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Trends in Climatic Variables and Their Impact on Crop Water Requirement and Crop Production

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Abstract Climate change have innumerable potential effects on agricultural production which is a key economic sector in Bangladesh. Bogra, Rangpur and Rajshahi in the north-west region have been selected as the study area. This paper aims to investigate the combined effects of climatic variables on ETo and NIR and to estimate the yield of the crop Boro and Aman in these study area. For testing the statistical significance of trends in different agro-climatic variables both parametric and non-parametric methods are used. The results of the analysis reveal that maximum temperature has decreasing trends of 0.20c, 0.10c and 0.30c per decade at Bogra, Rajshahi and Rangpur station and relative humidity has increasing trends in most 10-day periods. Sunshine hour and solar radiation show decreasing trends and minimum temperature and wind speed show increasing trends. It is found that ETo has decreasing trends at Bogra, Rangpur and Rajshahi station which are 0.41, 0.35 and 0.15 mm/day respectively per decade. NIR shows decreasing trend of 0.0428, 0.021 and 0.0434 mm/day per decade at those stations respectively. Sensitivity analysis was done in terms of percentage change in temperature, wind speed, relative humidity and radiation to identify the relative importance of climatic variables on Eto. Though the temperature is increasing due to global warming and it has a positive effect on ETo and NIR, the changes in other climatic variables are more prominent than the changes in temperature which result in a decrease in ETo and NIR. Aqua Crop version 4.0 software was used to estimate the crop yield Boro and Aman at the three stations. At Rajshahi station yield of Boro and Aman is found to be 6.407 and 4.732 tons per hectare respectively. At Bogra station, yield of Boro and Aman is 6.407 and 3.66 tons per hectare. The yield of Boro is found to be 6.42ton per hectare at Rangpur station. These values are found to be relatively close to the values obtained from the Agricultural Statistics Report, 2011of BBS.

Keywords: *crop water requirement, evapotranspiration, boro, amon, aquacrop*

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1. Introduction

Knowledge of crop-water requirements is crucial for water resources management and planning in order to improve water-use efficiency. Climate change is likely to affect agriculture in two distinct ways. One pathway is the direct effect of climate on crop growth and other pathway is through the supply of water for irrigation. So it is necessary to consider not only the direct effects of climate on crop yields but also on the effective water supply and the availability of water for agricultural users. Therefore the extent of this work covers the determination of various climatic variables such as rainfall, temperature, relative humidity, sunshine hour, solar radiation, wind speed etc and evaluate their combined on crop water requirement. The individual features and characteristics are analyzed and compared to establish a correlation in terms of climatic impacts on irrigational water requirement and the result is used in AQUACROP for crop production studies.

The latest prediction from the fourth assessment report of' Intergovernmental Panel on Climate Change (IPCC, 2007) shows a median increase of 3.3 °C in annual mean temperature throughout the South Asia by the 21st century [1]. Karmakar and Shrestha (2000) reported that overall annual mean temperature of Bangladesh was likely to increase by 0.29°C and 0.39°C by 2050 and 2100 respectively [2]. Persson (1999) found an increasing trend in global radiation of 7.2% per decade within the BALTEX area or Swedendue to the decreasing cloudinessspecially in summer months [3]. The relative sunshine decreases of 0.18%, 0.19%, 0.22% at Shanghai, Nanjing and Hangzhou stations located in Eastern China every year, respectively, from 1961 to 2000 (Zhang et al., 2003) [4]. Ahmed et al. (2007) reported a significant increasing trend of annual relative humidity by a rate of 0.13 (%) per year from 1923 to 2005 at Amman Airport Meteorological (AAM) station of Jordan [5]. Tuller (2004) discussed trends in measured wind speed for four stations on the west coast of Canada and found decline in mean annual and winter wind speeds at Cape St James, Victoria International Airport, and Vancouver International Airport [6].

