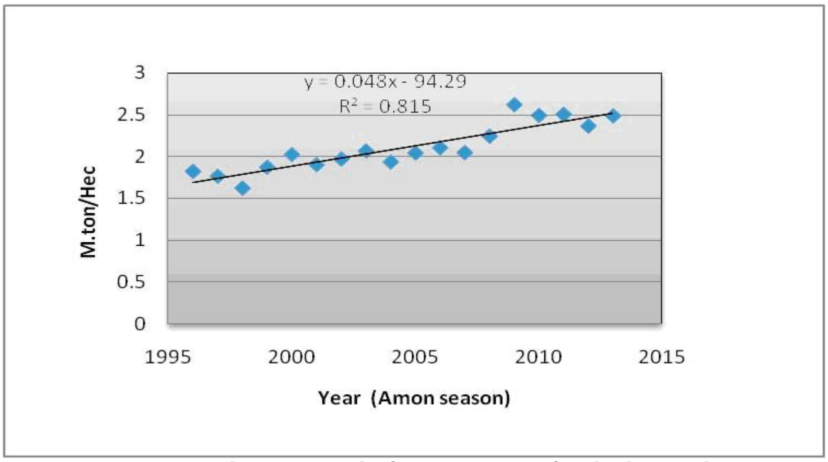

Figure 6.2: Production trend of Amon season for the last eighteen years

Figure 6.2 shows that the trend of Amon production for Sylhet region is increasing which indicates there is a positive linear relationship between Amon production and time. The R^2 value 0.815 means that only 81.5 percent variation in Amon production is explained by time. The strength of the linear relationship between the variable and time was then calculated to determine the trend of Amon production. These relationships are measured by the correlation coefficient.

Boro Production Variability

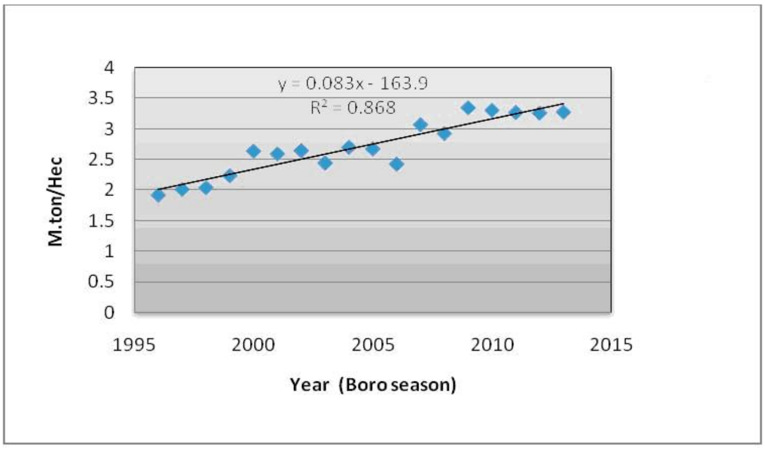

Figure 6.3: Production trend of Boro season for the last eighteen years.

Figure 6.3 shows that the trend of Boro production for Sylhet region is increasing which indicates there is a positive linear relationship between Boro production and time. The R^2 value 0.868 means that only 86.8 percent variation in Boro production is explained by time. The strength of the linear relationship between the variable and time was then calculated to determine the trend of Boro production. These relationships are measured by the correlation coefficient.