In India, Chattopadhyay and Hulme (1997) also found that increases in relative humidity and decreases in radiation are both correlated with the decreasing trend in potential evapo-transpiration [7]. Goyal (2004) suggested an increase of 14.8% of total evapotranspiration (ET) demand with increase in temperature by 20%. ET is less sensitive (11%) to increase in net solar radiation, followed by wind speed (7%) in comparison to temperature [8]. Various studies have been undertaken in the past to evaluate irrigation impact of climate change on water demand. Ahmed and Alam (1999) show that the average evaporation in Bangladesh would remain almost unchanged in 2030 but would be slightly higher in 2075 with respect to the base year 1990 but in 2075, evaporation would be much higher in winter [9].

Ramirez and Finnerty (2001) analyzed the effects of CO_2 and temperature effects on irrigated agriculture. Climate change scenarios were analyzed including both a 3°C increase and a 3^0C decrease in air temperature and both a 50 and 100% increase in CO_2 concentration and their combined effect on crop yield. A crop yield model for irrigated Potato crop in the Sun Luis Valley of Colorado was applied to maximize agricultural benefit. The results show that elevated CO_2 have beneficial effect on irrigated agriculture in Colorado as it increases water use efficiency but quality may be reduced (less nitrogen in grain) [10].

1.1. Study Area

In this study, two stations in Rajshahi and Rangpur are selected and data of these meteorological stations like maximum and minimum temperature, relative humidity, sunshine hour, wind speed, solar radiation, rainfall are collected from Bangladesh Meteorological Department (BMD) for 1961-2011. The North-West region was chosen as most of the agricultural return of our country comes from this region. The locations of the stations are shown in the Figure 1.

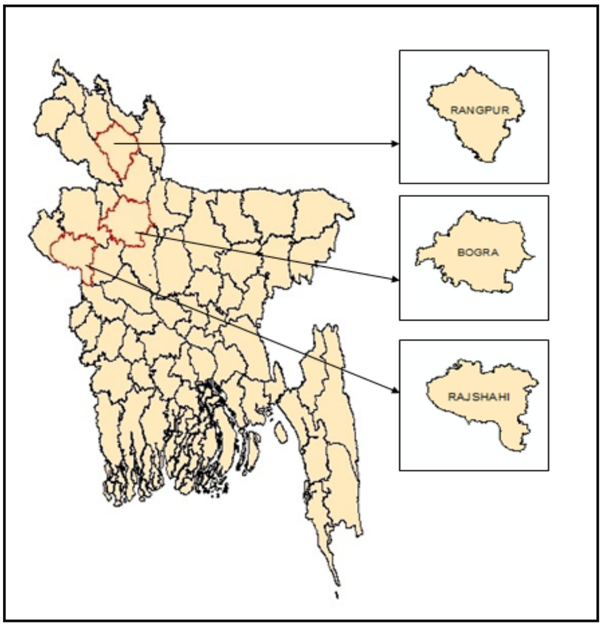

Figure 1. Study Area

2. Methodology

Parametric method and non-parametric method is used in SPSS for analyzing trend of climatic parameters. Linear regression is the most basic and commonly used parametric method. Here a scatter plot of the dependent variable(Y) and the independent variable(X) is first made. A least square linear regression line is then superimposed to the plot. The fitted regression line is represented in Eq. (1).

$$Y = a + bx \quad (1)$$

Where a and b are intercept and slope of the line means the trend of the given variable. In parametric method Pearson's correlation coefficient measures the correlation between two continuous variables. The following equation i.e. Eq. (2) is used to calculate the Pearson r correlation.

$$r = \frac{N\sum xy - \sum(x)\sum(y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}} \quad (2)$$

Where,
N= number of observation
Σx = sum of values under x variable
Σy = sum of values under y variable
Σx2= sum of squared values of x variable
Σy2= sum of squared values of y variable
Σxy = sum of product of x and y.

Non parametric Mann-Kendall test (Helsel & Hirsch, 1992) has been conducted for significance test of trends of climatic variables. According to Eq. (3), the Kendall Tau_b coefficient is defined as:

$$\tau_b = \frac{nc - nd}{\sqrt{(nc + nd + X_0)(nc + nd + Y_0)}} \quad (3)$$

nc= number of concordant pairs
nd= number of discordant pairs
X_O = number of pairs tied only on X variable
Yo = number of pairs tied only on Y variable.

2.1. Estimation of Evapotranspiration

ETo calculator is a software developed by the Land and Water Division of FAO which is used to calculate Reference evapotranspiration (ETo) according to FAO standards. This calculator assesses ETo from meteorological data by means of the FAO Penman-Monteith equation. The formula is as the following:

$$\text{ETo} = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where,
ETo=reference evapotranspiration (mm/day)
Rn= net radiation at the crop surface ($MJm^{-2}day^{-1}$)
G= soil heat flux density ($MJm^{-2}day^{-1}$)
T= mean daily air temperature (^{0}C)
U_2 = wind speed at 2m height (ms^{-1})
E_s =saturation vapor pressure (KPa)
e_a = actual vapor pressure (KPa)
e_s-e_a = saturation vapor deficit(KPa)
Δ= slope of pressure curve (KPa^0C^{-1})
γ= psychrometric constant (KPa^0C^{-1}).

2.2. Determination of Net Irrigation Requirement

To estimate net irrigation requirement, crop water requirement (ET_C) is to be estimated first. ET_C is determined by the following formula:

$$ETc = ETo * Kc,$$

where Kc is a crop- coefficient

The net irrigation requirement is estimated by the following formula:

$$NIR = ETc - Re + S + P$$

Where, NIR= net irrigation requirement
ETc = crop water requirement
Re = effective rainfall
S and P = seepage and percolation.

2.3. Estimation of Crop Production by AQUACROP

AquaCrop is a relatively simple crop water productivity model by design which was used to determine the yield of Boro and Aman crop and production of biomass from the years 1961-2011 at Rajshahi, Rangpur and Bogra station and compare the estimated yield value with that of the Agricultural Statistics Yearbook, 2011 of BBS. AquaCrop considers 369.47 parts per million by volume as the reference. It is the average atmospheric CO_2 concentration for the year 2000 measured at Mauna Loa Observatory in Hawaii. Here IPCC: SRES A1B scenario is selected for determining CO_2 concentration which describes a balance across all sources. Balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies. clay soil which also is suitable for the growth of Boro and Aman so it is selected from the soil type menu. 20% depletion is allowed in determining the net irrigation requirement for Boro as it is a shallow rooted crop. While for Aman, rain fed irrigation is chosen.

2.4. Calibration

In this research work calibration was done in order to match the model generated values for Boro and Aman crop with the value of Agricultural Statistics Report 2010-2011 of BBS. The calibrated crop parameters are shown in the following table:

Table 1. Calibrated Parameters for AQUACROP Model

Input calibrated	Value
initial canopy over	1.20%
transplanted seedling	6 cm^2/plant
plant density	20 plant/m^2
plant spacing	0.20m
row spacing	0.25m
planting method	transplanting
maximum canopy cover	95%
time to senescence	90 days
time to flowering	65days
time to maturity	110 days
maximum effective root depth	0.35 meter
time to maximum rooting depth	37 days
Input calibrated	duration of flowering
initial canopy over	allowable depletion
transplanted seedling	soil profile

3. Results and Discussion

The trends in several climatic variables during different ten day periods of the dry season (November-may) at three climatic stations (Bogra, Rajshahi and Rangpur) were estimated by the parametric method using the SPSS software.