Table 6.1: Correlation with climate parameter & Aus season

	Aus **h**/m.t	T_{mean}	T_{max}	T_{min}	*RF*	*RH*	*SSH*	*WS*
Aus h/m.t	1							
T_{mean}	0.542963	1						
T_{max}	0.408634	0.797941	1					
T_{min}	0.367301	0.617292	0.01837	1				
RF	-0.12141	-0.2597	-0.23751	-0.12078	1			
RH	-0.71941	-0.79214	-0.61256	-0.51447	0.354217	1		
SSH	0.308682	0.55723	0.466729	0.315136	-0.6182	-0.71009	1	
WS	0.849467	0.317162	0.13285	0.35271	0.037218	-0.53241	0.206808	1

Table 6.2: Correlation with climate parameter & Amon season

	Amon h/m.t	T_{mean}	T_{max}	T_{min}	*RF*	*RH*	*SSH*	*WS*
Amon h/m.t	1							
T_{mean}	0.266462	1						
T_{max}	0.336933	-0.31083	1					
T_{min}	-0.02961	0.158145	0.023157	1				
RF	0.146626	-0.13595	-0.0627	-0.34913	1			
RH	-0.66802	-0.12307	-0.48841	0.096888	0.116521	1		
SSH	0.21604	0.955419	-0.29271	0.077577	-0.25596	-0.16178	1	
WS	0.900942	0.272606	0.233095	0.145583	0.255546	-0.50153	0.198851	1

Table 6.3: Correlation with climate parameters & Boro season

	Boro h/m.t	T_{mean}	T_{max}	T_{min}	*RF*	*RH*	*SSH*	*WS*
Boro h/m.t	1							
Tmean	0.115262	1						
Tmax	0.245762	0.750172	1					
Tmin	-0.07371	0.7479	0.122112	1				
RF	-0.38546	-0.16028	-0.51345	0.274872	1			
RH	-0.60916	-0.30708	-0.48913	0.030107	0.521268	1		
SSH	-0.21764	0.152318	0.246771	-0.0191	-0.42608	-0.2557	1	
WS	0.849198	0.231649	0.449028	-0.10307	-0.36175	-0.62184	-0.1425	1

Table 6.4: Summary of Seasonal Correlation with climate parameter and Rice production (Aus, Amon & Boro season)

Weather Parameter	**Aus season Correlation coefficient (R^2)**	**Amon season Correlation coefficient (R^2)**	**Boro Season Correlation coefficient (R^2)**
T_{mean}	0.542963 (Moderate +)	0.266462 (weak +)	0.115262 (weak +)
T_{max}	0.408634 (weak +)	0.336933 (weak +)	0.245762 (weak +)
T_{min}	0.367301 (weak +)	-0.02961 (weak -)	-0.07371 (weak -)
RF	-0.12141 (weak -)	0.146626 (weak +)	-0.38546 (weak -)
RH	-0.71941 (Moderate -)	-0.66802 (Moderate -)	-0.60916 (Moderate -)
SSH	0.308682 (weak +)	0.21604 (weak +)	-0.21764 (weak -)
WS	0.849467 (strong +)	0.900942 (strong +)	0.849198 (strong +)

Impact of climate parameters on Rice production

Weather and agricultural production are correlated. Weather and climate are still key factors in agricultural productivity. Often the linkage between these key factors and production are obvious. To get a clear idea about impact of weather parameters on rice production, some relationships are developed among weather parameters and production of rice. The correlation coefficients for Sylhet region was calculated using excel 2007. The results are shown in the tables 6.1 to 6.4.

7. Conclusion

Rice is the staple food of about 135 million people of Bangladesh. It provides nearly 48% of rural employment, about two third of total caloric supply and about one-half of the total protein intakes of an average person in the country. Rice sector contributes one-half of the agricultural GDP and one-sixth of the state income in Bangladesh [14]. Presently, single, double and triple cropped areas of Bangladesh are 29%, 52% and 19%, respectively with an average cropping intensity of 191% [15]. All crops have their critical and optimum climatic requirements. Analysis of climatology at regional scale is most useful for the solution of practical agricultural problems. Agriculture and weather are interconnected, both of which take place on a global scale. Climatic components have an effect on agricultural production. The available climate as a resource, should therefore, be thoroughly understood and crop-weather relationships using different climatic components like rainfall, temperature, humidity, sunshine hour etc. need to be established to identify potential areas and at the same time to characterize the adverse areas with emphasis on research needs for improved cultural practices.

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