It is seen from the Table 2 that in Bogra station maximum temperature, sunshine hour, radiation has decreasing trends which are, 0.20c, 0.58 hours and 50.9cal/cm^2 per decade respectively and the rest of the parameters have increasing trends i.e minimum temperature shows a trend of 0.20c per decade, wind speed and humidity has a trend of 2.85 km/Day and1.8% per decade respectively. According to Kendall's tau value it can be said that max temperature has statistically increasing trends at 1st and 3rd 10 day period in the month of Nov at 1%level (significant level less than or equal to 0.01) of significance and 1st and 2nd 10-day period of Dec at the 5% level of significance (significant level being less than or equal to 0.05). So the probability of occurrence of rising trends is less than or equal to 5% and there are 95% probability that such trends are due to some genuine reasons. There is non-significant increasing as well as decreasing trends in the 3rd 10-day period of Dec, in the month of Jan, Feb 2nd&3rd 10-day period of April & May. The rest of other 10 day period shows significantly decreasing trend at 1% and 5%level of significance. According to degree of correlation, the values of Pearson's correlation coefficient lies between ± 0.50 and ±1 in the 1st 10 day period of Nov, April& May which indicates a strong correlation. In the 2nd 10-day period of Nov, 1st& 2nd 10-day period of JAN.2nd&3rd 10day period of March r value lies in the range ± 0.30 and ± 0.49. It means it is a medium correlation. The other r values lies below + 0.29, so it indicates small correlation exists between the two variables. The analysis of the remaining stations for dry season can be found in the M.Sc. thesis of Islam (2014). The trends in ETo during different ten day periods of the dry season (November-may) and NIR of the Boro season (Jan-May) at three climatic stations (Bogra, Rajshahi and Rangpur) are given in the following Table 4.It is seen from the table that ETo and NIR both have decreasing trends at all three stations.

3.1. Sensitivity Analysis

The average value of these climatic parameters and ETo of the first 10-day period of April at Bogra station has been used to analyze sensitivity. The % changes in ETo due to changes in different climatic variables are shown in Figure 2. It is seen from the figures that ETo that with each percentage increase in maximum temperature keeping other variables fixed, ETo increased by 0.92 %. There is 6% decrease in ETo due to 10% increase of relative humidity. If both maximum and minimum temperatures are increased or decreased by any percentage ETo will increase or decrease by 0.68%. As maximum temperature has decreasing trend and minimum temperature and relative humidity both has increasing trend at Bogra station so with each percentage decrease of maximum temperature and increase of relative humidity ETo will decrease by 1.27%. S, it is clear that the combined effect of change in maximum temperature and relative humidity on ETo is more sensitive than the change in any other climatic variables. This fact is the principal reason of decreasing ETo at these three stations.

Table 2. Trends of climatic variables per year during different 10-day periods at Bogra station

Month	10 day	Bogra					
		T_{max}	T_{min}	Humidity	Sunshine Hour	Wind Speed	Radiation
Nov	1	0.052	0.048	-0.036	-0.042	0.919	-4.32
	2	0.031	0.036	0.067	-0.059	0.869	-5.78
	3	0.036	0.018	0.022	-0.033	1.399	-4.91
Dec	1	0.021	0.038	0.102	-0.066	0.285	-5.38
	2	0.016	0.005	0.117	-0.078	0.898	-4.52
	3	0.004	-0.014	0.131	-0.096	0.952	-4.93
Jan	1	-0.039	-0.004	0.244	-0.098	0.35	-6.42
	2	-0.039	0.002	0.268	-0.108	0.617	-5.6
	3	-0.028	-0.002	0.2	-0.078	0.366	-5.41
Feb	1	0.016	0.031	0.19	-0.063	0.326	-5.18
	2	-0.017	0.044	0.229	-0.097	0.674	-4.22
	3	-0.032	0.052	0.317	-0.054	0.022	-4.35
Mar	1	-0.034	0.038	0.227	-0.023	0.406	-3.24
	2	-0.051	0.042	0.361	-0.036	0.656	-4.98
	3	-0.053	0.042	0.399	-0.054	-0.924	-4.61
April	1	-0.085	0.019	0.446	-0.045	-0.58	-5.84
	2	-0.014	0.014	0.287	-0.029	-0.964	-5.58
	3	-0.044	-0.003	0.227	-0.043	-0.957	-5.06
May	1	-0.085	0.007	0.015	-0.025	-0.377	-4.86
	2	-0.014	0.018	-0.028	-0.04	0.383	-5.98
	3	-0.044	0.003	0.01	-0.058	0.673	-5.81
Average		-0.02	0.02	0.18	-0.058	0.285	-5.09

Table 3. Trends of climatic variables per year during different 10-day periods at Bogra station

month	10 day	Kendall's tau_b	significance	Pearson's r
Nov	1	0.473	0	0.64
	2	0.247	0.012	0.4
	3	0.342	0.001	0.499
Dec	1	0.202	0.041	0.291
	2	0.21	0.033	0.154
	3	0.039	0.692	0.043
Jan	1	-0.161	0.099	-0.302
	2	-0.188	0.055	-0.359
	3	-0.15	0.126	-0.251
Feb	1	0.065	0.512	0.13
	2	-0.128	0.196	-0.151
	3	-0.182	0.065	-0.288
Mar	1	-0.22	0.024	-0.298
	2	-0.311	0.001	-0.431
	3	-0.278	0.004	-0.35
April	1	-0.367	0	-0.501
	2	-0.13	0.187	-0.04
	3	-0.17	0.085	-0.286
may	1	-0.367	0	-0.501
	2	-0.13	0.187	-0.04
	3	-0.17	0.085	-0.286

Table 4. Trends of ETo and NIR per year during different 10-day periods at three stations

Month	10-day	ETo			NIR		
		Bogra	Rajshahi	Rangpur	Bogra	Rangpur	Rajshahi
Nov	1	-0.029	-0.001	-0.015	-	-	-
	2	-0.03	-0.011	-0.014	-	-	-
	3	-0.022	-0.008	-0.012	-	-	-
Dec	1	-0.025	-0.01	-0.013	-	-	-
	2	-0.025	-0.014	-0.015	-	-	-
	3	-0.024	-0.016	-0.017	-	-	-
Jan	1	-0.031	-0.012	-0.022	-0.023	-0.012	-0.012
	2	-0.033	-0.021	-0.027	-0.035	-0.021	-0.024
	3	-0.031	-0.017	-0.026	-0.03	-0.016	-0.03
Feb	1	-0.028	-0.01	-0.025	-0.028	-0.007	-0.022
	2	-0.037	-0.012	-0.03	-0.044	-0.018	-0.03
	3	-0.045	-0.015	-0.035	-0.058	-0.015	-0.043
Mar	1	-0.043	-0.018	-0.035	-0.055	-0.022	-0.038
	2	-0.05	-0.025	-0.047	-0.046	-0.023	-0.026
	3	-0.061	-0.019	-0.058	-0.065	-0.03	-0.082
April	1	-0.068	-0.03	-0.073	-0.061	-0.051	-0.075
	2	-0.058	-0.019	-0.058	-0.04	-0.039	-0.051
	3	-0.063	0	-0.057	-0.02	0.012	-0.037
May	1	-0.049	-0.018	-0.047	-0.05	-0.025	-0.04
	2	-0.054	-0.014	-0.05	-0.032	-0.037	-0.104
	3	-0.054	-0.017	-0.056	-0.055	-0.011	-0.038
Average		-0.041	-0.015	-0.035	-0.0428	-0.021	-0.043

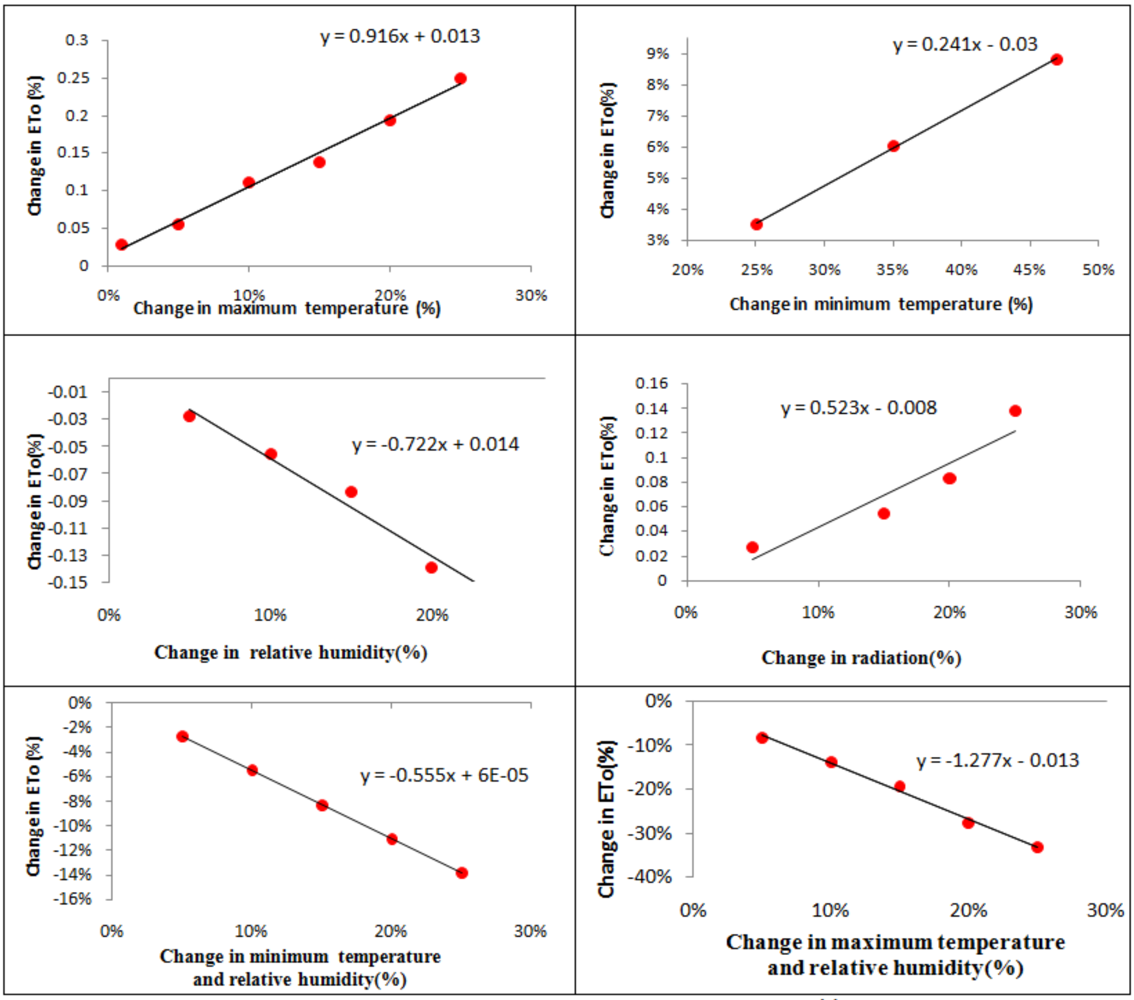

Figure 2. Sensitivity of ETo due to different climatic variables

3.2. Effect of Decreased ETo and NIR:

Due to decreasing trend of ETo and NIR soil moisture increases which make the soil wet and leads to decrease in NIR. Sometimes too much water in the soil causes water-logging and both excess and less water leads to susceptible damage to crop and reduce yield. If the water demand on agricultural sector is properly managed and sustainably utilized, the production of growing crops would increase.

3.3. Aqua Crop Model Generated Result

The output profile of climate-crop-soil water generated by Aqua Crop for Boro rice at Rashahi Station is shown in Figure 3.

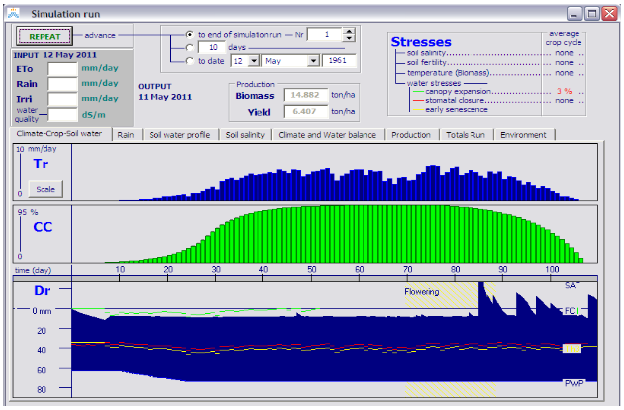

Figure 3. The output view of AquaCrop model

Table 5. The yield and biomass production of Boro and Aman paddy at Rajshahi station

Year	CO_2	Irri	Biomass(BORO)	Yield(BORO)	Biomass(AMAN)	Yield(AMAN)
	ppm	mm	ton/ha	ton/ha	ton/ha	ton/ha
1961	317.65	274	12.254	5.271	1.909	0
1962	318.45	243	12.304	5.292	2.393	0
1963	318.99	214	12.341	5.307	3.057	0
1964	319.61	413	12.285	3.08	12.248	5.274
1965	320.03	401	12.316	5.304	12.077	5.196
1966	321.37	518	12.332	5.337	12.469	5.499
1967	322.18	359	12.374	5.33	12.025	5.16
1968	323.05	430	12.409	5.344	12.285	5.262
1969	324.62	142	12.537	5.391	1.921	0
1970	325.68	151	12.227	5.258	2.204	0
1971	326.32	150	12.529	5.387	12.456	5.324
1972	327.46	444	12.578	5.416	11.905	5.076
1973	329.68	399	12.636	0.176	12.883	5.54
1974	330.17	429	12.637	5.441	12.803	5.494
1975	331.08	455	12.674	2.769	12.914	5.555
1976	332.06	492	12.752	4.134	12.262	5.275
1977	333.78	390	12.788	5.506	12.927	5.625
1978	335.4	353	12.878	5.546	13.022	5.591
1979	336.78	451	12.962	5.583	12.31	5.258
1980	338.7	429	12.993	3.552	12.911	5.604
1981	340.11	278	13.065	5.624	11.219	3.642
1982	341.22	475	12.973	5.57	9.23	3.678
1983	342.84	431	13.145	5.661	13.144	5.679
1984	344.4	457	13.203	4.212	13.162	5.726
1985	345.87	407	13.282	1.58	12.963	5.623
1986	347.19	337	13.336	5.738	13.444	5.781
1987	348.98	357	13.391	3.475	13.226	5.678
1988	351.45	295	13.504	1.792	12.056	5.072
1989	352.89	434	13.506	4.225	13.289	5.732
1990	354.16	225	13.608	5.856	13.272	5.707
1991	355.48	352	13.632	5.869	11.939	5.137
1992	356.27	397	13.679	1.67	11.288	4.861
1993	356.95	299	13.682	5.891	12.877	5.582
1994	358.63	312	13.78	5.931	13.132	5.742
1995	360.62	331	13.853	5.888	13.229	5.574
1996	362.37	322	13.907	4.193	13.396	5.707
1997	363.47	289	13.942	6.001	12.401	5.001
1998	366.5	260	14.063	6.052	14.053	6.048
1999	368.14	405	14.091	6.067	14.257	6.138
2000	369.41	239	14.177	5.614	13.593	5.83
2001	371.07	336	14.215	5.765	13.108	5.697
2002	373.16	297	14.272	6.142	14.26	6.138
2003	375.8	269	14.38	6.191	14.079	6.054
2004	377.55	347	14.412	6.204	13.324	5.694
2005	379.75	287	14.475	6.231	14.028	6.039
2006	381.85	315	14.565	6.269	14.489	6.234
2007	383.72	280	14.642	6.304	14.729	6.43
2008	385.57	313	14.635	6.3	11.628	5.001
2009	388.28	422	14.699	6.33	14.554	6.21
2010	391	434	14.78	2.705	11.388	5.01
2011	393.9	353	14.888	6.407	11.167	4.732

Figure 3 contains graphs of (i) the soil water depletion of the root zone (Dr), (ii) the corresponding development of the green canopy cover (CC), and (iii) the transpiration (Tr) plotted as functions of time. The absence or lower amount of rain and irrigation during long periods might lead to a drop in root zone water content below the threshold (green line) affecting canopy expansion. This will result in a slower canopy development than expected. More severe water stress will result in stomata closure (red line), resulting in reduced crop transpiration. Severe water stress might even trigger early canopy senescence when the root zone depletion exceeds the threshold for senescence (yellow line).

After the simulation, production of biomass (ton/ha) and yield (ton/ha) of Boro and Aman paddy, crop transpiration (Tr), canopy cover(cc), root zone depletion (Dr) was found for all the three stations. CO_2 concentration, net irrigation requirement, biomass production and yield found for Boro and Aman at Rajshahi station are given in Table 5. The area, yield and production of Boro and Aman paddy at Rajshahi according to BBS are given in the following table Table 6.

According to the Table 6 it can be said that the estimated yield of BORO and AMAN in 2011 are 6.407 and 4.732 tons per hectare respectively, which is very close to the value of the BBS report. The analysis of yield and biomass production of the remaining stations can be found in the M.Sc. thesis of Islam (2014).

Table 6. The area, yield and production of Boro and Aman paddy at Rajshahi according to BBS

Station	Crop	Area(ha)	Yield	Production
			(ton/ha)	Mton
Rajshahi	BORO	67106	6.4	262696
	AMAN	69439	4.5	190678

Effect of CO_2 in crop production:

Due to global warming CO_2 concentrations are expected to double at 21st century. More than 500 studies analyzing the effect of increase atmospheric CO_2 concentrations have reported an increase in crop yield, biomass production, leaf area, photosynthetic rate as well as a decrease in plant water use requirements. CO_2 enrichment increases stomatal resistance which reduces the amount of water they transpire. So increased CO_2 concentration ultimately decreases transpiration and evapotranspiration and NIR. Photosynthetic reactions due to increased CO_2 of C3 plants(rice, peanut, cotton) are more sensitive which results in a larger increase in biomass production. This study also reveals a decreasing trend of both ETo and NIR and from the Table 5 it is seen that CO_2 concentraion increases from 317.65m to 393.9 ppm from 1961 to 2011. As a result biomass production and crop yield also increases from 12.254 to 14.882 and 5.271 to 6.407. So the results of the study coincide with the fact that has been told in the literatures.

4. Conclusions and Recommendations

Climate change has turned into a global case of perturbation and the impact of these changes has been a matter of concerned in agricultural production and water use. By this study the trends in agro-climatic variables (temperature, relative humidity, sunshine hour, radiation, wind speed,) from 1961-2011 were analyzed for Bogra Rashahi and Rangpur stations. Maximum temperature, solar radiation and sunshine hour show decreasing trends in all 10-day periods at three stations. Minimum temperature and relative humidity show increasing trends for all stations. The average decrease in trends of maximum temperature for Bogra, Rajshahi and Rangpur are 0.2°C, 0.1°C and 0.3°C per decade respectively. Relative humidity has increasing trends which are 1.8%. 0.1% and 2.23% per decade at Bogra, Rangpur and Rajshahi station respectively. At Bogra, wind speed shows an increasing trend which is 2.85 km/Day per decade and for the rest of the stations it shows a decreasing trend. The combined effects of the trends of controlling climatic variables on ETo and NIR are evaluated. Both ETo and NIR show a decreasing trend for all the three stations. The average decreasing trends of ETo are 0.41, 0.35 and 0.15 mm/day and of NIR are 0.0428, 0.0434 and 0.021 mm/day per decade at Bogra, Rangpur and Rajshahi station. Though the temperature is increasing due to global warming and it has a positive effect on ETo and NIR, the changes in other agro-climatic variables are more dominant than the changes in temperature which result in a decrease in ETo and NIR. The yield of Boro and Aman for Bogra, Rajshahi and Rangpur station was found 6.407, 3.66, 6.407, 4.732, 6.42 ton respectively. These values are close to the values generated by Agricultural Statistics Report, 2011of BBS.

5. Recommendations

1. Future studies should include analysis of climatic variables for other stations to make more reliable conclusions.
2. Further studies can be carried out considering the monsoon season so that the trends in ETo and NIR can be observed throughout the year.
3. The effects of evapotranspiration rate can be studied for different crops.

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